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Cover image:
Black-and-Red Broadbill, *Cymbirhynchus macrorhyncos* (Photo credit: Lisette van Kolfschoten)

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Research Article

Carbon Sequestration in Selected Grass Species in a Tropical Lowland Rainforest at Obafemi Awolowo University, Ile-Ife, Nigeria

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Abstract

Dry matter production and carbon stock in the pools of *Panicum maximum, Axonopus compressus* and *Cynodon dactylon* grass species were evaluated within the Obafemi Awolowo University, Ile-Ife, Nigeria. This was with a view to provide information on grass species serving as carbon sink and to assess their contribution to carbon stock in the terrestrial ecosystem. Four 15 m x 15 m sampling plots were established in each of the grass species sites; the plant samples were harvested by randomly placing ten 1m x 1m quadrats. The harvested plants were divided into above and below ground biomass. Floor litters (residue) samples were also collected. Ten soil samples were randomly collected from ten points in each plot at a depth of 0-20 cm, air-dried and analyzed for carbon content. Bulk density was also determined in each plot. The harvested plants were oven dried at 70°C to a constant weight, weighed, ground and analyzed for organic carbon content. There were significant differences ($p < 0.05$) in the dry matter production, carbon concentration and carbon stock across the three grass species. *Panicum maximum* had the highest dry matter production and carbon stock in the above and below ground biomass. It also had the highest carbon concentration in below ground biomass. The results concluded that grasslands can serve as a terrestrial carbon sink and their contribution varied across the studied grass species.

Keywords: Biomass, carbon stock, floor litters, *Panicum maximum*, sequestration, soil carbon.

Introduction

Carbon sequestration is the process of capturing and long-term storage of atmospheric carbon dioxide (Roger & Brent, 2012). Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change (Holden, 2008). It has been proposed as a way to slow the atmospheric and

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marine accumulation of greenhouse gases, which are released by burning fossil fuels (Holden, 2008). Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes. Some anthropogenic sequestration techniques exploit these natural processes, while some use entirely artificial processes (Roger & Brent, 2012).

Terrestrial ecosystems constitute a major carbon sink owing to photosynthesis and storage of carbon dioxide in live and dead organic matter. Due to its numerous ancillary benefits (e.g. improved soil and water quality, restoration of degraded ecosystems, increased crop yield), terrestrial carbon sequestration is often termed as a win–win or no-regrets strategy (Lal et al., 2003). There are three principal components of terrestrial carbon sequestration: forests, soils and wetlands. Forest carbon is sequestered not only in harvestable timber, but also in woody debris, wood products and other woody plants encroaching upon grasslands (Wofsy, 2001).

Many debates have taken place on differences in the effectiveness of trees and native grasses in serving as carbon sinks (Piperno, 2006). It has been reported that trees and forest soils store more carbon than grasslands and grass vegetation (Pouyat et al., 2006). However, it is important to note some characteristics in grasses make it worthy of consideration as a terrestrial carbon sink and perhaps a more effective one than trees. Grasses are very effective at shifting carbon into the soil. Grasses for the most part have an annual root system with most of the smaller roots becoming established from the base of the plant. Thus, each year, many grasses will shed almost their entire root system into the soil which deposits large amounts of fibre (mostly carbon) into the soil and then plants go about consuming more carbon as they build a replacement root system (Anderson et al., 2010; Fissore et al., 2009).

Many native grasses form phytoliths (plant stones) that are solid aggregates of carbon within leaves. These are not just ordinary bundles of carbon but are highly durable globules of bound carbon that are not able to break down for thousands of years after production. It should be noted that not all grass species produce phytoliths, but native grasses seem particularly adept. However, trees are poor at forming phytoliths (Piperno, 2006). When trees break down either rapidly in a fire or slowly through death and decay, the carbon that was in their foliage is returned to the atmosphere. Thus, a tree is only a relative temporary solution to carbon sequestration. When grasses die, the leaves decompose and release carbon back into the atmosphere. Therefore the selection of longlife grass is important if the aim is to provide a long-term

carbon sink. Clearly, native grasses are highly persistent in their natural environment and these are a natural choice (Schlesinger, 1990).

Recently, there has been renewed interest in using grasslands as pathways for terrestrial carbon sequestration to mitigate the effect of CO_2 on global warming, as well as to utilize grassland biomass to produce biofuel and reduce our dependency on fossil fuels. This interest appears to be in conflict with each other. However, it is reasonable to believe that grasslands can be used in both roles while still maintaining their ability to provide environmental services without degradation of the grasslands (Larry & Dismas, 2008). A large proportion of the carbon that enters the soil has been reported to be returned to the atmosphere through respiration carried out by roots and soil organisms (Trumbore, 2000). The distinction between autotrophic and heterotrophic respiration in soils is difficult to make (Trumbore, 2000) and estimates are extremely uncertain, but the fraction of CO_2 evolution attributable to root respiration can vary between 16 and 95 %. Other significant losses of carbon in grasslands have been reported to be through soil erosion and soil water drainage containing dissolved organic carbon (Kalbitz et al., 2000).

More has been written about the use of vegetation as a means of removing carbon from the atmosphere and storing in a plant's tissue. Relatively little work has been carried out on the use of grasses as a carbon storage sink and this is probably because they are annual plants and their carbon sequestration potential is on a short-term basis. However, there is a need to continue to evaluate the roles grasses can play in the issue of carbon storage. This study focused on carbon sequestration in three grass species monocultures, *Panicum maximum, Axonopus compressus* and *Cynodon dactylon*. This is aimed at proffering insights into the contribution of these grass species in serving as a carbon sink via terrestrial carbon sequestration and also to provide information on the amount of organic carbon stored in the grasses' biomass and the soil on which they grow. The specific objectives of this study are: (i) to estimate the carbon stock in the above ground biomass (leaf and stems) and below ground biomass (roots) of each grass species; and (ii) to estimate the carbon stock in the soils on which the grass species grow and hence determine the total carbon sequestered by the grass species.

Materials and Methods

Study area

The study area is Obafemi Awolowo University, Ile-Ife, Osun state, Nigeria. Ile-Ife lies on Latitude 7˚32'N and Longitude N 4˚31'E with the elevation of Ife ranging from 215 m to 457 m above sea level (Hall, 1977). The climate of the area is a tropical type with two prominent seasons, the rainy and the dry seasons. The annual rainfall average is 1400 mm yr^{-1} (Oke & Isichei, 1997) and it showed two peaks, one in July and the other in September. The mean annual temperature ranges from 27˚C to 34˚C (Oke & Isichei, 1997). The soil of the area is derived from material of an old basement complex which is made up of granitic metamorphosed sedimentary rock (Hall, 1977). The soils are moderate to strongly leached and have low to medium humus content, weak acid to neutral surface layers and moderate to strongly acidic sub-soils. The soils which are usually acidic contain less than 10% clay which is mainly kaolinite and hence are characterised by low cation exchange capacity and low water holding capacity (Ayodele, 1986). The soil has been classified as lixisols (FAO/UNESCO, 1974) and utisols (USDA, 1975). The original vegetation of Ile-Ife is lowland rainforest as climax vegetation (Keay, 1989). The forest sub-type is dry deciduous forest (Onochie, 1979). Keay (1989) described the vegetation as the Guinea-Congolian drier forest type. Most of the original lowland rainforests have however been massively destroyed leaving remnants of fallow land and a secondary forest scattered around. Tree plantations like *Theobroma cacao, Cola nitida, Tectona grandis and Elaeis guineensis* are also common around the area.

Sampling procedure

Four 15 m x 15 m sampling plots were established in each of the grass species sites, each plot contained individual grass species of the tree grass species. Grasses were randomly collected at ten points per plot using the 1 m x 1 m sized quadrat. The detached parts of the grass species referred to as residue, within the quadrat were also collected. Both the grass species and their residues were bagged separately, labeled and transported to the laboratory where they were oven dried at 70˚C to a constant weight, weighed and ground. The collection was done in October 2013; the peak of the rainy season in Nigeria since the plants thrive better during the season and go into dormancy in the dry season. The ground grasses and residue were analyzed to determine organic carbon content according to the (Allen et al., 1986) method at the Department of Botany. The percentage of organic carbon concentration and carbon stock were calculated using the equation:

$$\text{Ash } \% = \frac{Wc - Wa}{Wb - Wa} \times 100 \quad (1)$$

$$\text{C concentration } \% = (100 - \text{Ash } \%) \times 0.58 \quad (2)$$

Where: W_a = weight of crucible; W_b = weight of oven dried ground sample and crucible; W_c = weight of ash and crucible and
C = organic carbon.
Carbon stock = Carbon concentration x Dry matter weight (3).

Soil collection

Ten soil samples were randomly collected from each of the plots at a depth of 0- 20 cm using a soil auger and bagged and labeled. Each soil sample was air-dried in the laboratory, passed through a 2-mm sieve and analyzed for organic carbon at the Soil Science Laboratory, Faculty of Agriculture, OAU Ile- Ife using the Chromic Acid Digestion method (Walkley-Black method, 1934). Soil bulk density measurements are needed to convert soil carbon concentration i.e. mass carbon per unit mass soil into inventories or storage i.e. mass per unit area. The soil bulk density was determined according to the method of (Blake & Hartge, 1986).

Statistical Analysis

One way analysis of variance (ANOVA) was used to test for significance in the carbon concentration, dry matter production and carbon stock of the above and below ground biomass and soil of each of the grass species. The significant means were separated using LSD post hoc analysis (p = 0.05). The statistical procedures were performed using SPSS 17 model; the values were first tested for normality and homogeneity in order to satisfy assumption of analysis of variance.

Results

Dry matter production

The dry matter production of the above ground biomass across the three grass species studied were significantly (p = 0.003) different. The highest value was recorded in *Panicum maximum* and there was no difference between the values of *Axonopus compressus* and *Cynodon dactylon* (**Table 1**). The dry matter production of the below ground biomass across the three grass species followed the same trend. The below ground biomass was significantly (p = 0.004) different with *P. maximum* having the highest value (**Table 1**). The values of the residue dry matter production were also found to be significantly

($p = 0.002$) different. *Panicum maximum* had the highest amount while *Axonopus compressus* and *Cynodon dactylon* had equal values (**Table 1**).

Table 1. Dry matter production of the above, below ground biomass and floor litter recorded at the three grass species studied. Results are presented as mean and standard error, where n = 10

Grass species	AGB (Kg m^{-2})	BGB (Kg m^{-2})	Residue (Kg m^{-2})
Panicum maximum	0.11 ±0.03[a]	0.07±0.02[a]	0.06±0.02[a]
Axonopus compressus	0.04±0.00[b]	0.01±0.00[b]	0.01±0.00[b]
Cynodon dactylon	0.03±0.00[b]	0.01±0.00[b]	0.01±0.01[b]

*Values with different letters are significantly different across the column at α level of 0.05.
AGB and BGB means above ground biomass and below ground biomass respectively.

Organic Carbon concentration (%)

Results from this study showed that there was no significant ($p > 0.05$) difference in the concentration of carbon of the above ground biomass across the three grass species studied (Figure 1). The highest value was observed in *Axonopus compressus* and the lowest was observed in *Cynodon dactylon* (Figure 1). There was a significant ($p = 0.000$) difference in the carbon concentration of the below ground biomass across the three grass species studied. The value was highest in *Panicum maximum* while *Cynodon dactylon* had the lowest value (**Figure 1**). The result obtained in the carbon concentration of the residue was similar to that of above ground biomass, where the concentration was not found to be significantly ($p > 0.05$) different for all the grasses (**Figure 1**).

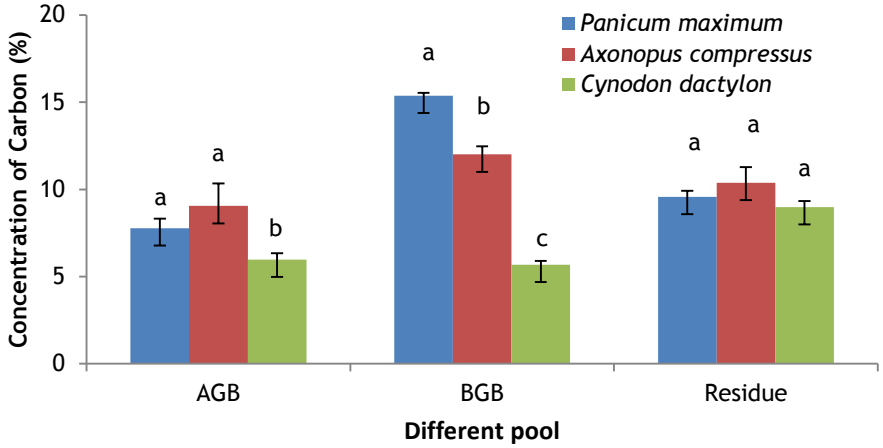

Figure 1. Carbon content of the above, below ground biomass and floor litter (residue) recorded at the three grass species sites. Vertical bar represents the standard error of the mean, (n = 10). Bars with similar letters are not significantly different across the species at $p < 0.05$.

Carbon stock

The carbon stock for each species of grasses were studied across the four different pools i.e. the above ground biomass, the below ground biomass, residue and soil. Result from this study showed that there was a significant ($p = 0.017$) difference in the above ground biomass carbon stock across the three species of grasses studied (**Table 2**). The highest carbon stock in the above ground biomass was recorded in *Panicum maximum* while the lowest value was recorded in *Cynodon dactylon* (**Table 2**). In the below ground biomass, carbon stock was found to be significantly ($p = 0.002$) higher in *Panicum maximum* compared to the other two grass species, while there was no significant difference in the other two grasses (**Table 2**). Similarly, there was a significant ($p = 0.010$) difference in the carbon stored in residues across the three grass species. *Panicum maximum* residue stored the highest carbon while *Cynodon dactylon* stored the lowest (**Table 2**).

Table 2. Mean carbon stock and standard error of the different pools across the three grass species. Results are presented as mean and standard error, where n = 10.

Grass species	AGB (Kg m^{-2})	BGB (Kg m^{-2})	Residue (Kg m^{-2})
Panicum maximum	0.93 ± 0.28^{a}	1.01 ± 0.28^{a}	0.54 ± 0.14^{a}
Axonopus compressus	0.32 ± 0.07^{b}	0.10 ± 0.04^{b}	0.04 ± 0.01^{b}
Cynodon dactylon	0.19 ± 0.02^{b}	0.06 ± 0.01^{b}	0.03 ± 0.01^{b}

*Values with different letters are significantly different across the column at α level of 0.05.
AGB and BGB means above ground biomass and below ground biomass respectively.

Soil

The mean values of soil bulk densities determined for *P. maximum, A. compressus* and *C. dactylon* were not significantly (p = 0.853) different (**Table 3**). However, the carbon concentration was significantly (p = 0.004) different across the three grass species (**Table 3**). The highest carbon concentration was recorded in *Cynodon dactylon* while *Panicum maximum* had the lowest. There was a significant (p = 0.033) difference in the soil carbon stock across the three grass species. The highest carbon was stored in soils of *Cynodon dactylon* while *Axonopus compressus* stored the least amount of carbon (**Table 3**).

Table 3. Bulk density, carbon concentration and carbon stock across the soils of the three grass species. Results are presented as mean and standard error, where n = 10

Grass species	Bulk density ($g\ cm^{-3}$)	Carbon concentration ($g\ kg^{-1}$)	Carbon stock ($Kg\ m^{-2}$)
Panicum maximum	1.03 ± 0.04^{a}	0.86 ± 0.20^{b}	0.18 ± 0.02^{b}
Axonopus compressus	1.05 ± 0.09^{a}	1.01 ± 0.18^{b}	0.21 ± 0.04^{b}
Cynodon dactylon	1.00 ± 0.00^{a}	2.22 ± 0.35^{a}	0.45 ± 0.08^{a}

*Values with different letters are significantly different across the column at α level of 0.05

Generally, the summary of the total of dry matter production, carbon concentration and carbon stock determined across the grass species studied is shown in Table 4. Results showed that the highest total carbon in all the pools was stored by *Panicum maximum* while *Cynodon dactylon* had the least carbon concentration. *Panicum maximum* produced the highest dry matter while both *Cynodon dactylon* and *Axonopus compressus* produced equal amount of dry matter (**Table 4**).

Table 4. Total dry matter production, Carbon concentration and Carbon stock across the three grass species

Grass species	Dry matter ($Kg\ m^{-2}$)	Concentration of Carbon (%)	Carbon stock ($Kg\ m^{-2}$)
Panicum maximum	0.24	33.57	2.66
Axonopus compressus	0.05	32.45	0.67
Cynodon dactylon	0.05	22.87	0.73

Discussion

Carbon concentration

Among the three grass species, the highest total carbon concentration was recorded in *Panicum maximum* while the lowest concentration was found in *Cynodon dactylon*. The highest total carbon concentration recorded in *Panicum maximum* compared to other grasses might be the result of its high below ground biomass carbon concentration. The higher below ground biomass carbon concentration of *Panicum maximum* was attributed to its deep penetrating roots unlike the other grass species, *Panicum maximum* which has a deep penetrating and bulky root structure. This observation is in agreement with the findings of (Anderson et al., 2010; Fissore et al., 2009) who reported that the deeper the root of native grasses, the greater the amount of carbon that could be stored in their roots.

The highest soil carbon concentration that was observed in *Cynodon dactylon* compared to other pools across the three grass species may show that *Cynodon dactylon* has a limit to the amount of carbon it can store in its vegetative parts even when there is an abundance of carbon in its soil pool. Schnitzer (1991) had earlier pointed out that there was a high rate of root decomposition in *Cynodon dactylon* and this may have contributed to the enhanced addition of carbon from the plant's root to the soil during the decomposition process.

The higher dry matter production recorded in *Panicum maximum* and across the various pools may be a result of its high vegetative yield. The vegetable matter produced by *Panicum maximum* was the highest. Various adaptive characteristics of this plant conferred upon it this advantage, part of which is its preference for shade which was well provided for by the trees growing around. With the availability of this condition and many others, the plant will multiply quickly and form a luxuriant growth unlike the creeping *Axonopus compressus* and the less large *Cynodon dactylon* (Botha & Botha, 1996). *Cynodon dactylon* does not grow well under the shade (Walker et al., 2001) while *Axonopus compressus* is generally a low-growing grass (Wong et al., 1998). The lack of significant difference in the bulk density of soils across the study sites where the three grass species were collected from could be due to similarities in the climate and management history of the plots from which the grass monocultures were collected.

Carbon stock

The soil across the three grass species except for *Panicum maximum* and *Axonopus compressus* stored more than 30 % of the total carbon and this is in

agreement with reports cited in (Daigneault, 2006) where it was reported that soil stores about 39 % of the total carbon sequestered in grasses. *Panicum maximum* soil stored about 6.67 % carbon and this may be due to the hoard of carbon by the luxuriant, vibrant, hale and bulky above and below ground biomass (Schnitzer, 1991). This observation however contradicts the findings of Lal et al. (1995) who reported that soil stores up to three times organic carbon compared to other components of plants. High soil carbon stock in *Cynodon dactylon* is dependent on its soil carbon concentration and storage and this could be the result of high decomposition rate of its above and below ground biomass. The carbon stock of a plant is determined by how long the plant lives and how big it grows at maturity. It has been reported that grasses for the most part have an annual root system with most of the smaller roots becoming established from the base of the plant. Thus, each year, many grasses shed almost their entire root system into the soil which deposits large amounts of fibre (mostly carbon) into the soil and then the plants go about consuming more carbon as they build a replacement root system (Anderson et. al, 2008, Fissore et al., 2009.

The high carbon storage in the soil of *Cynodon dactylon* may also be dependent on its dislike for shade (Walker et al., 2001), which inhibits the vibrant and agile growth of its vegetative and root part and hastens its death and decomposition. Deep penetrating roots store and hoard carbon away from the soil (Fissore et al., 2009) and this could explain the high soil carbon stock in *Panicum maximum* compared with the reported soil storage (Daigneault, 2006) of about 39 % of the total plant's carbon.

Conclusion

From this study, it was clear *Panicum maximum* had the highest carbon stock among the three grass species across the above and below ground biomass. It also had the highest dry matter production and carbon concentration. The *Cynodon dactylon* soil stored more carbon than the *Axonopus dactylon* soil. However, *Axonopus dactylon* stored more carbon across its other pools i.e. above ground biomass, below ground biomass and residue in comparison with *Cynodon dactylon*. The carbon stored in above ground biomass was more than the below ground biomass among the grass species. From the study, it is entirely reasonable to believe that grasslands can be used as terrestrial carbon sinks while still maintaining their ability to provide environmental services without degradation of grasslands.

Based on this study, it is recommended that disturbance through burning and harvesting of biomass from these grass species should be discouraged as much as possible since disturbance is most likely to alter the level of carbon stored in the biomass. Also the integrity of soils of the grass cover should be maintained by reducing disturbance that is associated with soil erosion, burning or harvesting.

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Review Article

Studies on Congregating Fireflies (Coleoptera; Lampyridae; *Pteroptyx* sp.) in Sabah, Malaysia: A Review

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Abstract

Five species of congregating firefly (Lampyridae; *Pteroptyx* sp.) in mainly mangrove forests of Sabah, Malaysia have been recorded. The recorded species are *P. tener*, *P. bearni* (formerly known as *P. similis* in Sabah), *P. gelasina*, *P. valida*, and *P. malaccae*. In certain parts of Sabah, these congregating fireflies are used in firefly-watching activities. This activity has no negative impact on the mangrove ecosystem, and it helps generate a profitable 13for local tourism operators. In light of this, congregating fireflies could be designated as umbrella species for the conservation of the mangrove ecosystem. However, in spite of the number of studies on congregating firefly in Sabah, only a few scientific findings have been reported and published locally. In this paper, the authors compiled and reviewed Sabah's congregating firefly studies. The compilation reveals that firefly studies were concentrated at the Klias peninsula, and were mainly focused on species diversity, population density, description of their habitats and display trees; while bionomics and life-cycle of these congregating fireflies are scantly known. Apart from Klias peninsula, the other areas studied and findings published are for the Kinabatangan floodplain, Paitan, Tuaran, Sepilok, Pulau Sakar off the coast of Lahad Datu and Kawang River, while another four unpublished studies were also included. More scientific studies are needed since the only habitat for congregating fireflies, the mangrove area, is fast depleting due to infrastructural development and mangrove deforestation pressures.

Keywords: *Pteroptyx*, fireflies, mangrove, Sabah, Malaysia

Introduction

Large congregations and synchronous flashing of fireflies in wetland areas were reported as early as 1680 by Dutch physician Engelbert Kaempfer in 1680 after his voyage downriver from Bangkok to the sea (Buck & Buck, 1968). These fireflies are actually from the genus *Pteroptyx* which have the unique characteristics of large congregations and synchronous flashing (Ohba & Sim

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1994; Ohba, 1999). So far, this phenomenon is only recorded in Southern Asia and the western Pacific, from East India through Thailand, Malaysia and Indonesia to the Philippines and Papua New Guinea (Hogarth 1999). All synchronous displays occur in trees or shrubs along tidal rivers in mangrove-nypa swamps (Ballantyne & McLean, 1970).

Fireflies are not actually "flies." They are beetles in the family Lampyridae. True "flies" have one pair of wings (like houseflies) while all other winged insects have two pairs of wings, or, four wings altogether. Fireflies have the ability to emit light through chemical reactions from the light organ which is located at the tip of their abdomen. The synchronous flashing of large congregations of fireflies gives a spectacular view along river banks, attracting nature lovers and tourists. It has been hypothesized that synchrony facilitates the female's ability to recognize her conspecific male's flash pattern (Buck & Buck 1968). A recent finding suggests that synchronous flashing is a behavioral strategy to minimize visual clutter (Moiseff & Copeland, 2010).

In Peninsular Malaysia, firefly tourism has become a popular attraction ever since it was introduced in the 1980s (Syed et al., 2001). Kampung Kuantan (upstream) and Kampung Bukit Belimbing (downstream) in Kuala Selangor are two important sites for this activity. Here, firefly tourism was commercialized since 1985 and 1997 respectively. The species of firefly which dominate at Kampung Kuantan has been identified as *Pteroptyx tener* along with two other species, *P. valida* dan *P. malaccae*. In 1999, it was estimated that about RM50, 000 was earned in a month from firefly tourism in both sites (Menayah, 2001). Fireflies in Kuala Selangor are being studied quite extensively by the Malaysian Nature Society. However in Sabah, very few studies on fireflies have been carried out so far.

Firefly (*Pteropteryx* spp.) Studies in Sabah

Firefly study has currently been a subject of interest because this particular insect has the potential of becoming a product for nature tourism in Sabah. Their ability to produce rhythmic, synchronous flashing lights in large population densities has made them an attraction. In addition, the loss of their natural habitat, the mangrove forests, has caused their extinction in several places, making them a subject for serious study. The firefly that has the potential as a nature tourism product is the one from the genus *Pteroptyx*. This genus has the unique characteristics of large congregations and synchronous flashing (Ohba & Sim, 1994; Ohba, 1999). To date, this phenomenon is only recorded in southern Asia and western Pacific, from East

India through Thailand, Malaysia and Indonesia to the Philippines and Papua New Guinea (Hogarth, 1999). In the Oriental region, congregations of these magnificent insects can be only found principally from mangrove trees along brackish rivers (Buck & Buck, 1968).

Ballantyne (2001) reported 11 species of this genus in South East Asia and added another four new species later in 2015 (Ballantyne et al., 2015). In the past, studies in Sabah were only focused on the taxonomic revisions of specimens collected by Ivan Polunin from a wide selection of localities, and supported by field data. From this collection, four species of *Pteroptyx* have been recorded in Sabah (Ballantyne, 2001). The first one, *P. gelasina* from Sipitang River was collected in 1970 and this specimen has been made as the holotype specimen of this species. Four other specimens were collected in Likas and kept as paratypes. Apparently, this species no longer exists in Likas at present time. The second species is *P. similis*, collected from Kudat Bay in 1970 and has been made as the holotype specimen of this species. Five other specimens were collected in Likas, and kept as paratype specimens. This species has also been wiped out from Likas. The third species, *P. malaccae*, was collected from Sipitang River in 1970 and the fourth species, *P. tener* was collected in Abai, Lower Kinabatangan in 1970. In a recent development of firefly study, *P. similis* which was thought to be endemic to Sabah (Ballantyne 2001) is actually a synonym to *P. bearni*, which is commonly recorded in many places in Peninsula Malaysia (Ballantyne & Lambkin, 2013). In 2007, Mahadimenakbar et al. discovered a fifth species, *P. valida* from Garama River at Klias peninsula, Sabah. The differences between the five species are shown in figure 1.

Presently in Sabah, there are a few places where we can see large population density of congregations of fireflies flashing and some even show mass synchrony among them (especially *P. tener*, and some said *P. malaccae*, but not other species in the genus). Almost all other natural habitats have been wiped out following infrastructural development, such as in the Likas area. Mangroves in Likas are now not suitable for sustaining firefly populations due to human disturbances. These disturbances do not only bring pollutants to mangrove areas but also artificial light, which disturbs light communication among fireflies, eventually eliminating their populations.

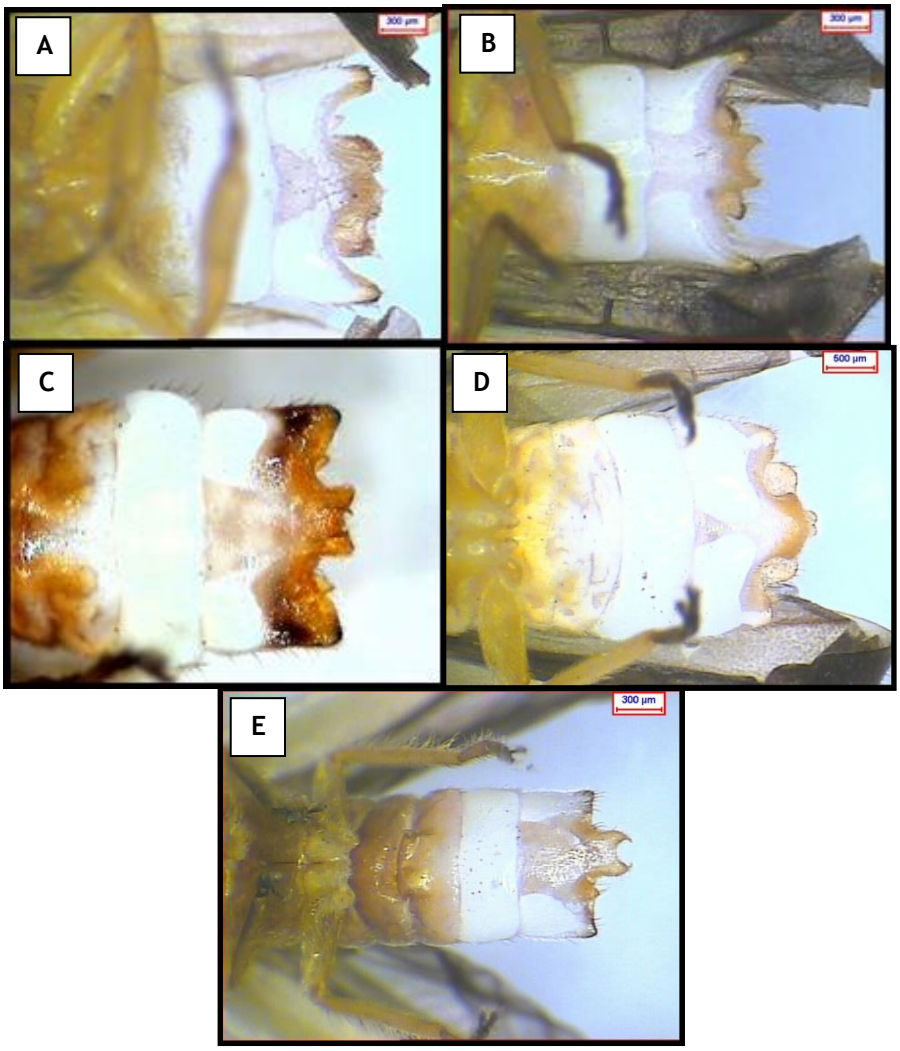

Figure 1. The morphological features of apex of abdomen of males of the five different species of *Pteroptyx* found in Sabah. **A** *P. malaccae*, **B** *P. gelasina*, **C** *P. bearni*, **D** *P. valida*, and **E** *P. tener*

In the west coast of Sabah, congregations of fireflies can be seen in many rivers in Klias Peninsular. Fireflies can be found along Garama River, Binsuluk River, Klias River, Teratak River and many other rivers towards Weston. Here, *P. bearni*, *P. tener*, *P. malaccae* and *P. valida* can be found living together in

the same rivers but in different colonies (Chey, 2004; Mahadimenakbar et al., 2007; Chey, 2010). *P. bearni* and *P. tener* were the two most common species spotted in the area while *P. malaccae* and *P. valida* were quite rare (Mahadimenakbar et al., 2007). From all of these species, only *P. tener* is known to flash synchronously in large numbers (Chey, 2010). *Rhizophora apiculata*, *Ficus microcarpa*, *Clerodendrum inerme*, *Glochidion littorale*, *Bruguiera parviflora*, *Nypa fruticans*, *Excoecaria indica*, *Ficus benjamina* and *Hibiscus tiliaceus* were listed as the display trees for the fireflies (Mahadimenakbar et. al., 2007; Chey, 2010). In Kampung Garama, firefly tourism has been commercialised as a part of tourism packages, and this is a similar case in Kampung Padang Teratak and in Weston. There are a few tour operators operating in these areas. In Teratak River however, the species compositions were a bit different. *P. bearni* dominated the area while *P. valida*, P. *malaccae* and *P. tener* were found in smaller proportions (Foo & Mahadimenakbar, 2015).

Apart from Klias Peninsular, another place in the west coast of Sabah where fireflies are abundant is in Trayong, Tuaran. Here, *P. bearni* was reported as the most common firefly species while *P. gelasina* was the less common one, found on two dominant mangrove trees, *Scyphiphora hydrophyllacea* and *Lumnitzera littorea* (Chey, 2009). In the east coast, congregations of synchronous flashing fireflies are mainly found in Kinabatangan Floodplain. The best place to see these fireflies is at Kampung Abai. We can see congregations of fireflies flashing in unison on mangrove trees, *Sonneratia caseolaris* along brackish rivers. Danau Pitas, an ox-bow lake, located about 10 minutes from Kampung Abai is a good spot to see these fireflies. Here we can see thousands of *P. tener* flashing synchronously, mostly on *Excoecaria indica* (Mahadimenakbar et al., 2003).

In the northern part of Sabah in Paitan River, *P. bearni* and *P. gelasina* were reported to be found on *Avicennia alba*, *Rhizophora apiculata*, *Scyphiphora hydrophyllacea* and *Xylocarpus granatum* (Chey, 2006). The same species of fireflies can also be found in the north eastern part of Sabah, in the mangrove forests of Sepilok Forest Reserve (Chey, 2008). Although there are many rivers and tributaries that are believed to be potential habitats of fireflies in the northern region of Sabah, not many studies have been conducted in these areas. Table 1 summarizes the published / in press studies so far conducted in Sabah.

Table 1. Summarized of published / in press studies on congregating fireflies found in Sabah

River/area	Firefly species	Display tree	Source of info	Remarks
Kawang River	*P. bearni* & *P. malaccae*	*Rhizophora mucronata, Aegiceras floridum* & *Lumnitzera littorea*	Foo & Mahadimenakbar (in press)	Random samplings 3 sampling occasions
Teratak River	*P. bearni, P. valida, P. malaccae* & *P. tener*	*Avicennia alba*	Foo & Mahadimenakbar, 2015	10 display trees (stations) 6 sampling occasions
Sakar Island off coast of Lahad Datu Sabah	*P. bearni* & *P. gelasina*	*Scyphiphora hydrophyllacea, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa*	Chey, 2011	6 display trees (stations) 1 sampling occasion Threats from oil palm plantation
Garama River, Beaufort	*P. bearni, P. malaccae* & *P. tener*	*Rhizophora apiculata, Ficus microcarpa, Clerodendrum inerme*	Chey, 2010	7 display trees (stations) 1 sampling occasion Threats from oil palm plantation
Klias River, Beaufort	*P. bearni, P. malaccae* & *P. tener*	*Rhizophora apiculata, Glochidion littorale*	Chey, 2010	4 display trees (stations) 1 sampling occasion Threats from oil palm plantation
Trayong, Tuaran	*P. gelasina* & *P. bearni*	*Scyphiphora hydrophyllacea, Lumnitzera littorea*	Chey, 2009	Random samplings 09/07, 01/08, 05/08 6 sampling occasions
Mangrove of Sepilok Forest Reserve, Sandakan	*P. gelasina* & *P. bearni*	*Lumnitzera littorea, Rhizophora apiculata, Scyphiphora hydrophyllacea, Rhizophora mucronata*	Chey, 2008	10 display trees (stations) 1 sampling occasion

(continued on next page)

Table 1. (continued)

River/area	Firefly species	Display tree	Source of info	Remarks
Garama River, Klias	*P. bearni*, *P. tener*, *P. malaccae*, *P. valida*	*Rhizophora apiculata*, *Bruguiera parviflora*, *Nypa fruticans*, *Excoecaria indica*, *Ficus benjamina*, *Hibiscus tiliaceus*	Mahadimenakbar et al., 2007	14 display trees (stations) April-June 2004 6 sampling occasions Light pollution from nearby villages
Paitan River	*P. bearni* & P. gelasina	*Avicennia alba*, *Rhizophora apiculata*, *Scyphiphora hydrophyllacea* & *Xylocarpus granatum*	Chey, 2006	4 display trees (stations) 1 sampling occasion
Klias River	*P. tener*	*Heritiera littoralis*, *Rhizophora apiculata*, *Excoecaria indica*, *Ficus sp.* & *Sonneratia alba*	Chey, 2004	1 sampling occasion
Kinabatangan River	*P. tener*	*Sonneratia caseolaris* & *Excoecaria indica*	Mahadimenakbar et al. 2003	Random samplings

Wong 2010 has produced a poster showing the congregating firefly zones (CFZ) throughout Malaysia. The distribution of these zones in Sabah is shown in figure 2.

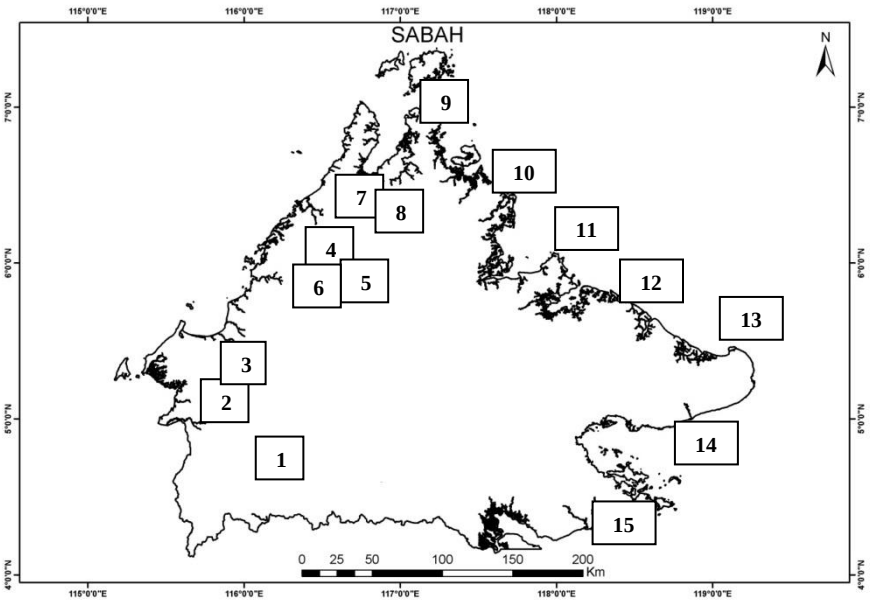

Figure 2. Congregating firefly zones (CFZ) in Sabah. 1- Sipitang River (s), (n); 2- Padas River-Weston Nature Park; 3- Klias-Binsulok-Garama Rivers (s), (n); 4- Likas River (s); 5- Likas Wetland (s); 6- Kinarut-Kawang Rivers, (s); 7- Mengkabong River, Tuaran (s),(n); 8- Kampung Sabandar, Tuaran (s), (n); 9- Kudat Bay (s); 10- Paitan River (s), (n); 11- Sugut River, Sabang Estate; 12- Sepilok Kecil River (s),(n); 13- Kinabatangan River, Danau Pitas (s); 14- Pulau Sakar, Lahad Datu (s), (n); 15- Semporna River-Pegagau-Tawau area (s), (n); (S) = synchronous fireflies; (n) = non-synchronous fireflies. Adapted from Wong 2010.

At the moment, studies are being conducted to study the ecology and habitat of these fireflies and to see the potential of these insects as a product of nature tourism in Sabah. Apart from that, the natural requirements of this insect are being investigated based on existing physical conditions and observations to obtain more accurate data and understanding. This includes the relationship between fireflies and their display trees, food chain and life circle. References on firefly ecology are limited, making the effort to study this organism difficult and challenging. At present time, our knowledge on this organism is based much on reports from the Malaysian Nature Society and also from a Japanese researcher, Dr. Ohba who has carried out a similar study in Singapore on *P. valida* (Ohba & Sim, 1994). The development of firefly tourism

as a tourist attraction obviously requires knowledge on the biology and ecology of firefly populations. It also needs careful planning and implementation to avoid environmental pollution which will eventually lead to population extinction.

There are also a few unpublished and ongoing studies on fireflies conducted by bachelor and postgraduate students. These studies, although unpublished, have a lot of information that need to be shared in the scientific world (Table 2).

Table 2. Summarized of unpublished studies on congregating fireflies found in Sabah

River/area	Firefly species	Display tree	Source of info	Remarks
Si Jam Jam River, extension Bukau-Maraba River and Bukau River, Weston	*P. tener, P. malaccae* & *P. bearni*.	*Sonneratia caseolaris*	Lim, 2016. MSc theses, unpublished	Only 1 sampling occasion, 30 stations
Beringis River	*P. bearni* & *P. gelasina*	*Rhizophora apiculata*	Azizul Shararudin 2011. BSc theses, unpublished	20 sampling stations, 6 sampling occasions
Likas Wetland, Kota Kinabalu	*P. bearni*	*Avicennia alba*	Walters 2010. BSc theses, unpublished	4 sampling stations
Klias River	*P. tener, P. malaccae* & *P. valida*	*Excoecaria indica, Heritiera littoralis, Cerbera odollam, Hibiscus tiliaceus, Ficus benjamina, Sonneratia alba, Rhizophora apiculata, Nypa fruticans, Hernandia nymphaeifolia, Barringtonia racemose, Acrostichum sp.* & *Acacia magnum*	Poukin 2007. MSc theses, unpublished	12 sampling occasions

Discussion

In Malaysia, most of the detailed published firefly studies were in West Malaysia (Wan Jusoh, 2010a; Wan Jusoh, 2010b; Wong & Yeap, 2012; Wan Juliana et al., 2012). In East Malaysia, the published studies mainly mention the presence of fireflies and their display trees (Chey, 2004; Chey, 2006; Chey 2008; Chey, 2009; Chey, 2010; Chey, 2011). Furthermore, most of the studies whether published or unpublished, were concentrated in the west coast of Sabah. This could be due to easy access to these locations coast as compared to other areas. More work needs to be done at other places such as in north and east Sabah. Most of the published studies were short term ones, mainly looking at the diversity of fireflies and their display trees, and all were published locally. Long term and detailed studies are very scarce. The detailed ecological studies, i.e. studies made for gaining Masters and Bachelor degrees were not published by the researchers, as shown in Table 2 above. More studies on life cycles, habitat requirements and preferences as well as disturbances and threats to the firefly populations should be done and published in international journals.

Pteroptyx sp. can be used as an umbrella species to protect mangrove ecosystems through the firefly watching activity, which can be done all year-round. It has the potential to attract a lot of tourists. Thus, another scope of study that relates to firefly watching that could be done is on the survival of this tourism activity, similar to what has been done in Kuala Selangor (Moktar et al., 2010). Another type of study could be to look at conservation consciousness among tourists involved in firefly watching activities. Apart from that, involvement of the local community in firefly watching activities appears to be increasing and may play a role in preserving the habitat of fireflies because of the perceived economic benefits. Studies on this aspect should also be carried out.

There is an urgent need to protect and conserve the unique congregating fireflies as well as the inter-tidal mangrove estuaries, freshwater swamp and riparian forests that forms their habitat. These forests are in imminent danger of being lost as a result of rapid and indiscriminate clearing for quick socio-economic benefits such as mangrove clearing for oil palm plantations (Chey, 2010; Chey, 2011). Oil palm plantations could reduce firefly habitats and hence adversely affect the firefly population (Chey, 2010). Erosion and application of chemical fertilizers in plantations cause pollution and subsequently decimation of wildlife including fireflies (Chey, 2011). Climate change may also threaten the survival of fireflies, as decreasing rain or rising

sea levels will increase salt water intrusion and wave action (Wong & Yeap, 2012).

Conclusion

The occurrence of congregating firefly populations can be wisely manipulated for tourism. This will directly provide benefits to local communities. Due to their importance in tourism, fireflies can be considered as an umbrella species that can be used to protect the whole mangrove ecosystem. Despite their popularity as a tourist attraction, comprehensive studies on them were very limited. More studies on firefly bionomics should be carried out in Sabah. Upon completing the studies, these should be published at least in local journals.

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Research Article

Protection of *Rafflesia* through the Appreciation of the Dusun's Indigenous Knowledge; A Preliminary Case Study at Poring-Sabah

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Abstract
Rafflesia is a rare parasitic plant species that is becoming vulnerable to extinction due to the loss of its habitat. To protect this plant from extinction, stakeholders need to coordinate their efforts in maintaining its habitat. Indigenous people are a stakeholder and appreciating their indigenous knowledge about plant and habitat management could help protect the plant. To investigate the potential effects of appreciating indigenous knowledge about *Rafflesia*, a case study was carried out. The investigation was carried out at Poring-Sabah with 59 Dusun residents and tourists interviewed using questionnaires. A content analysis was carried out on the questionnaires. The investigation uncovered the existence of indigenous names and uses for *Rafflesia*. Apart from the plant being used as a tourist attraction, the analysis showed that there are some traditional health uses for the *Rafflesia* plant. The investigation also noted a higher awareness about the protection of the *Rafflesia* plant among the Dusun community compared to the tourists. A description about the protection of the *Rafflesia* plant through the integration of the Dusuns' indigenous knowledge with current knowledge and management systems is provided.

Keywords: Conservation, Kokuanga, Poring Hot Springs, Poring Village, tourists

Introduction
Conservation Biology is a discipline derived from a biological crisis that emerged in the mid-eighties as a result of biologists noticing dramatic ecological changes in certain regions and society being alarmed by the drastic reduction of biological diversity in those regions (Soule, 1985; Buchholz, 2007). Its two main goals are to examine human impacts on biodiversity and to develop a mixture of practical scientific and humanity approaches to prevent the extinction of species (Soule, 1985). In fact, its success is based on its ability to reconnect people with nature (Balmford & Cowling, 2006). One such

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approach is the development of "The *Rafflesia* Conservation Incentive Scheme" (RCIS) by Sabah Parks as a step in protecting habitats of the *Rafflesia* plant which is a rare plant (Nais, 2001).

The step to protect the habitat of *Rafflesia* has its challenges, and the most immediate challenge is to empower indigenous people i.e. the Dusun ethnic group with conservation-related knowledge (Nais, 2001). This challenge emerged because empowered indigenous people tend to "stereotype" their respective sites that might result in low site diversity when they apply tourism as a tool for conservation as for tourism purposes (Peters, 2008). Central to the said challenge is stakeholders' misunderstanding of the "the underlying assumptions that may constrain the use of theory in practice" (With, 1997; Hayles, 1995); conservation biologists did not take advantage of the Dusun ethnic group's indigenous knowledge when strategising the conservation of *Rafflesia*.

Research was carried to identify perceptions of selected stakeholders about the *Rafflesia* plant and to determine certain terminological aspects of the Dusun language that could support the conservation of *Rafflesia*. This research is aimed at documenting the opportunity of integrating scientific-based information and humanities-based information about *Rafflesia* to help diversify its conservation approaches.

Conservation status of *Rafflesia* in Sabah

Rafflesia is a parasitic genus with only its flower visible and one that grows in limited localities around the tropical rainforest of Southeast Asia. It is a holoparasitic plant that lacks vegetative parts and grows on a specialised host grape-like vine plant from the genus *Tetrastigma* for water and nutrients (Kamarudin, 1991; Nais, 2001). This parasitic plant has no seasonal bloom period. While this parasitic plant habitat is associated to the habitat of its host, scientists generally regard it as a rare plant with specific ecological needs (Nais, 2001). Thus, *Rafflesia* is perceived as a rare plant.

In general, between 50 % and 70 % of the literature on conservation deals with biodiversity threats, species ecology, and species status (With, 1997); decision-making, recovery planning, public perception, attitudes, history and legal aspects are least understood subjects (With, 1997). In this context, although the plant had been known to western sciences for some two centuries now (Kamarudin, 1991; Nais, 2001), studies about it are largely taxonomical and ecological related. Two publications provide a rich source of information about

the morphology, taxonomy and ecology of *Rafflesia*. These publications are *Rafflesia: Magnificent Flower of Sabah* that was authored by Kamarudin Mat Salleh in 1991, and *Rafflesia of The World* that was authored by Jamili Nais in 2001. As a result, the subject of risk assessment and policy for the conservation of *Rafflesia* presents an academic opportunity.

In Sabah, the public's *Rafflesia* conservation effort is in the form of the establishment of a *Rafflesia* reserve, information centre and conservation incentive scheme. The two former efforts have given the public better understanding about the current status of the plant's population as well as the opportunity for environmental education and tourism (Sabah Parks, 2011). Information on the plant in bloom is provided via social media e.g. Facebook. Meanwhile, the Rafflesia Conservation Incentive Scheme (RCIS) was the government's initiative to increase indigenous peoples' participation in the conservation of *Rafflesia*. This scheme, aimed at increasing participation among indigenous people in the conservation of *Rafflesia* was largely established based on the understanding that most blooms are found in lands of local communities. Through RCIS, many *Rafflesia* sites were successfully protected from shifting cultivation and conserved through tourism by the Dusun people (Nais & Wilcock, 1998). However, more could be done.

Unaccounted understanding about the *Rafflesia* plant

Historically, although it was first discovered almost 20 years before by the French (Nais, 2001), the *Rafflesia* plant became known through an English publication that dates back to 1818 (Kamarudin, 1991; Nais, 2001). The source of this discovery was a lesser known fact of the *Rafflesia* plant being used by indigenous people for medicinal purposes e.g. a post-natal tonic for women and as an aphrodisiac for men (Kamarudin, 1991; Nais, 2001). Only now is this medicinal potential being looked at; and in a recent phytochemistry study, tannin which has anti-cancer, anti-oxidant and anti-microbial properties was discovered in the *Rafflesia* flower (Tancharoen et al., 2013). This new branch of exploration enriches current understanding about the *Rafflesia* plant other than it being an attractive plant.

In general, the backbone to the conservation of *Rafflesia* is ecology and tourism. Ethno-botanical aspects of the plant were not reasons for society to see this plant as being crucial for conservation. Since other sources of information are lacking, the conservation of *Rafflesia* is limited to its current form. More could be accomplished if certain understandings could be drawn from phytochemistry studies and indigenous knowledge. Hence,

conservationists are challenged to integrate scientific western knowledge with indigenous knowledge.

Merging scientific knowledge and indigenous knowledge

Different people have different views and opinions about knowledge, and this difference could affect the notion of valid knowledge. This is particularly evident when comparing the understanding of scientific knowledge and indigenous knowledge systems. Both knowledge systems have different forms and can perform independently and the distinction between indigenous knowledge and scientific knowledge are based on three aspects which are the substantive differences, epistemological differences as well as contextual differences (Agrawal, 1995). Scientific knowledge is regarded as being open, quantitative, objective and dependent on being a detached centre of rationality and intelligence; while indigenous knowledge is regarded as being closed, subjective, qualitative and emotional yet with a holistic approach (Agrawal, 1995; Mazzocchi, 2006). Indigenous people do not document their knowledge but it is stored in the form of stories, songs, folklore, proverbs, dances, myths, cultural values, beliefs and local language (Halim et al., 2012). As a result, more often indigenous knowledge is hidden and dismissed by the tendency of scientific knowledge to deny the importance of the other (Agrawal, 1995).

The term 'biocultural diversity' was outlined to explore links between the world's biodiversity and linguistics, as well as the causes and consequences of diversity loss at all levels (Maffi, 2002). This connection is significant in itself because it suggests that the diversity of life is made up of diversity in nature, culture and language (UNESCO, 2003) since there is a relationship between languages and biodiversity where there are interrelations between language and the environment, language being a major repository of and transmission vehicle for knowledge (Maffi, 2002).

A barrier to the use of information such as indigenous knowledge and medicinal knowledge to support conservation is the distinction between scientific knowledge and non-scientific knowledge. Scientific knowledge and indigenous knowledge differ in three aspects (Agrawal, 1995): 1) substantive differences 2) methodological and epistemological differences and 3) context differences; indigenous knowledge and scientific knowledge have their own strengths and weaknesses (DeWalt, 1994). To integrate the two different knowledge systems, a complimentary form is needed (DeWalt, 1994).

The use of local language i.e. indigenous language could overcome this limitation where indigenous language carries the information of indigenous knowledge. Hence, biodiversity could be well conserved when local language is applied. The loss of local language means loss of knowledge, beliefs and values of a community.

Methods and Results

This research empirically explored on the appreciation of indigenous language in the conservation of the *Rafflesia* plant. Due to the specification of the subject, Poring-Sabah was selected as the research location. Poring-Sabah, which provides access to one of the Kinabalu World Heritage Site's stations, covers the Poring Hot Springs Substation and the adjacent Poring Village. The chosen research site is illustrated in the following Figure 1.

Data collection for this research was carried out using two social sciences methods i.e. the interview method and the textual frequency method. A total of 59 responses were obtained from nine members of the Dusun ethnic group residing in the village of Poring and who were involved in *Rafflesia*-related activities; and 50 tourists who visited the Poring Hot Springs Substation. Research was done using an open-ended questionnaire to explore the extent of their knowledge about the *Rafflesia* plant, while the documentation of ecological and medicinal information about the *Rafflesia* plant became central to the frequency method.

Data analysis was carried out using descriptive statistic and content analysis approaches; and the analysis was of the interviewees' responses and the groups of information contexts. For analysis, the content of the interviews were summarised and coded (Neuendorf, 2002; Patton, 2002), and coding was carried out in accordance with four themes that carry the local name of the *Rafflesia* plant, the uses of the plant, its characteristics and its conservation. The coded data was statistically described into charts, and compared to determine differences between tourism players.

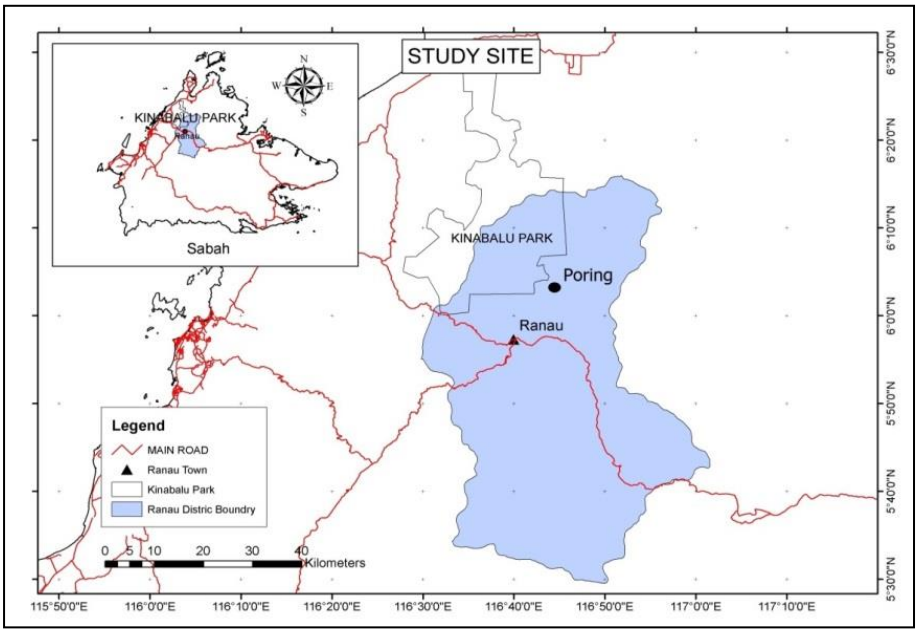

Figure 1. Poring-Sabah as the research site in reference to the research location

Rafflesia of Poring-Sabah

Endemic to the island of Borneo, *Rafflesia keithii* is the largest among the three species of *Rafflesia* found in Sabah. It populates the research location. In general, *Rafflesia keithii* produces the largest flower of all Rafflesia found in Sabah. The flower size is between 60 cm to 80 cm. Due to its size, the flower is generally found on the forest floor. Figure 2 shows a flower at the research location.

Figure 2. *Rafflesia* bloom during the period of survey

With exception to the *Rafflesia* within Sabah Parks' Poring Rafflesia Research Centre i.e. Poring Hot Springs, the entire plant specimen in Poring-Sabah is located on lands privately owned by the Dusuns of Poring Village. The distribution of these specimens is shown in Figure 3.

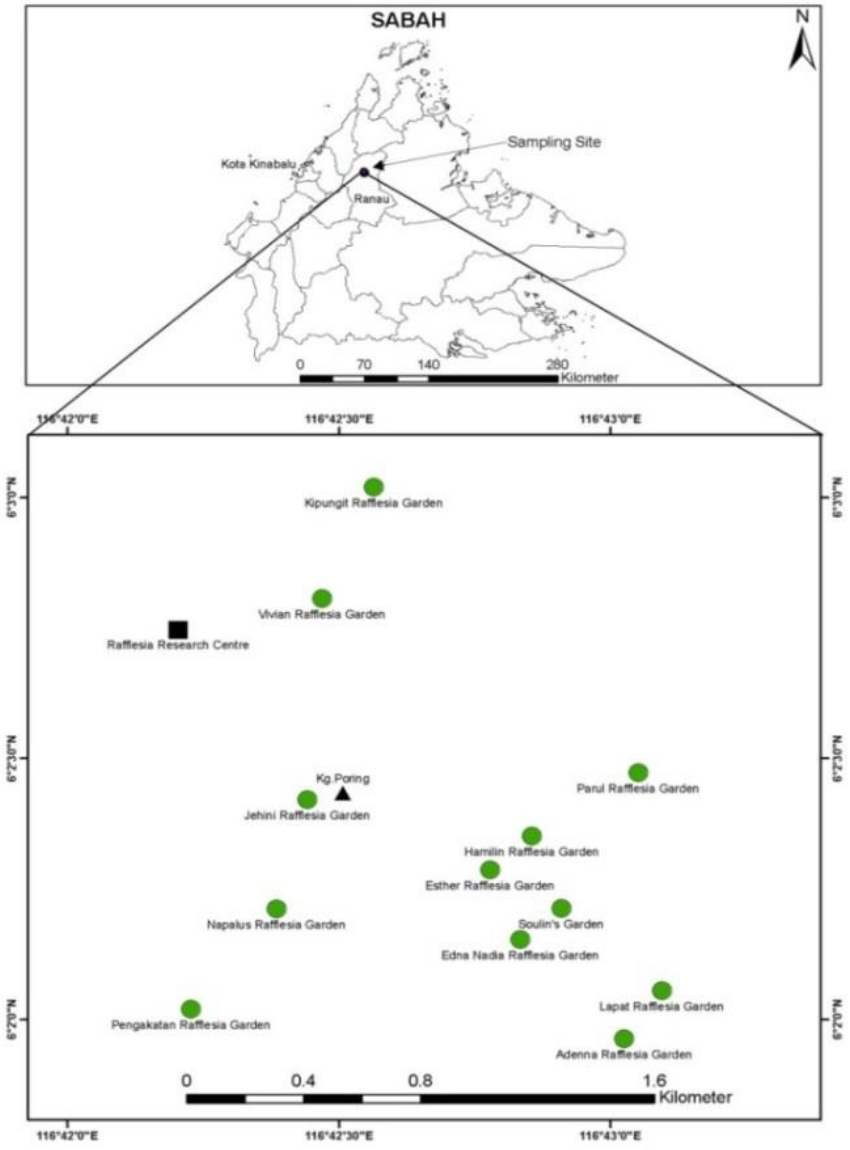

Figure 3. Distribution of *Rafflesia* sites in the research location

In Figure 3, the green dots show the location and ownership of the property where the specimens are found. About 60 % of the families have its own *Rafflesia* garden, which is largely for tourism purposes. Because of this, the local community upkeeps the host and parasite.

To manage a *Rafflesia* garden, the site is fenced to avoid human and animal disturbance. In addition, the site is covered to prevent direct penetration of sunlight to the flower which will cause death of the flower and buds. Some land owners even built boardwalks to prevent tourists from disturbing Rafflesia flowers and buds. At the time of the field survey, there were thirteen *Rafflesia* sites in Poring. On days when there is a bloom, a signage about the bloom is placed at the road side to attract tourists. A reasonable entrance fee is collected from every visitor based on the discretion of land owners. In areas where the *Rafflesia* is outside of state protection, local communities have devised their own protection approaches.

Respondents' Background

The village of Poring and the Poring Hot Springs were two sites where responses of residents and visitors were obtained. The village in the research location consists of 60 houses and is occupied by the Dusun ethnic group estimated at 650 people. In this study, 78 % of the Dusun respondents come from the 26 to 45 years age group. Some are farmers, while others are involved in the civil service as employees of Sabah Parks. A small number of residents in Poring have taken up tourism as a job by working as porters, guides, handicraft makers, and souvenir sellers and site attraction managers. Some 78 % of the local respondents have secondary level education. As for the tourists, 82 % of them are from a younger group i.e. the 18 to 35 years old age group. Some 80 % of the interviewed tourists possess tertiary education. The age difference and academic difference between host respondents and the visiting respondents suggest that the Dusun people draw their understanding about *Rafflesia* practically, while tourists depend their understanding about the plant academically. A total of 30 % of the interviewed visiting respondents had just seen the *Rafflesia* flower for the first time.

The perception of local contribution in the conservation of *Rafflesia* among Poring's residents and visitors

Among the local community of Poring-Sabah, the *Rafflesia* plant is largely used as a tourism attraction. Similarly, tourists also see *Rafflesia* as a tourism attraction. The following figure shows the perception about the conservation of *Rafflesia* through tourism. Based on the general conservation narrative

about *Rafflesia*, local people support the notion that *Rafflesia* could be conserved through tourism; and this was confirmed by all of the interviewed Dusuns as noted in Figure 4. However, not all tourists support this notion. Sixteen percent of the interviewed tourists disagree that tourism helps in conservation of *Rafflesia*, while 84 % of the interviewed tourists either agree or strongly agree tourism can help conserve *Rafflesia*. A reason for tourists' disagreement about the prospect of *Rafflesia* conservation through tourism is because some tourists do not believe local people would participate

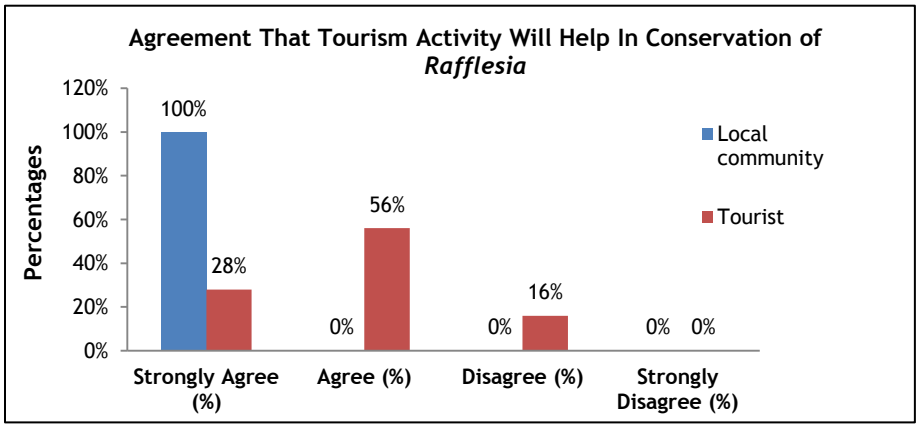

Figure 4. The agreement that tourism activity will help in conservation of Rafflesia by the tourists and the local community.

significantly in conservation work; these tourists see conservation work as something more than just the act of land allocation for a particular living organism. Such understanding would certainly influence the perception about local communities' involvement in conservation. The following figure shows the perception of local contribution in *Rafflesia's* conservation.

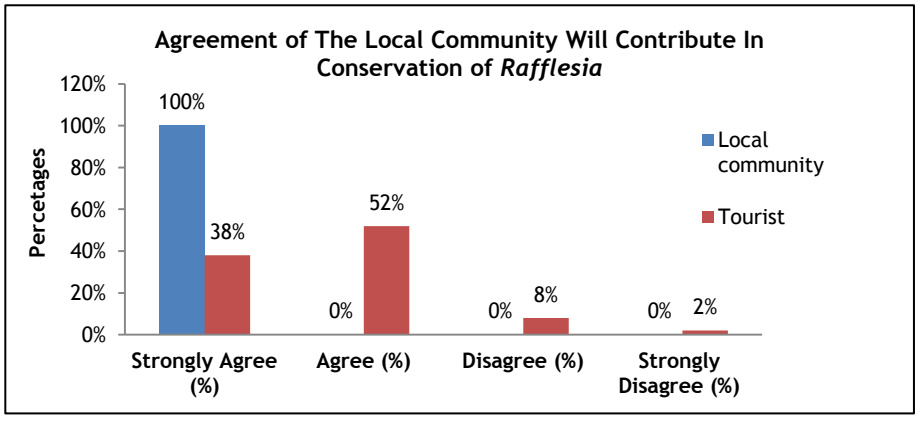

Figure 5. The agreement of the local community will contribute in conservation of Rafflesia by tourists and local community

As shown in Figure 5, all interviewees from the local Dusun community in Poring-Sabah strongly agreed that indigenous people do contribute in the conservation of *Rafflesia* since local people did establish *Rafflesia* gardens on their land, thus sacrificing other possible land use. On the other hand, Figure 5 showed that tourists have a different opinion about local contribution in conservation. With certain tourists having some understanding about the need for local participation in conservation, 90 % of tourists agree or strong agree that locals can and do contribute to the conservation of *Rafflesia*. Nevertheless, a significant 10 % of tourists disagree that local people could ever contribute significantly to the conservation of the plant. Taking consideration that some tourists do not believe tourism is sufficient in the conservation of the *Rafflesia* plant; this 10 % of tourists who disagree about local communities' contribution are those who perceive local peoples' involvement in *Rafflesia*-related tourism activities as not related to the act conservation.

The understanding of *Rafflesia* among Poring's residents and visitors

In context of the conservation of *Rafflesia*, this research showed significant difference in perceptions between residents and visitors. Further investigation into the respondents' knowledge reveals factors for the difference in perceptions. In relation to knowledge about the use of *Rafflesia* in medical treatment, tourism and research; there are differences in understanding among Poring's residents and visitors. The following table tabulates these understandings.

Table 1. Respondents understanding about the various application of *Rafflesia*.

Interviewees	Understanding about *Rafflesia* value		
	Tourism	Education	Medicine
Dusun Residents at the Poring Village	40 %	10 %	50 %
Visitors i.e. Tourists	66 %	26 %	2 %

Table 1 shows the percentage of respondents who have an understanding about the various importance of *Rafflesia*. From the table above, all members of Poring's local community see *Rafflesia* as a valuable plant either in tourism, education or medicine; while among tourists, many knows its tourism value. Six per cent of the tourists interviewed do not know how *Rafflesia* could be useful to society.

Medicinal use of *Rafflesia* shows knowledge difference of Poring's residents and visitors. The interviewed Dusuns of Poring believe that the *Rafflesia* has medicinal properties as opposed to the interviewed tourists. From the interviews, Dusuns claim *Rafflesia* buds could cure high blood pressure and gastric. Besides this, extracts of Rafflesia buds could be used as a post-natal tonic to revitalise mothers who had recently delivered.

The Dusun interviewees knew more about *Rafflesia* than tourists for many reasons. Apart from the obvious i.e. the plant is found within the vicinity of the Dusun people' residency, the interviewees know more about *Rafflesia* because they could draw on their indigenous knowledge about the plant. According to a Dusun interviewee, Dusun people do not use the word *Rafflesia* to signify the plant. Instead they named the plant according to the situation in which the plant is spotted in. Accordingly, it was named 'Kokuanga' because it was always seen in a state of full bloom (Abidin, pers. comm.). Apart from naming the flower by its condition, some local names were derived from stories. 'Bunga Rogon' was said to have derived from a hunter's ill encounter with *Rafflesia*. Accordingly, a 'spirit' or locally referred as 'penunggu' seem to possess the flower (Norbert, pers. comm.). From knowledge of the Dusun interviewees, *Rafflesia* has five different local names, largely obtained from ancestors. The flower is also referred among the interviewees as 'Bunga Patma' which they obtained from a Malay term that appeared in the *Rafflesia of The World* publication. The following table contains a list of the indigenous based information.

Table 2. Summary of the local name, its language and its meaning

Local name of *Rafflesia*	Meaning
Kokuanga	The full blooming of the flower. General name of a flower.
Romoh Runtuk	Dangling. The shoot of the host plant is growing upwards and the flower is growing down on the ground.
Romus	The local community who gave this local name do not know its meaning.
Tembuakar	Refers to the host plant of the *Rafflesia*. It also comes from the Dusun language. The local community did not known the exact meaning of this word. It might refer to the host plant of the *Rafflesia* flower.
Bunga Rogon	'Rogon' means ghost.

The most widely used local name is 'Kokuanga'; it dominates 34 % of the Dusuns' knowledge. It also happens to be the general name for most flowers. Among tourists, 76 % did not know *Rafflesia* had a local name, while the rest of the Dusun respondents had heard of its Malay name before i.e Bunga Patma. As a result of the Dusun interviewees drawing on their indigenous knowledge, awareness of *Rafflesia* conservation is extrapolated to be higher among the local community as compared to tourists; tourists see the flower and understand it merely based on its characteristics and ecology.

Discussion and Conclusion

Culture which is dependent on a set of basic assumptions and values, orientations to life, beliefs, policies, procedures and behavioural conventions that are shared by a group of people (Spencer-Oatey, 2008), is the basis for differences that exist between different groups of people. This difference has resulted in one object having a number of names in different languages (Cooper, 2007), and the parasitic plant *Rafflesia* provides an example. Through this research it was discovered that residents of Poring-Sabah recognise *Rafflesia* as 'Kokuanga', 'Romoh Runtuk', 'Romus', 'Tembuakar', 'Bunga Patma' and 'Bunga Rogon', as well as *Rafflesia*. On the other hand, visitors of Poring-Sabah are only familiar with the term *Rafflesia*.

The existence of vernacular names does more than just show cultural differences. It suggests local communities possessing *a priori* knowledge that could be useful in contemporary conservation exercises. In the context of this study, the only parasitic plant that lives off the *Tetrastigma* vine in Poring-Sabah i.e. *Rafflesia keithii* is scientifically unique and rare. However, its current conservation value and status is closely associated as a tourism attraction and in relation to biodiversity. Cultural related characteristics of *Rafflesia* could influence the plant's conservation value and status.

The conservation value and status of an organism has many aspects. One aspect relates to the level of education that a person. Under contemporary science, higher education level people tend to have a greater level of conservation awareness. This means that a person's attitude and perception can have an impact on the management of a natural resource (Shibia, 2010). In this study, most of Poring-Sabah's local residents who were interviewed only had secondary level education as opposed to visitors of Poring-Sabah who generally has tertiary education. However, locals have a higher level of conservation awareness as opposed to tourists. This finding is in contrast to

Mohamed Shibia's research, and the reason is Poring-Sabah's local community constantly engages with conservation-related activities through their own *Rafflesia* gardens, Rafflesia Conservation Incentive Scheme, or through other Dusuns who work at the adjacent public conservation agency i.e. Sabah Parks. Along with the Dusuns' cultural understanding about *Rafflesia*, higher level of education does not guarantee greater level of conservation awareness. Hence, cultural and traditional practices could affect the conservation value and status of an organism.

Culture and traditional practices affect the conservation value and status of an organism. To maintain this value and status, the management of the organism needs to incorporate cultural aspects. Currently, *Rafflesia* is a tourism attraction that is heavily promoted by local tourism agencies. Successful destinations that have capitalised on *Rafflesia* include Kokob village in Ranau and Poring-Sabah (Nais & Wilcock, 1998). While *Rafflesia* might have medicinal properties due to the existence of tannin and phenols, its use for that purposed is still localised (Nais, 2001). Given that the medicinal properties of *Rafflesia* are still localised and not incorporated into the larger body of knowledge about *Rafflesia*, its conservation is also rather limited.

Indigenous peoples have developed their own indigenous systems that have safeguarded their communities, a sustainable lifestyle and use of resources within their surroundings (Halim et al., 2012). This system is incorporated into their language. Since, a local language is an important tool for the transmission of indigenous knowledge, languages associated with the indigenous knowledge could bring to the sustainable management of resources and conservation of biodiversity (Unasho, 2013). This is because language and indigenous knowledge cannot be seen in isolation and should be conserved simultaneously in order to guarantee sustainable management of biodiversity conservation (Unasho, 2013).

Besides being part of one's identity (Melissa & Chen, 2010), language is a major repository of and a transmission vehicle for knowledge (Maffi, 2002). The need to pay tribute to indigenous languages could go beyond this and include indigenous people partaking in conservation activities. When the local language is stressed on, local people may be willing to put more effort in conservation. Loss of vocabulary as social genes of culture and some words becoming obsolete have not only negative impacts on the proficiency and communicative functions of the language, but also on biodiversity conservation because life in a particular human environment is dependent on

people's ability to express the environment using words (cultural genes) of the language. Like knowledge, language is capable of dying when "rather than *Rafflesia* being transformed through use and intergenerational transmission, a given language becomes increasingly restricted in use, and ultimately ceases to be passed on from one generation to the next" (Maffi, 2002). Therefore, language has a direct positive effect on biodiversity conservation (Unasho, 2013).

The understanding of *Rafflesia* and conservation differs between indigenous people and non-indigenous people. Indigenous people possess more knowledge about the *Rafflesia* and have high conservation awareness compared to the non-indigenous people. The understanding of *Rafflesia* differs in the aspects of the usage of *Rafflesia*, local names and characteristics to distinguish the flower. Indigenous people may possess useful knowledge that could complement western sciences in conserving the plant and its habitat, but the conservation of *Rafflesia* has yet to make use of people' knowledge, and benefit from it.

This study focuses on the potential of local language, in this case, the Dusun language, in the conservation of *Rafflesia*. The Dusun language is a tool to transmit indigenous knowledge of the local people. To use this language, the Dusuns need to be involved in conservation activities. *A priori* knowledge can be integrated into the conservation of the species. In this case, appreciation of the local name could be used in conservation of the *Rafflesia* flower. Scientists need to understand the local language so that they can work together effectively because appreciation means an expression of gratitude towards local names; or to increase the value of local names among the public since the appreciation of local names could have a positive effect in the conservation of *Rafflesia*. More research on the use of local languages in conservation of biodiversity is needed.

Acknowledgement

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Research Article

The Diversity of Birds in Kota Belud Bird Sanctuary, Sabah

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Abstract

This research was conducted in the Kota Belud Bird Sanctuary (KBBS), with the objectives to determine the diversity and species richness of birds in KBBS and to identify habitats of birds that occur there. The overall purpose was to provide information for managing and conserving birds in the Sanctuary. The methods applied in this study were point counts, line transects and mist-netting. Shannon and Margalef indices indicated the bird diversity was quite high (3.4664) for Shannon index, as was species richness (9.232) for Margalef index. *Lonchura atricapilla* was the most abundant resident species whereas *Himantopus himantopus* was the most dominant migratory species. In addition, there were four general habitats of birds that were identified within the study area: i) grassland, scrub, bush, and open and suburban areas, ii) paddy fields and flooded paddy, iii) coastal strand and mudflats, and iv) swamp, mangrove, lakes and pools. This study added six species into the list of birds in KBBS, which was previously compiled in 1985. Among species recorded were the critically endangered (CR) *Fregata andrewsi* and near threatened (NT) *Anhinga melanogaster*.

Keywords: Kota Belud Bird Sanctuary, bird diversity, species richness, Shannon-Wiener index, Margalef index, IUCN red list status

Introduction

The island of Borneo, which is divided among three countries; Malaysia, Indonesia and Brunei, has about 620 bird species, of which 52 species are endemic (Phillipps & Phillipps, 2011). Apart from high endemism, the island is also a hot spot for migrating birds to stop-over. This is especially true for birds requiring wetland and coastal areas. An important site that provides a wintering habitat for such migrants is the Kota Belud Bird Sanctuary (KBBS) which was gazetted in 1960 on the west coast of Sabah, Malaysia. KBBS is one of the most important bird sanctuaries in Sabah as indicated by significant records of migratory birds, such as Garganey (*Anas querquedula*), Tufted duck (*Aythya fuligula*) and Mallard (*Anas platyrhynchos*). Black coot (*Fulica atra*)

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was a particularly unusual migrant recorded in this sanctuary by Burgess in February 1964 (de Silva, 1968). During a survey that was conducted in KBBS in 1984 – 1985 by Payne & Parish (1985), about half a million individual birds were recorded, representing 127 resident and migrant species. The majority were birds that migrated from the northern hemisphere (although some austral migrants also occur). Swallows were the most common bird species during the survey, with 300,000 individuals. Other migrants included Christmas island frigatebird (*Fregata andrewsi*), Grey heron (*Ardea cineria*) and Great egret (*Ardea alba*).

Four types of habitats were identified as foraging and breeding sites for birds in KBBS. These habitats were: i) grassland, scrub, bush, open land and suburban areas, ii) paddy fields and flooded paddy, iii) coastal strand and mudflats, and iv) swamp, mangrove, lakes and pools. KBBS is unique as it is associated with people, settlements and development. It also affords a beautiful view of Mount Kinabalu from the west side. The local people are of various ethnic groups, such as Bajau, Dusun and Iranun and they still practice agricultural activities such as farming and cattle raising.

The objectives of our study were to determine the diversity and species richness of birds in KBBS and to identify habitats of the birds that occur there. The overall purpose was to provide information for managing and conserving birds in the Sanctuary. We censused birds and incorporated information gathered by other researchers in the last 25 years.

Methods

Study area

The study was carried out in KBBS, which is located on the west coast of Sabah at N 6°27'52" E 116°29'15" (Figure 2). The total area of the sanctuary is approximately 12,200 ha, starting from the northern part of Kota Belud town and continuing along the coast of Sabah until Rampayan village (Payne & Parish, 1985).

Field surveys

A total of 19 days of sampling were conducted from October 2011 until March 2012. There were seven (7) villages that had been selected as sampling stations namely Pantai Emas (PE), Kg. Taun Gusi (TG), Kg. Tempasuk-Sangkir (TS), Kg. Kesapang (KG), Kg. Kawang-Kawang-Rosok (KKR), Kg. Nanamun (NN)

Figure 1. Diagram of line transect of 1 km that was applied during the survey

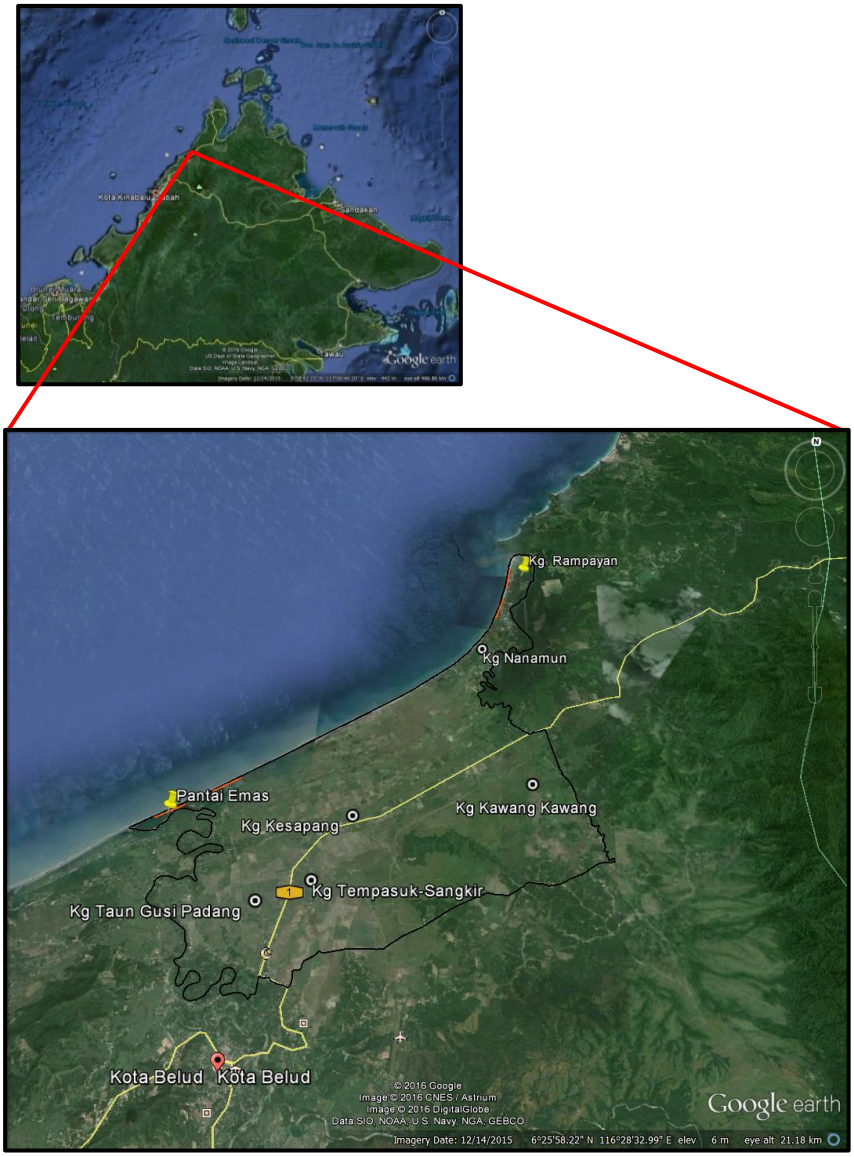

Figure 2. Map of Kota Belud Bird Sanctuary indicating locations of point (•) and line transect (red line) sampling (Source: Google Earth)

and Kg. Rampayan (RN). Censusing methods consisted of direct observation on line transect and point counts (Figure 1 & 2), and also mist-netting.

Four transects of one kilometre (km) each were established, two in the coastal area of Pantai Emas and two at Rampayan, respectively as these areas are open habitat and large, thus this method was effective and practical (Bibby et al., 1992). Transects were divided into five stop points 200 metres (m) apart. Each point was surveyed for 10 to 15 minutes. In addition, five point counts were established within the study area, and 30 minutes or more were spent at each site based on the occurrence of birds. Each point covered mainly habitats that are associated with humans such as settlements and agricultural sites. TG and KG stations mostly covered the habitat of suburban area and paddy field. TS and KKR stations covered the habitat of paddy field and flooded paddy and the habitat of grassland and bushes, respectively. Meanwhile, NN station covered the habitat of swamp and mangrove.

Sampling was conducted in the early morning from 0600 hours to 1000 hours and at dusk, from 1600 hours to 1800 hours. For mist-netting, there were only two types of habitats that could be accessed in order to set up the nets namely paddy fields and flooded paddy, and the habitat of grassland, scrub, bush and open and suburban area. Four mist-nets of 12 - 13 m were set up based on bird flight direction in each habitat for four days of sampling and they had been opened at 0700 hours and closed at 1800 hours. The nets were checked for any captured birds every two hours. The captured individuals or birds were identified and released after measurements of standard methods were taken such as beak length, wingspan, body length and tail length as well as tarsus length.

Analysis

Shannon and Margalef indices were calculated to determine bird diversity and species richness, respectively using Species Diversity and Richness version 2 software (Seaby & Henderson, 1998).

Results

Richness and bird composition

Overall, a total of 2,717 birds were recorded during the study, of which 74 species from 31 families were identified. October 2011 had recorded the highest number of birds in which a total of 689 birds were recorded in the sanctuary. A total of 27 out of 74 species were migrants; 12 species were

classified as both migrants and residents; and the remaining 35 species were residents. Four types of habitats were identified as foraging sites and breeding sites for birds (see Table 1). These habitats were: i) grassland, scrub, bush, and open and suburban areas which was found in TG, KN and KKR, ii) paddy fields and flooded paddy which was found in TG, KN and TS, iii) coastal strand and mudflats in PE, NN and RN and iv) swamp, mangrove, lakes and pools mostly found in PE, NN, RN and KKR (Table 1).

The abundance of individual bird species of all types (resident and migrant species) and in all habitats is shown in Figure 3-6. In grassland, scrub, bush, and open and suburban areas, the most dominant species was *Lonchura atricapilla* (21.47 %) followed *by Aplonis panayensis* (15.3 %) and *Hirundo tahitica* (9.71 %). Paddy fields and flooded paddy were dominated by *Egretta intermedia* (13.3 %) and *Himantopus himantopus* (10.7 %). Coastal strand and its surrounding area were dominated by *Artamus leucorhynchus* (29.96 %), followed by *Hirundo tahitica* and *Bubulcus ibis* with 14.76 % and 10.5 %, respectively. In swamp, mangrove, lakes and pools, *Dendrocygna arcuata* was the most recorded species, with 53 individuals (73.6 %). Overall, *Lonchura atricapilla* was the most recorded species (359 individuals), followed by *Hirundo tahitica* (197 individuals) and *Aplonis panayensis* (194 individuals).

Species Richness and Diversity of Birds

KBBS possessed a high species diversity and richness in which Shannon index was H'=3.4664 and Margalef index was D_{mg} = 9.232.

Table 1: The presence and absence of bird species based on habitat

Habitat 1: Grassland, open areas, bush and suburban areas (TG, KN & KKR),**Habitat 2:** Paddy fields and flooded paddy (TG, KN & TS)
Habitat 3: Coastal strand and associated areas (PE, NN & RN),**Habitat 4:** Swamp, mangroves, lakes and pools (PE, NN, RN & KKR)

No	Common Name	Species Name	Habitat 1	Habitat 2	Habitat 3	Habitat 4
1	Eastern Marsh Harrier	*Circus spilonotus*	-	/	-	-
2	Brahminy Kite	*Haliastur indus*	-	/	/	-
3	Black-shouldered Kite	*Elanus caeruleus*	/	/	-	-
4	Peregrine Falcon	*Falco peregrinus peregrinator*	-	/	-	-
5	Great Egret	*Ardea alba*		/	/	
6	Intermediate Egret	*Egretta intermedia*	/	/		
7	Little Egret	*Egretta garzetta*	/	/		
8	Little Egret	*Egretta nigripes*		/		
9	Grey Heron	*Ardea cineria*	/			
10	Purple Heron	*Ardea purpurea*		/		/
11	Chinese Pond Heron	*Ardeola bacchus*		/		
12	Javan Pond Heron	*Ardeola speciosa*		/		
13	Cattle Egret	*Bubulcus ibis*	/		/	
14	Yellow Bittern	*Ixobrychus sinensis*		/		
15	Cinnamon Bittern	*Ixobrychus cinnamomeus*		/		
16	Wandering Whistling Duck	*Dendrocygna arcuata*		/		/
17	Darter	*Anhinga melanogaster*				/
18	Slaty-breasted Rail	*Gallirallus striatus*		/		
19	Watercock	*Gallicrex cineria*		/		
20	Common Moorhen	*Gallinula chloropus*		/		
21	Purple Swamphen	*Porphyrio porphyrio*		/		
22	White-breasted Waterhen	*Amaurornis phoenicurus*	/	/	/	
23	Black-winged Stilt	*Himantopus himantopus*		/		
24	Little Ringed Plover	*Charadrius dubius curonicus*		/		
25	Kentish Plover	*Charadrius alexandrinus*			/	
26	Lesser Sand Plover	*Charadrinus mongolus*			/	
27	Pacific Golden Plover	*Pluvialis fulva*		/	/	
28	Whimbrel	*Numenius phaeopus*		/		
29	Common Redshank	*Tringa totanus*		/		
30	Common Greenshank	*Tringa nebularia*		/		

(Continued on next page)

Table 1. (Continued)

No	Common Name	Species Name	Habitat 1	Habitat 2	Habitat 3	Habitat 4
31	Wood Sandpiper	*Tringa glareola*		/		
32	Marsh Sandpiper	*Tringa stagnatilis*		/		
33	Common Sandpiper	*Actitis hypoleucos*		/		
34	Red-necked Stint	*Calidris ruficollis*		/		
35	Whiskered Tern	*Chlidonias hybridus*		/		
36	Black-naped Tern	*Sterna sumatrana*		/		
37	Little Tern	*Sterna albifrons*	/	/		
38	White-winged Black Tern	*Chlidonias leucopterus*		/		
39	Zebra Dove	*Geopelia striata*	/	/	/	
40	Spotted Dove	*Streptopelia chinensis*	/		/	
41	Feral Pigeon	*Columba livia*	/			
42	Greater Coucal	*Centropus sinensis*	/			
43	Lesser Coucal	*Centropus bengalensis*	/			
44	Large-tailed Nightjar	*Caprimulgus macrurus*	/			
45	Collared Kingfisher	*Todiramphus chloris*	/	/	/	/
46	Stork-billed Kingfisher	*Pelargopsis capensis*				/
47	Common Kingfisher	*Alcedo atthis*				/
48	Blue-throated Bee-eater	*Merops viridis*			/	
49	Dollarbird	*Eurystomus orientalis*	/		/	
50	Pied Triller	*Lalage nigra*	/			
51	Brown Shrike	*Lanius cristatus lucionensis*	/			
52	White-breasted Woodswallow	*Artamus leucorhynchus*	/	/	/	
53	Sand Martin	*Riparia riparia*	/			
54	Barn Swallow	*Hirundo rustica*	/	/	/	
55	Pacific Swallow	*Hirundo tahitica*	/	/	/	
56	Red-headed Tailorbird	*Orthotomus ruficeps*	/			/
57	Oriental Reed Warbler	*Acrocephalus orientalis*	/			
58	Striated Grassbird	*Megalurus palustris*		/		
59	Yellow-bellied Prinia	*Prinia flaviventris*	/			
60	Olive-winged Bulbul	*Pycnonotus plumosus*	/			

(Continued on next page)

Table 1. (Continued)

No	Common Name	Species Name	Habitat 1	Habitat 2	Habitat 3	Habitat 4
61	Yellow-vented Bulbul	*Pycnonotus goiavier*	/	/		/
62	Oriental Magpie Robin	*Copsychus saularis adamsi*	/			
63	Pied Fantail	*Rhipidura javanica*	/	/		/
64	Olive-backed Sunbird	*Nectarinia jugularis*	/		/	/
65	Brown-throated Sunbird	*Anthreptes malacensis*	/			/
66	Scaly-breasted Munia	*Lonchura punctulata*	/	/		
67	Chestnut Munia	*Lonchura atricapilla*	/	/		
68	Dusky Munia	*Lonchura fuscans*		/		
69	Yellow Wagtails	*Motacilla flava*	/	/	/	
70	Paddyfield Pipit	*Anthus rufulus*	/	/		
71	Eurasian Tree Sparrow	*Passer montanus*	/			
72	Asian Glossy Starling	*Aplonis panayensis*	/			
73	Common Iora	*Aegithina tipia*	/			
74	Christmas Island Frigatebird	*Fregata andrewsi*			/	
	Total Number of Species		**37**	**46**	**18**	**11**

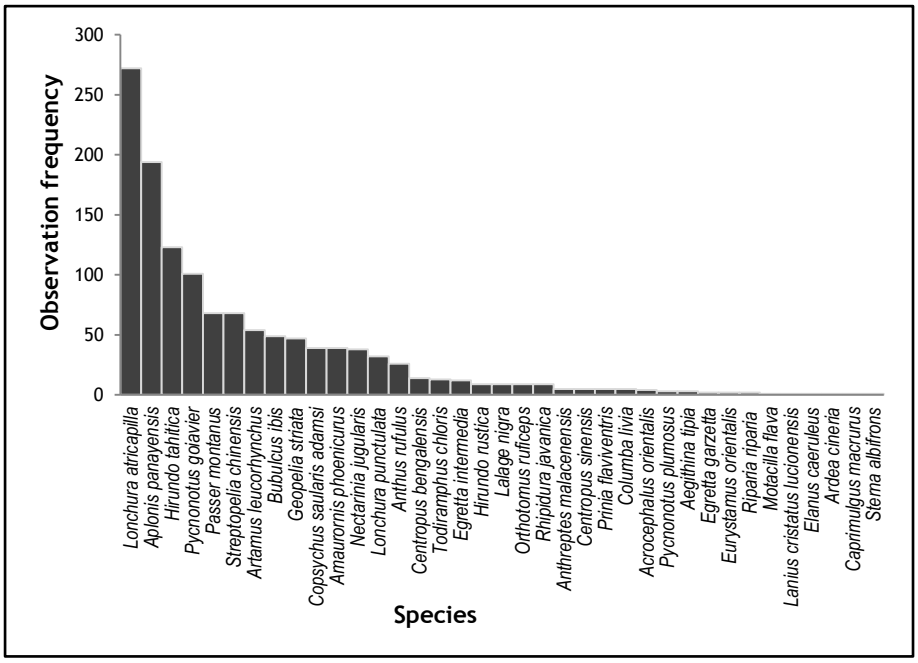

Figure 3. Bird species abundance in habitat of grassland, scrub, bush, and open and suburban areas.

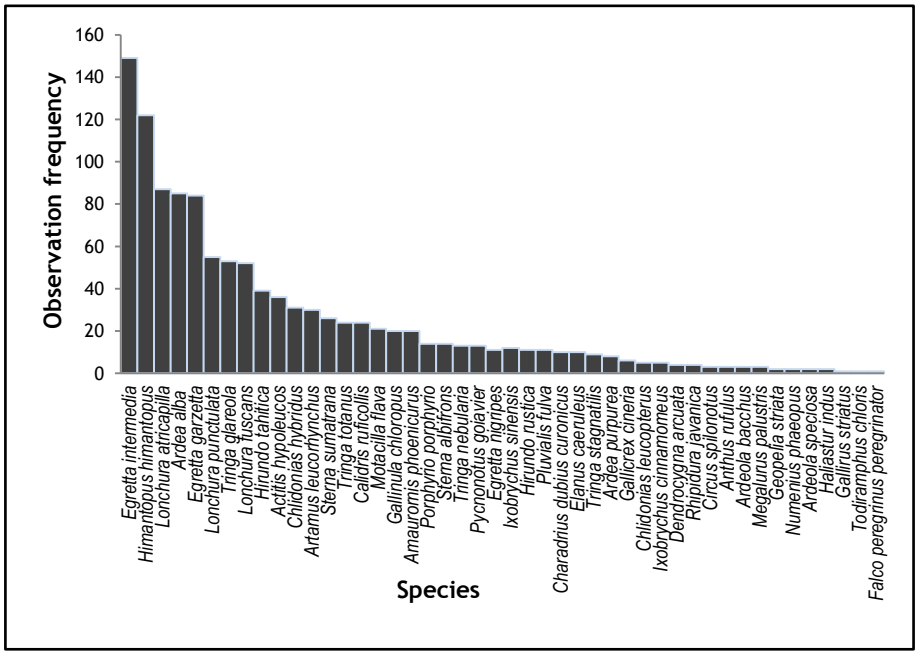

Figure 4. Bird species abundance in habitat of paddy fields and flooded paddy.

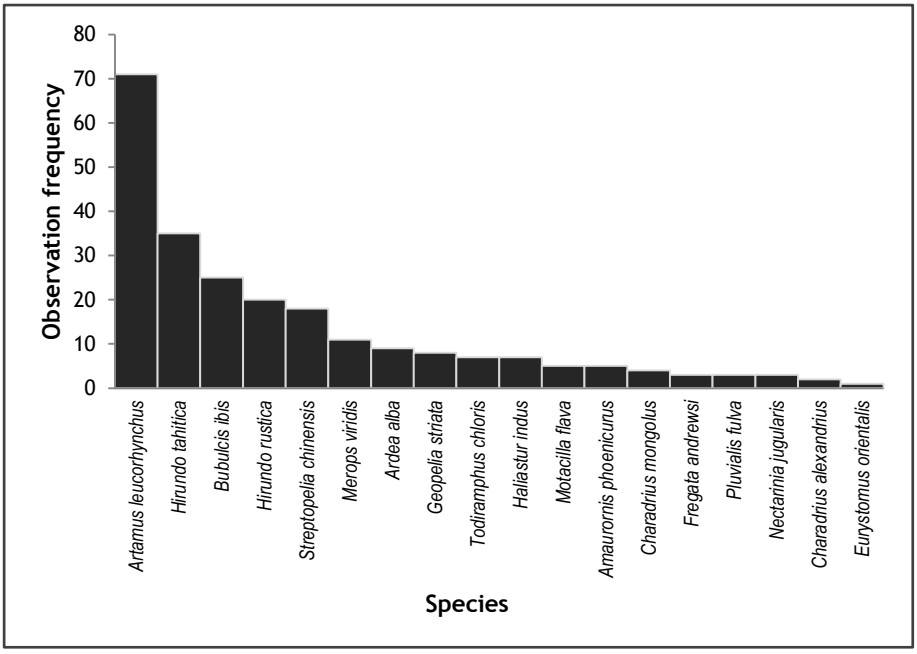

Figure 5. Bird species abundance in habitat of coastal strand and mudflats.

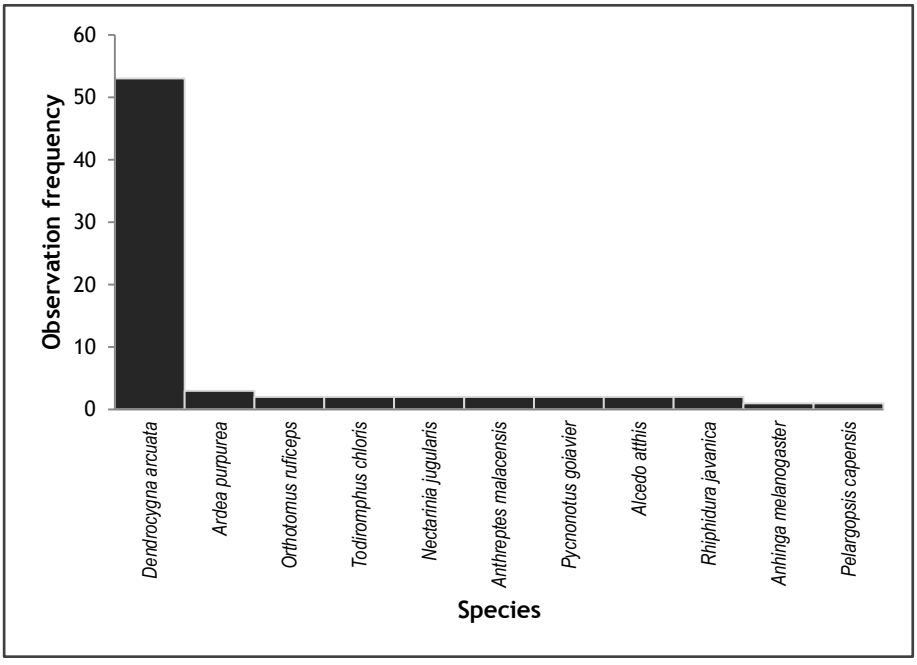

Figure 6. Bird species abundance in habitat of swamp, mangrove, lakes and pools.

Discussion

The timing of bird migration is expected to have a strong influence on the number of birds using KBBS. According to Phillipps & Phillipps (2011), October is the peak migration period for northern migrants to reach the north-western coast of Borneo. In addition to that, Payne & Parish's (1985) survey reported that October to March recorded the highest number of migrant birds in KBBS. *Himantopus himantopus* was one migrant species that was recorded in a big group during these months.

Overall, the total bird individuals that were recorded in this study was lower compared to the previous survey by Payne and Parish in a one year period from 1984 until 1985. This could be due to the short term sampling effort as 19 days of surveys in five months is fairly limited for better results. Since most part of the sanctuary is associated with settlements and communities (private land), it was quite difficult to access the entire sanctuary therefore the sampling stations were chosen because of accessibility and this may have influenced the sampling effort. In terms of diversity, 74 bird species were identified, but we were able to classify numerous others in specific taxonomic groups. Of these Charadriidae (shorebird) was particularly abundant (about one hundred) in flooded paddy. Although this study documented only 74 species compared to 127 species from the 1985 survey, we still managed to add a few bird species to the KBBS list that were not recorded during the past study, namely *Ardeola bacchus*, *A. speciosa*, *Columba livia*, *Dendrocygna arcuata*, *Lonchura punctulata* and *Passer montanus*.

Four main habitats were identified in the sanctuary as important locations for foraging and breeding. Grassland, open areas, shrub and suburban areas had similar vegetative structure made up mainly of grasses and secondary plants. Thus, these areas were considered as one habitat. In this habitat we recorded 37 species, of which *Pycnonotus goiavier* and *Passer montanus* were among the common species. The urban species, *Columba livia* was found in this habitat group, indicating that some parts of the sanctuary are experiencing urbanization with the increase in human population and development. As in the forested areas of Borneo (Davison, 2001), parts of KBBS have faced land use changes and associated problems. However, land use changes in an agricultural area such as KBBS has had a different impact on the bird community.

According to Lansdown (1986), 16 species of ardeid had been recorded in KBBS including both herons and bitterns. These birds were found in six different

habitats, namely grazing areas, mangroves, swamp, paddy fields and in a large agricultural area consisting of paddy, plantation, and river, Little Egret (*Egretta garzetta*) was the most common among all species found in those habitats. Paddy fields and flooded paddy are outstanding locations to watch birds in KBBS, as a lot of migrant birds can be seen here, mainly waders of water birds. This habitat serves a good foraging site for birds as it attracts other organisms, such as insects and several vertebrate species. In fact, vertebrate diversity is higher in cereal crops compared to oil palm (Neave & Neave, 1998; Lee et al., 2006). However, gramnivorous or seed-eating species, especially birds of family Estrildidae, were found in this habitat in large numbers. A few raptors were also recorded during the survey in this habitat, namely *Circus spilonotus*, *Elanus caeruleus* and *Haliastur indus*.

Coastal strand and associate areas also held *Haliastur indus*, as it is a raptor that occurs widely in coastal habitats. The vegetation structures of coastal strand are mainly short grasses and open woodland consisting of beach-edge trees. A few wader species were recorded in this area as well, and interestingly, a few individuals of critically endangered *Fregata andrewsi* were recorded flying above the sea at Rampayan in March 2012. March until July is the breeding period of sea birds and the seas are calmest during that time, thus facilitating the foraging activity of those birds (Phillipps & Phillipps, 2011).

The final habitat (swamp, mangroves, lakes and pools), held 11 recorded species of birds, including a large group of *Dendrocygna arcuata* in the lakes. It was the only resident duck species that was found, and unfortunately, there was no record of migrant ducks within the 19 days of sampling in the KBBS. *Ardea purpurea* and *Alcedo atthis* were found in the swamp and mangroves areas.

KBBS has significant values as a resting and wintering site for migratory birds, and it complements other wetland areas such as Padang Teratak Wildlife Sanctuary on Klias Peninsula and the urban Kota Kinabalu Wetland Centre (KKWC). KBBS has different types of habitats compared to the other sites. It provides ideal foraging for both resident and migrant birds, and breeding sites for residents. Its paddy fields and flooded paddy, as well as the coastal strand, are attractive spots for migrants such as shorebirds and waders, as evidenced by their commonality in these habitats from October to March.

An important issue is that it lacks wildlife patrolling and signage that indicates its purpose. It also does not have an information centre that would be useful for eco-tourists. Thus, the local communities of KBBS do not have much information and knowledge of the sanctuary. In this respect it is different from other sanctuaries. Therefore, the importance of the sanctuary should be looked into as well as to inculcate public awareness about bird conservation and the value of this bird sanctuary.

Conclusion

In conclusion, KBBS is one of the favourite hotspots or locations for migratory birds to stop-by or stay in Borneo during the northern migration season. This is especially true for migratory waders. The sanctuary has at least four different types of habitats. Its coastal strand even featured the critically endangered species *Fregata andrewsi*. Although the total recorded species in this study is lower than the previous survey, KBBS still possesses a high diversity of birds. Our study can act as reference for future studies and can be useful in assisting conservation efforts to preserve this important site.

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Research Article

SRAP Markers Based Genetic Analysis of *Silene* Species

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Abstract

Plant genetic resources are an essential part of the world's natural resources, and knowledge of genetic diversity and its distribution is essential for plant conservation. In the present work, the genetic variation was studied among thirteen species of *Silene* genus. Samples were collected from different locations of West Azarbijan and Khorasan provinces in Iran. This investigation, for the first time, has studied sequence-related amplified polymorphism (SRAP) marker to assess the genetic diversity and genetic similarity among 13 species of *Silene* in Iran. These species belonge to eight sections including *Sclerocalycinae, Melandriforms, Lychnidiforms, Inflatae, Lasiocalycinae, Spergolifoliae, Auriculatae* and *Conoimorpha*. Fifteen SRAP primer combinations generated 62 fragments, of which 46 (71.90 %) were polymorphic. Percentage of polymorphism ranged from 50 % to a maximum of 100 % and Jaccard's similarity coefficient ranged from 0.48 to 0.91. Minimum Evolution analysis revealed four main clusters. The study indicates that SRAP markers with targeting ORFs, high reproducibility and optimal marker distribution could be good candidates for assessing genetic variation in *Silene*.

Keywords: Genetic variation, *Silene*, polymorphism, SRAP

Introduction

Silene belongs to silenoideae subfamily, caryophyllaceae family, and is composed of 700 species around the world (Jurgens et al., 2002; Jurgens, 2004). This genus is distributed in Turkey, Russia, Italy, Iraq, Iran, east of Mediterranean, Europe, Japan, Spain and England (Boissier, 1884; Tutin, 1964; Zohary, 1966; Groshkova, 1970; Davis, 1965-1985; Anzalone, 1982; Melzheimer, 1988). In Iran, *Silene* includes 110 species of which 35 are endemic (Melzheimer, 1988).

Plant genetic diversity represents the heritable variation within and between species which is the basis for selection and plant improvement. Hence, genetic

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diversity conservation is essential for the future of humans. Plant genetic diversity changes in time and space with extent and distribution depending on breeding system, ecological and geographical factors, past bottlenecks, and human factors. A better knowledge of genetic diversity will help us to understand the taxonomy, origin and evolution of plant species. Morphological characteristics often do not result in a clear identification of species due to effects of different environmental conditions (Ebrahimi et al., 2011). However, DNA markers offer many advantages over morphological characters for the determination of genetic diversity and the identification of species, such as not being influenced by the environment, and detection directly at the DNA level (Joy et al., 2007; Pradeepkumar et al., 2003).There are a variety of DNA marker techniques, such as random amplified polymorphic sequence (RAPD) (Juchum et al., 2007; Ro et al., 2007), amplified restriction fragment polymorphism (AFLP) (Percifield, 2007;Yuan et al., 2007) and microsatellite markers (SSR) (Legesse et al., 2007; Tommasini et al., 2003). The sequence-related amplified polymorphism (SRAP) technique is simple, reliable with moderate throughput ratio and facile sequencing of selected bands. The marker is highly reproducible DNA marker useful for both mapping and gene tagging in plants (Li & Quiros 2001).

SRAP has been shown to be more informative than other PCR-based techniques in detecting genetic diversity (Budak et al., 2004) and has been successfully used to study the genetic diversity of, and relationships among, several species (Ferriol et al., 2003; Budak et al., 2004; Riaz et al., 2004; Esposito et al., 2007; Fu et al., 2008; Feng et al., 2009; Uzun et al., 2009; Castonguay et al., 2010; Talebi et al., 2011b; Abedian et al., 2012). In SRAP, the first ten bases of the forward primers consist of a core sequence with no specific constitution which is followed by CCGG and then by three selective bases at the 3′ end. The reverse primers consist of the same core sequence as the forward primers with the following AATT and then three selective nucleotides to the 3′ end of the primer. The CCGG motif falls usually into exons and exonic sequences are conserved among individuals. In contrast, AATT sequence is frequently found in promoters and introns (Li & Quiros 2001).

Although the genetic diversity of *Silene* genus has been studied by use of molecular markers in the world (Rettig et al., 1992; Richards et al., 2003; Tero et al., 2003; Welch et al., 2006; Minder et al., 2007; Jolivet & Bernasconi, 2007), there is not much systematic study on the genetic relationship among the species of *Silene* based on molecular markers in Iran (Sheidai et al., 2008; Sheidai et al., 2010; Aghaee Bargish & Rahmani, 2015). Specifically, no

attempts have been made to use SRAP markers, which target ORFs as functional regions of the genome resulting in a moderate number of co-dominant markers. SRAP works like a random amplified polymorphic DNA (RAPD) marker, but targets specific regions of the genome (Dalong et al., 2010). The SRAP markers have been shown to be sustainable and less complex compared to other molecular marker systems. The genetic diversity potency of RAPD, ISSR, SSR and SRAP has been reported in the following order: SRAP> SSR> ISSR> RAPD (Budak et al., 2004). Thus, the objective of this study was to assess the genetic relationship between thirteen species of *Silene* genus in Iran using SRAP marker.

Materials and methods

Plant materials. Species of *Silene* genus were collected from their natural growing regions of West Azerbijan and Khorasan area (Figure 1).The details on sample collection are given in Table 1. Fresh young leaves of 5 to 6 plants were collected from the field-grown plants and stored at -80 °C prior to DNA extraction. Plant leaves of the same species were mixed prior to DNA extraction.

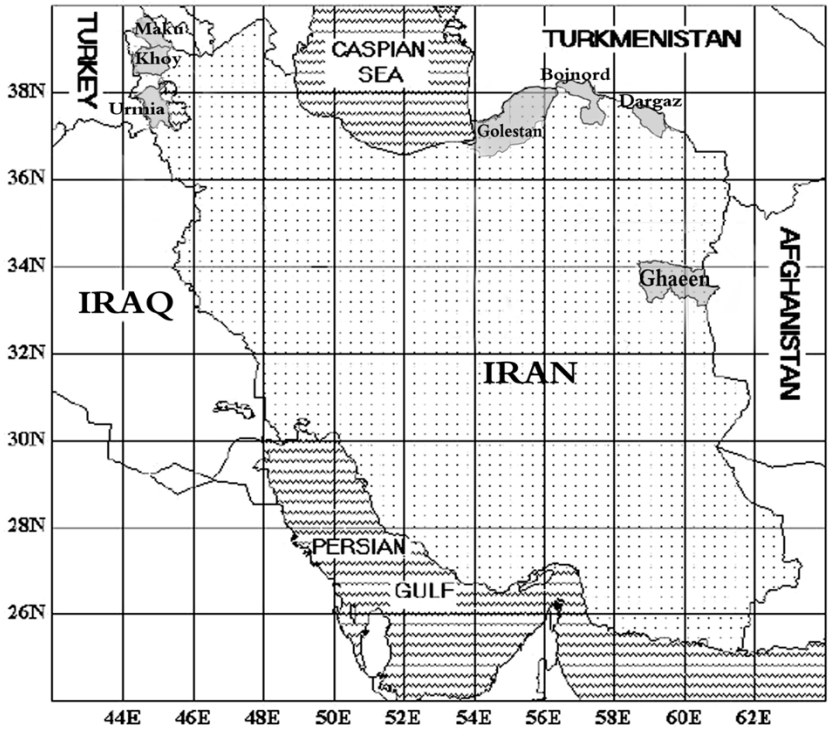

Figure 1. Geographical distribution of selected *Silene* spp. used in this study. The collection area has been highlighted in grey colour.

Table 1. Location of *Silene* species used in the present study.

Bil.	Species	Location
1	*S. bupleuroides*	Urmia, Salmas road, Ghoshchi 1800 m.
2	*S. vulgaris*	Maku Between GarehKhaj and Dibak, 1850 m.
3	*S. aucheriana*	Maku Between GarehKhaj and Torkan 1850 m.
4	*S. dichotoma*	Urmia, Jade Sero, Nazlu, 1273 m.
5	*S. latifolia*	Urmia, Jade Emamzade, 1273 m.
6	*S. chlorifolia*	Urmia, Ghoshchi, koheSomakh, 1800 m.
7	*S. araratica*	Maku Between GarehKhaj and Dibak, 1850 m.
8	*S. conoidea*	Khoy, Psak Village,1700 m.
9	*S. spergulifolia*	Urmia,45 km Oshnaviyeh, 1300 m.
10	*S. parjumanensis*	Western Khorasan, W-Ghaeen, Tajan mountains, 2000 m.
11	*S. noctiflora*	North Khorasan, W-S Bojnord, Rien, 1700 m.
12	*S. indeprensa*	Khorasan, Daregaz, International Park Tounduoreh, 2400 m.
13	*S. coronaria*	Goulestan, E-N International Park Goulestan, 1200 m.

DNA extraction. The genomic DNA was extracted following the modified CTAB method (Liu et al., 2003). The concentration of each DNA sample was determined spectrophotometrically at 260 nm (Biophotometer 6131; Eppendorf, Hamburg, Germany). The quality of genomic DNA was determined by electrophoresis on 1.0 % (w/v) agarose gel and then diluted to 10 ng /µl for PCR reactions.

SRAP-PCR amplification. In total, 5 forward and 9 reverse primers (Guo et al., 2013) were purchased from Cinnagen, Tehran, Iran. Nineteen random SRAP primer combinations were selected for SRAP analysis (Table 2). SRAP amplifications were performed in 25 µl reaction volumes containing 12.5 µl Master mix (Taq DNA polymerase, 10x PCR buffer, dNTPs and $MgCl_2$ and 0.5 µl primer (100 µM) and 9 µl ddH2O and 3 µl of genomic DNA template. Amplification conditions were as follows: initial denaturation at 95 °C for 3 minutes, 5 cycles of 95 °C for 1 minute, 32 °C for 1.5 minute and 72 °C for 1.5 minute; 35 cycles of 95 °C for 1 minute, 55 °C for 1.5 minute and 72 °C for 1.5 minute; followed by a final 10 minutes extension at 72 °C. Amplification products were visualized by 5 hours running on 3 % agarose gel with constant voltage of 50 V, following ethidium bromide staining (10 µg/ ml). The size of DNA fragments were estimated by comparison with the 50 bp Gene Ruler DNA size marker (Fermentas).

Table 2. Primer sequences used for SRAP analysis in this study.

SRAP primers			
Forward primers		**Reverse primers**	
ME1	5'-TGAGTCCAAACCGGATA-3'	EM1	5'-GACTGCGTACGAATTCAAT-3'
ME2	5'-TGAGTCCAAACCGGAGC-3'	EM2	5'-GACTGCGTACGAATTCTGC-3'
ME3	5'-TGAGTCCAAACCGGAAT-3'	EM3	5'-GACTGCGTACGAATTCGAC-3'
ME4	5'-TGAGTCCAAACCGGACC-3	EM4	5'-GACTGCGTACGAATTCTGA-3'
ME5	5'-TGAGTCCAAACCGGTGC-3'	EM6	5'-GACTGCGTACGAATTCGCA-3'
-	-	EM17	5'-GACTGCGTACGAATTCGAG-3'
-	-	EM18	5'-GACTGCGTACGAATTCGCC-3'
-	-	EM19	5'-GACTGCGTACGAATTCTCA-3'
-	-	EM20	5'-GACTGCGTACGAATTCTCC-3'

Table 3. Genetic diversity of *Silene* species revealed by SRAP.

Primers	Total number of bands	Number of polymorphic bands	Number of monomorphic bands	Percentage of polymorphic bands (PPB)	PIC value
ME1-EM2	3	2	1	66. 6	0.44
ME1-EM17	3	3	0	100	0.71
ME2-EM20	4	4	0	100	0.58
ME3-EM19	6	4	2	66.6	0.59
ME4-EM17	2	2	0	100	0.56
ME4-EM18	3	3	0	100	0.37
ME5-EM6	3	3	0	100	0.43
ME1-EM3	6	5	1	83.3	0.79
ME1-EM4	6	5	1	83.3	0.81
ME3-EM4	3	2	1	66.6	0.67
ME4-EM2	4	2	2	50	0.50
ME5-EM1	3	2	1	66.6	0.64
ME5-EM2	3	2	1	66.6	0.64
ME1-EM6	2	1	1	50	0.50
ME5-EM3	2	1	1	50	0.48
ME4-EM1	3	2	1	66.6	0.34
ME3-EM3	2	1	1	50	0.50
ME2-EM6	2	1	1	50	0.36
ME5-EM4	2	1	1	50	0.49
Total	62	46	16	-	-
Mean	3.2	2.4	-	71.90	0.54

Data analysis. The amplified DNA fragments were recorded as either (1) or (0), representing the presence or absence of the band, respectively. Data analysis was conducted using polymorphic bands. Faint or unclear bands were not considered. Amplified fragments were scored to create binary data matrices. Data analyses were performed using the numerical taxonomy multivariate analysis system software package (NTSYS-pc); version 2.02 (Rohlf, 2002) and MEGA4 (Tamura et al., 2007). Polymorphism information content (PIC) values were estimated according to the formula: PIC= 1 – Σ (Pij) 2, where Pij is the frequency of the ith pattern revealed by the jth primer summed across all patterns revealed by the primers (Botstein et al., 1980). Dendrogram was constructed later based on Minimum Evolution method. The representativeness of the dendrogram was evaluated by estimating cophenetic correlation coefficient for the dendrogram and comparing it with the similarities matrix using Mantel matrix correspondence test (Mantel, 1967). For statistical support, bootstrap analysis was performed using MEGA4 with 1000 replicates to obtain the confidence of the tree (Tamura et al., 2007).

Results

SRAP analysis. Nineteen SRAP primer combinations generated a total of 62 bands of which 46 (71.90 %) were polymorphic (Table 4). The number of scorable markers produced per primer ranged from 2 (ME4-EM17, ME1-EM6, ME5-EM3, ME3-EM3, ME2-EM6& ME5-EM4) to 6 (ME1-EM4, ME1-EM3 & ME3-EM19), with an average of 3.2 fragments per primer. The size of the amplified products ranged from 100 bp to 600 bp. Figure 2 represents the SRAP profile of 13 *Silene* species using ME1-EM4 primer.

The PIC values ranged from 0.34 (ME4-EM1) to 0.81 (ME1-EM4) with a mean of 0.54. Jaccard's similarity coefficients based on 62 SRAP markers ranged from 0.48 to 0.90. *S. vulgaris* and *S. indeprensa* showed the lowest genetic similarity (0.48), and *S. conoidea* and *S. araratica* revealed the highest similarity (0.91).

Table 4. Jaccard's similarity coefficient between thirteen *Silene* species based on SRAP molecular marker.

	S. bupleuroides	*S. vulgaris*	*S. aucheriana*	*S. dichotoma*	*S. latifolia*	*S. chlorifolia*	*S. araratica*	*S. conoidea*	*S. spergulifolia*	*S. parjumanensis*	*S. noctiflora*	*S. indeprensa*	*S. coronaria*
S. *bupleuroides*	1.00												
S. vulgaris	0.63	1.00											
S. aucheriana	0.63	0.55	1.00										
S. *dichotoma*	0.72	0.66	0.74	1.00									
S. latifolia	0.66	0.57	0.62	0.74	1.00								
S. chlorifolia	0.78	0.66	0.74	0.82	0.75	1.00							
S. araratica	0.75	0.64	0.67	0.78	0.72	0.84	1.00						
S. conoidea	0.67	0.62	0.62	0.76	0.71	0.76	0.90	1.00					
S. spergulifolia	0.64	0.59	0.78	0.66	0.55	0.72	0.65	0.64	1.00				
S. parjumanensis	0.66	0.57	0.69	0.75	0.65	0.76	0.73	0.66	0.63	1.00			
S. noctiflora	0.67	0.62	0.62	0.82	0.80	0.72	0.74	0.76	0.64	0.66	1.00		
S. indeprensa	0.55	0.48	0.65	0.57	0.54	0.65	0.63	0.62	0.63	0.53	0.54	1.00	
S. coronaria	0.78	0.72	0.70	0.82	0.70	0.76	0.78	0.72	0.72	0.76	0.76	0.54	1.00

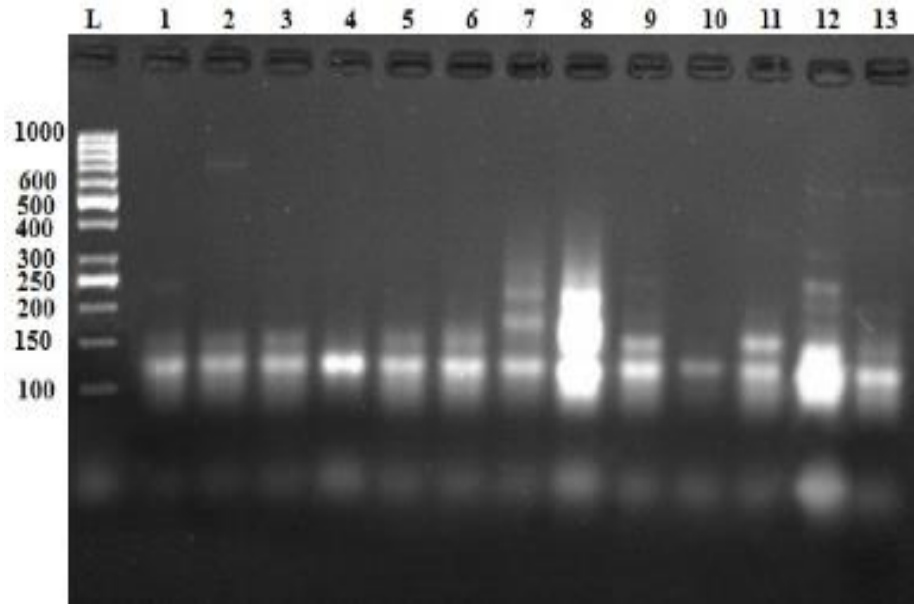

Figure 2. Amplification profile of 13 species of *Silene* based on ME1-EM4 primers combination. The numbers from left to right are representative of 1) *S.bupleuroides*; 2) *S.vulgaris*; 3) *S.aucheriana*; 4) *S.dichotoma*; 5) *S.latifolia*; 6) *S.chlorifolia*; 7) *S.araratica*; 8) *S. conoidea*; 9) *S.spergulifolia*; 10) *S.parjumanensis*; 11) *S.noctiflora*; 12) *S.indeprensa*; 13) *S.coronaria*. L represents 50bp DNA ladder.

The dendrogram, constructed based on Minimum Evolution method using MEGA4 software distinguished four main groups among 13 species of *Silene* (Figure 3). Cluster I comprised of 8 species that were delineated into two sub-clusters. Sub-cluster I included *S.latifolia, S. noctiflora, S.dichothoma, S.araratica* and *S.conoidea*. Sub-cluster II consisted of *S. parjumanensis, S.vulgaris and S.coronaria*. Clusters II and III contained *S.bupleuroides* and *S.chlorifolia,* respectively. Cluster IV comprised of *S.indeprensa, S.aucheriana* and *S.spergulifolia*.

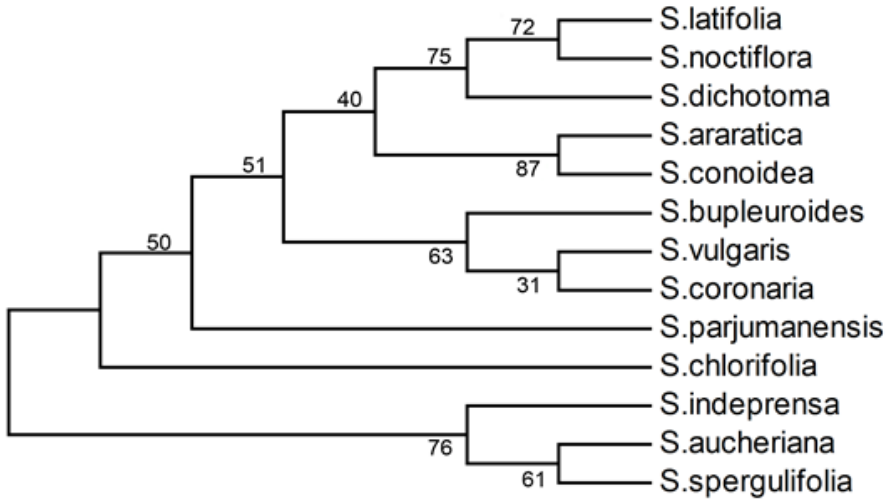

Figure 3. Dendrogram obtained by Minimum Evolution cluster analysis based on SRAP

Discussion

There are many examples of successful application of molecular markers in genetic diversity analysis. Study of genetic relationship among plant taxa at species or/and genera level is very important because it provides information about the direction and sequential scale for plant evolution (Savolainen & Chase, 2003). SRAP marker with the advantages of RAPD markers and AFLP markers is a relatively new type of molecular marker and is more suitable for application in practice because of its features such as simple, low-cost test, security and rich in polymorphism (Li & Quiros, 2001; Li & Zhang, 2005). Rich polymorphism of these features is the most important characteristics. SRAP has also been reported as the most powerful DNA marker due to polymorphism

detection in coding sequences which are usually conserved among closely related species and varieties with low mutation rate (Mishra et al., 2011).

In this study, 19 SRAP primer combinations generated 62 fragments, of which 46 (71.90 %) were polymorphic**.** This value appeared to be lower than other SRAP based studies, detecting higher polymorphism, e.g. 95.76 % for *Dianthus* accessions (Xiao et al., 2008) and 93 % for coffee species (Mishra et al., 2011). However, ISSR molecular analysis detected higher genetic variability (98.85 %) among these *Silene* species (Aghaee Bargish & Rahmani, 2015). The reason behind this difference could be explained by association of ISSR markers to both coding and non-coding genome sections (Roldan-Ruiz et al., 2001), while SRAP marker targets the coding sequence (Liaol et al., 2012). Detection of relatively high polymorphism indicates efficiency of SRAP markers for analyzing polymorphism in *Silene*. In the SRAP study, the mean number of alleles obtained for each primer was 2.4. The obtained value appeared to be much lower than 14.3 and 18.6 reported for *Dianthus* accessions (Xiao et al., 2008) and *Eremochloa ophiuroides* (Milla-Lewis et al., 2012), respectively, which could be related to difference in species and populations. Our genetic variability analysis detected similarity coefficient ranged from 0.48 to 0.90 (Table 4) reflecting sufficient amount of diversity among *Silene* species in Iran. It has been known that genetic variation is influenced by a number of evolutionary factors such as mating system, seed dispersal, geographic range, natural selection and gene flow (Hamrick & Godt, 1989). Jolivet & Bernasconi (2007) also studied genetic and morphological diversity in six populations of *S. latifolia* and reported significant molecular and genetic differentiation.

Polymorphic information content (PIC) as a diagnostic capacity of the marker is associated not only to polymorphic alleles, but also to polymorphic allele frequencies. Based on this definition, values > 0.5 are classified as highly informative diversity loci (Botstein et al., 1980). In our study, the average PIC value for SRAP marker primer combinations obtained 0.54 revealing the high efficiency of applied primers in the isolation of *Silene* samples which could be proposed for similar studies. The ME4-EM1 (0.34) and ME1-EM4 (0.81) primer combinations produced the lowest and highest PIC value, respectively.

For accurate detection of genetic diversity between species, cluster analysis was performed by help of the Minimum Evolution method which revealed four main clusters (Figure 3). In general, SRAP clustering was in accordance with morphological classification. Based on morphological classification, *S. latifolia* and *S.noctiflora* belong to *Sect. Melandriformes* (Boissier, 1867) and *S.*

coronaria belong to *Sect. Lychnidiformes* (Melzh, 1988). Clustering based on SRAP grouped the *S.latifolia* and *S.noctiflora* in one cluster (Sub-cluster I) and *S. coronaria* was placed in cluster II. Morphologically, they are the closest relatives and *Sect. Melandriformes* differs from *Sect. Lychnidiformes* based on calyx veins and indumentum (Edalatiyan et al., 2010). The SRAP marker placed *S.bupleuroides* and *S.coronaria* in one group (Cluster I, sub-cluster II). Although, the ISSR and SRAP markers target different regions of the genome, clustering based on ISSR also placed these two species in one group (Aghaee Bargish & Rahmani, 2015). The *S. araratica* and *S. conoidea* appeared to have the maximum similarity (0.90). These two species belong to close geographical area according to distribution map of *Silene* in Iran (Table 1).

According to our SRAP molecular marker investigation, S. *indeprensa, S. aucheriana, and S. spergulifolia* were grouped in cluster IV. *S. spergulifolia* belongs to *Sect. Spergulifoliae* and *S. aucheriana* and *S. indeprensa* belong to *Sect. Auriculatae* (Boissier, 1867). These two sections are morphologically close with difference in flower type and inflorescence (Edalatiyan et al., 2010). These species were also grouped in one cluster according to our ISSR clustering (Aghaee Bargish & Rahmani, 2015).
The statistical support for clustering exhibited bootstrap values greater than 31 % (Figure 3). The branch point that grouped *S. araratica* and *S. conoidea* had the highest value (87 %). These two species are of close geographical origin. Up to now, only a few studies have looked at genetic diversity in *Silene* (Rettig et al., 1992; Richards et al., 2003; Tero et al., 2003; Welch et al., 2006; Minder et al., 2007; Jolivet & Bernasconi, 2007). The present study demonstrated that genetic fingerprinting based on SRAP is informative for estimating the extent of genetic diversity, as well as to determine the pattern of genetic relationships. Our results revealed sufficient level of genetic distance (0.10 to 0.52) among 13 different *Silene* species in Iran. However, application of more molecular markers is proposed in generating future information (Mishra et al., 2011). In this study, the existence of a relatively high polymorphism level was sufficient enough to establish fingerprints with relatively few primer sets. Additional phylogenetic studies using appropriate nuclear, chloroplast and mitochondrial gene sequences could also help to evaluate the systematic position of *Silene* species.

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Research Article

The Checklist of Plants Occurring at the Abandoned Mamut Copper Mine, Sabah, Malaysia

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Abstract

The abandoned Mamut Copper Mine (MCM) is located at the southeastern slope of Mount Kinabalu. It lies between elevations of 1,300 to 1,600 metres above sea level. General collection of plants was carried out on the five main waste rocks dumping sites: Mamut Valley Dump, Lohan Dump, Nasapang Dump, North Dump and West Dump. The enumeration recognizes 204 species represented by 73 different families and 152 different genera. Of these, 59 are tree species, 55 shrub species, 64 herbaceous species (including ferns), 23 graminioid species, and two moss species. This study has identified 25 plant species that are frequently found at all of the waste dumpsites around the abandoned MCM. This checklist can be used for a rehabilitation programme of mine wastes.

Keywords: Colonization, mine rehabilitation, waste dump

Introduction

Mamut in Ranau is an ex-copper production site and was the first opencast mine in Malaysia. The former Mamut Copper Mine (MCM) was in operation for 24 years from 1975 to 1999. It produced copper concentrate that also contained significant amounts of gold and silver. The mining lease covers an area of 1942 hectares of rugged montane terrain on the southeastern slopes of Mount Kinabalu. It is located between the elevations of 1,300–1,600 metres above sea level. The overburden materials and waste rocks were dumped at five main dumpsites called Mamut Valley Dump, Lohan Dump, Nasapang Dump, North Dump and West Dump. The open pit, process-plant site and waste rock dumping areas occupy an area of over 200 hectares (Figure 1). The annual precipitation at the mine area varies little from year to year. There is a dry season from March to August and a wet season from December to February.

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The yearly rainfall ranges from 2,500 – 3,500 mm and the daily temperature ranges from 15 – 28°C (MCM, 1997).

Like most abandoned mines, the former Mamut Copper Mine has caused environmental problems including dust pollution, soil erosion and soil run-off into the surrounding rivers. Although the mining company took the initiative to rehabilitate waste rock dumps with grasses, legumes and trees, most areas have not undergone rehabilitation and remain devoid of vegetation (MCM, 1997; Jopony & Tongkul, 2004). There are still large areas that are bare without vegetation especially at the slopes and benches of the West Dump and Nasapang Dump. Any plants surviving in these areas have a potential use for rehabilitation programme of the former mine.

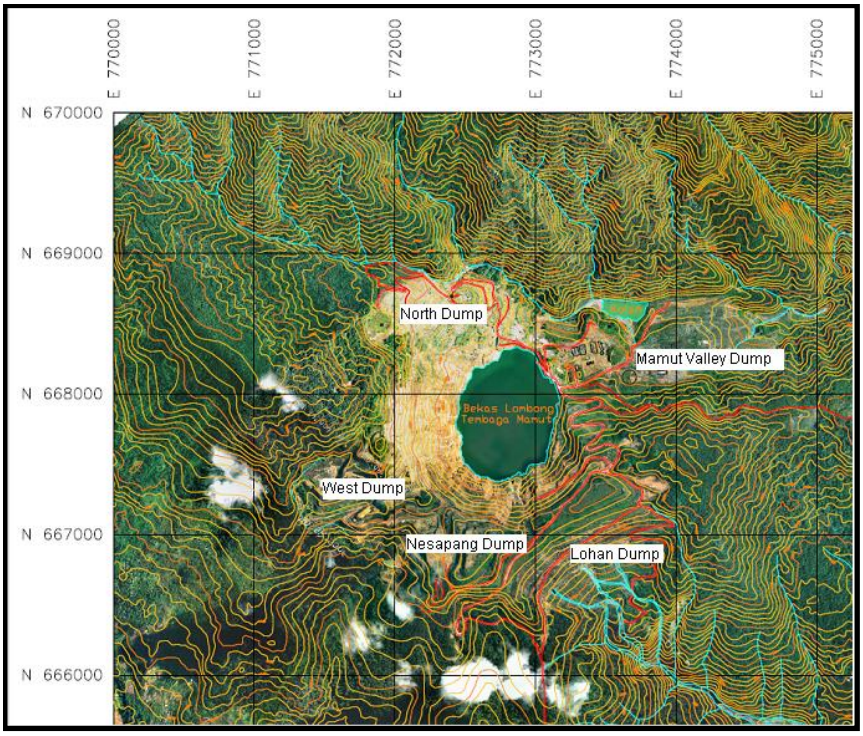

Figure 1. The locations of waste rock dumps at the former Mamut Copper Mine (Source: JMG, 2009)

Materials and Methods

Several visits were made to the former mine from April to August 2009. An attempt has been made to cover all areas of the dumps sites. The plant sample collections were grouped into four on the basis of the growth form: trees (≥10 cm diametre at breast height), shrubs (<10 cm dbh), herbaceous plants and graminioids. Each group was collected and voucher specimens deposited at BORH (UMS herbarium), SAN (Sandakan herbarium) and SNP (Sabah Parks herbarium).

All oven-dried specimens were sorted according to morpho-species and identified to species-level by cross-checking with existing specimens at the BORH, SAN and SNP herbariums. Flora reference books were used in the identification processes (Airy Shaw, 1975; Argent *et al*., 2007; Soepadmo, *et al*., 1995; 1996; 2000; 2002; 2004; 2007; Sugau, 2008).

Results and Discussion

The original forest cover of the abandoned Mamut Copper Mine was the upper part of the lower montane forest on ultramafic soil. This forest is an Oak-laurel forest (Fagaceae and Lauraceae) and Ericaceous forest (Conifers, Myrtaceae and Ericaceae). This is evident from the surrounding forests. Unfortunately, the original forest cover of the abandoned Mamut Copper Mine has long disappeared due to the copper mining activity. The area is currently abandoned and is being slowly colonized by pioneer montane plant species. The surrounding forests fortunately serve as seed source to the abandoned mine site. . Seedlings and saplings of forest species were encountered in the survey areas, such as *Phyllocladus hypophyllus* and *Tristaniopsis whaetiana*.
A detailed list of all the plant species found during the surveys from each of the dumpsites is listed in tables 1, 2 and 3. Most of the specimens were identified to species level. However, 13 specimens were identified up to genus-level only and four specimens remain unidentified.

The total number of species found at the abandoned Mamut Copper Mine totals 204 represented by 73 families and 152 genera (Table 4). Of these, 59 are tree species, 55 are shrub species, 64 are herbaceous species (including ferns), 23 species of graminioids, and two different moss species. The total number of voucher/herbarium specimens is 156.

Not all of the species found in this study are native to Sabah. Some species were introduced either for rehabilitation or for other purposes. A shrub,

Allamanda cathartica (Apocynaceae) and eight trees species were identified as introduced species: *Mangifera indica* (Anarcardiaceae), Psidium *guajava* and *Eucalyptus robusta* (Myrtaceae), *Artocarpus odoratissimus* (Moraceae), *Acacia mangium*, *Leucenea leucocepala* and *Paraserianthes falcataria* (Leguminosae), and *Pinus caribea* (Pinaceae). In addition, there is a tree species that is naturalized: *Sambucus javanica* (Caprifoliaceae).

The most common tree and shrub species found frequently (≥ 4) in different dump sites include: trees such as *Adinandra excelsa* (Pentaphylaceae), *Duabanga mollucana* (Sonneratiaceae), *Gymnostoma nobile* (Casuarinaceae), *Litsea cubeba* (Lauraceae), *Macaranga kinabaluensis* (Euphorbiaceae), *Neonauclea artocarpoides* and *Neonauclea gigantean* (Rubiaceae), *Pinus caribea* (Pinaceae), *Pittosporum resiniferum* (Pittosporaceae), *Tristaniopsis whaetiana* (Myrtaceae), *Vaccinium retivenium* (Ericaceae) and *Wightia borneensis* (Schrophulariaceae); shrubs namely *Blumea arnakidophora* (Asteraceae), *Schefflera calyptrate* (Araliaceae) and *Vaccinium retivenium* (Ericaceae).

The most common herbaceous plants are ferns like *Aglaomorpha brooksii* (Polypodiaceae), *Blechnum orientale* (Blechnaceae), *Christella arida* (Thelypteridaceae), *Dicranopteris clemensiae* (Gleicheniaceae) and *Pityrogamma calomelanos* (Adianthaceae); orchids including *Dilochia wallichii* (Orchidaceae), *Arundina graminifolia* (Orchidaceae) and *Dendrochilium crissum* (Orchidaceae); and others namely *Nepenthes stenophylla* (Nepenthaceae), *Polygala paniculata* (Polygalaceae), *and Rhaucophica javanica* (Hemerocallidaceae).

Table 1. List of trees and shrub species occurring at the former Mamut Copper Mine
ND = North Dump, WD = West Dump, NSD = Nasapang Dump, MVD = Mamut Valley Dump, LD = Lohan Dump, t = tree, sh = shrub, sc = scrambler

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Anacardiaceae	*Mangifera indica*	Mesen 15	t				✓	
Apocynaceae	*Allamanda cathartica*	PS02	sh				✓	
Apocynaceae	*Alstonia angustifolia*	Nspg 18	t		✓		✓	
Apocynaceae	*Alstonia iwahigensis*	Nspg 17	t			✓		
Apocynaceae	*Alstonia scholaris*	W 18	t			✓		
Asteraceae	*Blumea arnakidophora*	N 8; Mesen 16; W 17	sh	✓	✓		✓	
Asteraceae	*Blumea balsamifera*	PS04	sh				✓	
Asteraceae	*Chromolaena odorata*	M 3	sh				✓	
Asteraceae	indet.	W 13; Nspg 1; N 11	t	✓		✓		
Asteraceae	*Vernonia arborea*	L 9; Nspg 31; L 2	t			✓		✓
Aquifoliaceae	*Ilex spicata*	W 2; Nspg 37	t		✓	✓	✓	
Araliaceae	*Aralia Montana*	M 25	t				✓	
Araliaceae	*Schefflera calyptrata*	Nspg 38; N 6; W 47	sc	✓	✓	✓	✓	
Araliaceae	*Schefflera lanata*	Nspg 48	sh			✓		
Araliaceae	*Schefflera lineamentorum*	N 16	sh	✓				
Araliaceae	*Schefflera ridleyi*	W 23	sh		✓			
Bignoniaceae	*Radermachera pinnata*	W 45	t		✓		✓	
Caprifoliaceae	*Sambucus javanica*	Mesen 19	t				✓	
Casuarinaceae	*Gymnostoma nobile*	Nspg 15; M 1	t	✓		✓	✓	✓
Cecropiaceae	*Poikilospermum scabrinervium*	N26, PS56, W41	sh	✓	✓		✓	
Cecropiaceae	*Poikilospermum suaveolens*	N12	sc	✓			✓	
Celastraceae	*Perrottetia alpestris*	M 12; M 4; M 19	sh				✓	
Clethraceae	*Clethra pachyphylla*	W 16; N 4	t	✓	✓		✓	
Convolvulaceae	*Merremia* sp	PS14	sc				✓	
Crypteroniaceae	*Crypteronia paniculata*	Nspg 14; W 51	t		✓	✓		
Cunoniaceae	*Weinmannia fraxinea*	Nspg 6; W 15	t		✓	✓		
Cyatheaceae	*Cyathea contaminans*	seen	t				✓	
Elaeocarpaceae	*Elaeocarpus angustipes*	W 27	t		✓			
Elaeocarpaceae	*Elaeocarpus murudensis*	W 1	t		✓			
Ericaceae	*Diplycosia pinifolia*	W 10	sc		✓			
Ericaceae	*Rhododendron baconii*	Nspg 21	sh			✓		
Ericaceae	*Rhododendron borneensis*	W 26	sh		✓			
Ericaceae	*Rhododendron ericoides*	Nspg 10	sh			✓		

(continued on next page)

Table 1. (continued)

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Ericaceae	*Rhododendron fallacinum*	W 19	sh		✓			
Ericaceae	*Rhododendron javanicum* ssp. *Kinabaluense*	W 50	sh	✓	✓			
Ericaceae	*Rhododendron praetervisum*	Nspg 32; N 15; W 21	sh	✓	✓	✓		
Ericaceae	*Rhododendron scrobuculatum*	Nspg 8; W 22	sh		✓	✓		
Ericaceae	*Vaccinium claoxylon*	W 6	sh		✓			
Ericaceae	*Vaccinium clementis*	W 15; Nspg 12	sh		✓	✓		
Ericaceae	*Vaccinium retivenium*	Mesen 3; L 7; W2 0; N 19	sh	✓	✓		✓	✓
Ericaceae	*Vaccinum simulans var. leptopodum*	Nspg 23	sh			✓		
Euphorbiaceae	*Homalanthus populneus*	Mesen 10	t				✓	
Euphorbiaceae	*indet.*	Nspg 29				✓		
Euphorbiaceae	*Macaranga* cf. *curtisii*	W 11	t		✓			
Euphorbiaceae	*Macaranga kinabaluensis*	Mesen 4; Nspg 36; L 12	t	✓	✓	✓	✓	✓
Euphorbiaceae	*Macaranga winkleri*	N 9	t	✓				
Gesneriaceae	*Aeschynanthus magnificus*	N 23	sh	✓				
Gesneriaceae	*Cyrtandra chrysea*	W 5	sh		✓			
Ixonanthaceae	*Ixonanthes reticulate*	Mesen 23	t				✓	
Juglandaceae	*Engelhardtia serrata*	M 20	t				✓	
Lauraceae	*Litsea cubeba*	W 46; L 11; Mesen 5; N 17	t	✓	✓		✓	✓
Lauraceae?	*indet.*	W 28	t		✓			
Leguminosae	*Acacia mangium*	seen	t				✓	
Leguminosae	*Alysicarpus voginalis*	PS21	sh				✓	
Leguminosae	*Archidendron clyperia*	N 7	sh	✓				
Leguminosae	*Centrosema pubescens*	PS20	sh				✓	
Leguminosae	*Crotalaria pallida*	M 22	sh					
Leguminosae	*Desmodium purpureum*	PS24, MV04, W11	sh		✓		✓	
Leguminosae	Indet	W13	sh		✓			
Leguminosae	*Leucenea leucocepala*	Nspg 20; Mesen 6	t			✓	✓	
Leguminosae	*Macroptilium atropureus*	PS22, Ng13, L12, MV05	sc			✓	✓	✓
Leguminosae	*Paraserianthes falcataria*	seen	t				✓	✓
Leguminosae	*Desmodium congesta*	M 22					✓	

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Table 1. (continued)

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Loganiaceae	*Buddleja asiatica*	M 24	sh				✓	
Loganiaceae	*Fagraea collina*	Nspg 16; W 42	t		✓	✓		
Melastomataceae	*Medinella beamanii*	W 49	sh		✓		✓	
Melastomataceae	*Medinella speciosa*	N 1	sh	✓			✓	
Melastomataceae	*Melastoma beccarianum*	M 5	sh				✓	
Melastomataceae	*Melastoma malabatrichum*	W 25; Nspg 28; N 25	sh		✓	✓		
Moraceae	*Artocarpus odoratissimus*	Mesen 12	t				✓	
Moraceae	*Ficus macilenta* var. *ilicifolia*	W 37; Nspg 33	sc		✓	✓		
Moraceae	*Ficus oleaefolia*	Nspg 2	t			✓		
Moraceae	*Ficus septica*	Mesen 13	t				✓	
Moraceae	*Ficus setiflora* var. *adelpha*	W 24	sh		✓			
Myricaceea	*Myrica esculenta*	Nspg 9	t			✓		
Myrsinaceae	*Embelia dasythyra*	W19	Sc		✓			
Myrsinaceae	*Myrsine porteriana*	W 52	t		✓			
Myrtaceae	*Decaspermum fruticosum*	M 13	t				✓	
Myrtaceae	*Eucalyptus robusta*	Mesen 18	t				✓	
Myrtaceae	*Psidium guajava*	Mesen 8	t				✓	
Myrtaceae	*Syzygium grande*	W 34	t		✓			
Myrtaceae	*Tristaniopsis whaetiana*	W 39; L 1; Nspg 11; N 12	t	✓	✓	✓	✓	✓
Pentaphylacaceae	*Adinandra collina*	L 13; Nspg 35; W 14	t		✓	✓		✓
Pentaphylacaceae	*Adinandra cordifolia*	Nspg 30	t			✓	✓	
Pentaphylacaceae	*Adinandra excelsa*	Mesen 2; W 3; N 22	t	✓	✓		✓	
Pentaphylacaceae	*Adinandra impressa*	Nspg 3	t			✓		
Pentaphylacaceae	*Ternstroemia lowii*	Nspg 24; W 9	t		✓	✓	✓	
Pinaceae	*Pinus caribea*	W 30; Mesen 17; N 5	t	✓	✓		✓	
Pittosporaceae	*Pittosporum ferrugineum*	Nspg 13	t			✓		
Pittosporaceae	*Pittosporum resiniferum*	Mesen 9; Nspg 26; N 18	t	✓		✓	✓	
Podocarpaceae	*Dacrydium xantandrum*	W 4	t		✓			
Podocarpaceae	*Phylloclados hypophyllus*	W 7; Nspg 25	t		✓	✓	✓	
Podocarpaceae	*Dacrydium* cf. *pectinatum*	W 10	t		✓			
Polygonaceae	*Polygonum chinensis*	Mesen 14	sc				✓	
Polygonaceae	*Polygonum lapathifolium*	PS48	sc				✓	
Rosaceae	*Rubus fraxinifolius*	L 3; N 14	sh	✓			✓	✓
Rosaceae	*Rubus mollucanus*	MV18, N25, PS52	sh	✓			✓	
Rubiaceae	*Neonauclea artocarpoides*	L 5; Nspg 7; W 38	t	✓	✓	✓	✓	✓
Rubiaceae	*Neonauclea gigantea*	L6; Nspg 5; W 33	t	✓	✓	✓	✓	✓

(continued on next page)

Table 1. (continued)

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Rubiaceae	*Paederia foetida*	W38	sh		✓			
Rubiaceae	*Wendlandia paniculata*	Nspg 22	t			✓		
Schrophulariaceae	*Wightia borneensis*	L 8; W 31; N 24	t	✓	✓	✓	✓	✓
Smilacaceae	*Smilax leavis*	W39	sc		✓			
Sonneratiaceae	*Duabanga mollucana*	L 10; Mesen 7; L 4	t				✓	✓
Theaceae	*Schima brevifolia*	W 12	t		✓			
Theaceae	*Schima wallichii*	N 20	t	✓				
Thymelaeceae	*Wikstroemia* sp.	M 11	sh				✓	
Ulmaceae	*Trema tomentosa*	Mesen 1	t				✓	
Urticaceae	*Debregeasia longifolia*	Mesen 11	sh	✓			✓	
Urticaceae	*Leucosyke capitellata*	M 16	t				✓	
Urticaceae	*Pouzolzia sanguinea*	Mesen 20	sh				✓	
Verbenaceae	*Lantana camara*	M 18	sh				✓	
Vitaceae	*Tetrastigma papillosum*	MV19, PS57	sc				✓	
Winteraceae	*Drymis piperita*	W 35	t		✓			

Table 2. List of herbaceous species occurring at the former Mamut Copper Mine
ND = North Dump, WD = West Dump, NSD = Nasapang Dump, MVD = Mamut Valley Dump, LD = Lohan Dump, h = herb.

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Adianthaceae	*Pityrogramma calomelanos*	W01,L 01, g01,PS01,MV01	h		✓	✓	✓	✓
Araceae	*Scindapsus kinabaluensis*	L36	h					✓
Asteraceae	*Bidens pilosa*	PS06, W07	h		✓		✓	
Asteraceae	*Conyza bonariensis*	L03	h					✓
Asteraceae	*Conyza sumatrensis*	PS03	h				✓	
Asteraceae	*Crassocephalum crepidioides*	PS08, Ng03, W04	h		✓	✓	✓	
Asteraceae	*Gynura sarmentosa*	L02	h					✓
Asteraceae	*Hypochaeris radicata*	Ng02, L04	h			✓		✓
Asteraceae	*Mikania micrantha*	PS10, W06	h		✓		✓	
Asteraceae	*Sonchus* sp	PS11, MV02, L05	h				✓	✓
Asteraceae	*Wedelia trilobata*	PS09	h				✓	
Begoniaceae	*Begonia cucullata*	N01	h	✓				
Blechnaceae	*Blechnum orientale*	L07, PS12, MV03, W08, N02	h	✓	✓	✓	✓	✓
Convolvulaceae	*Ipomoea cairica*	Ng06, PS13	h			✓	✓	
Davalliaceae	*Davallia denticulata*	L08, Ng08	h			✓		✓
Davalliaceae	*Davallia* sp	Ng09, N04	h	✓		✓		
Dennstaedtiaceae	*Histiopteris incise*	W10, L09	h		✓			✓
Dennstaedtiaceae	*Pteridium esculentum*	L10	h					✓
Dennstaedtiaceae	*Sphenomeris chinensis*	N05,Ng10	h			✓		
Dicksoniaceae	*Cibotium arachnoidecum*	Ng10	h			✓		
Dipteridaceae	*Dipteris conjugata*	Ng12	h			✓		
Equisetaceae	*Equisetum romosissimum*	PS18	h				✓	
Gleicheniaceae	*Dicranopteris clemensiae*	PS25, W16, L13,Ng14	h		✓	✓	✓	✓
Gleicheniaceae	*Diplopterygium* sp	W15	h		✓			
Hemerocallidaceae	*Rhaucophica javanica*	PS26, L25, N19, MV11	h	✓			✓	✓
Hypoxidaceae	*Cucurligo latifolia*	Ng15, N09, W17, PS27	h	✓	✓	✓	✓	
Leguminoseae	*Mimosa pudica*	W14, PS23	h		✓		✓	
Lycopodiaceae	*Lycopodiella cernua*	MV06, PS29, L14	h				✓	✓
Lycopodiaceae	*Lycopodium clavatum*	Ng16, N10	h	✓		✓		
Lythraceae	*Cuphea hyssopifolia*	PS28	h				✓	
Nepenthaceae	*Nepanthes reinwardtiana*	PS3, Ng17, MV07	h			✓	✓	
Nepenthaceae	*Nepenthes burbidgeae*	Ng 35	h				✓	
Nepenthaceae	*Nepenthes fusca*	W22	h		✓			

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Table 2. (Continued)

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Nepenthaceae	*Nepenthes macrovulgaris*	L16, W21	h		✓			✓
Nepenthaceae	*Nepenthes stenophylla*	W42	h		✓			
Nephrolepidaceae	*Nephrolepis cordifolia*	L17, PS32, Ng19,W23	h		✓	✓	✓	✓
Nephrolepidaceae	*Nephrolepis tuberosa*	N13,MV08	h	✓			✓	
Orchidaceae	*Acriopsis* cf. *javanica*	L20	h	✓				
Orchidaceae	*Agrostophyllum sp.*	N18	h	✓				
Orchidaceae	*Arundina graminifolia*	PS34, L23,N15, MV10,Ng21	h	✓		✓	✓	✓
Orchidaceae	*Coelogyne cf.moultonii*	W25	h		✓			
Orchidaceae	*Coelogyne clemensii*	W26	h		✓			
Orchidaceae	*Coelogyne* sp	PS37,L19	h				✓	✓
Orchidaceae	*Dendrobium* sp	L18	h					✓
Orchidaceae	*Dendrochilium crassum*	W29, MV09, Ng20, N14, PS35	h	✓	✓	✓	✓	
Orchidaceae	*Dilochia wallichii*	Ng22, N16, PS33,W24, L24	h	✓	✓	✓	✓	✓
Orchidaceae	*Eria* sp	L22	h					✓
Orchidaceae	*Peristylus hallieri*	W28	h		✓			
Orchidaceae	*Phaius tankervilliae*	PS38	h					
Orchidaceae	*Spathoglottis aurea*	PS36, W27	h		✓		✓	
Orchidaceae	*Spathoglottis* cf. *microchilina*	N17	h	✓				
Orchidaceae	*Thrixspermum* sp	L21	h					✓
Polygacaceae	*Polygala paniculata*	MV16,Ng28, W32, PS47	h		✓	✓	✓	
Polypodiaceae	*Aglaomarpha brooksii*	PS50, MV17, L33,W36	h		✓		✓	✓
Polypodiaceae	*Belvisia callifolia*	N24	h	✓				
Polypodiaceae	*Belvisia revolta*	N23	h	✓				
Polypodiaceae	*Belvisia spicata*	PS49,W34	h		✓		✓	
Polypodiaceae	*Goniophlebium pecussum*	W35	h		✓			
Polypodiaceae	*Microsorum membranifolium*	Ng29	h			✓		
Polypodiaceae	*Pyrrosia lanceolata*	N22	h	✓				
Polypodiaceae	*Pyrrosia rasamalae*	Ng30, PS51	h			✓	✓	
Schizaeaceae	*Lygodium* cf. *microphyllum*	PS54	h				✓	
Thelypeteridaceae	*Christella arida*	W40, Ng33, PS55	h		✓	✓	✓	
Zingiberaceae	*Hedychium cylindricum*	Ng34, PS58, L35, N27	h	✓		✓	✓	✓

Table 3: List of grasses and mosses occurring at the former Mamut Copper Mine
ND = North Dump, WD = West Dump, NSD = Nasapang Dump, MVD = Mamut Valley Dump, LD = Lohan Dump, g = grass, m = mosses

Family	Species	Voucher	Habit	ND	WD	NSD	MVD	LD
Cyperaceae	*Cyperus kyllingia*	Jg01	g	✓			✓	
Cyperaceae	*Fimbristylis littoralis*	Jg02	g				✓	
Cyperaceae	*Fuirena umbellata*	Jg03	g	✓			✓	
Cyperaceae	*Gahnia javanica*	Jg04	g	✓	✓	✓		
Cyperaceae	*Hypolytrum nemorum*	Jg05	g	✓			✓	
Cyperaceae	*Scirpus mucronatus*	Jg06	g	✓			✓	
Cyperaceae	*Eleocharis* sp	Jg25	g	✓			✓	
Cyperaceae	*Schoenopteris juncoides*	Jg26	g	✓			✓	
Poaceae	*Axonopus compressus*	Jg08	g	✓	✓	✓	✓	
Poaceae	*Coix lacryma-jobi*	Jg09	g	✓			✓	
Poaceae	*Cynodon dactylon*	Jg10	g	✓			✓	
Poaceae	*Cyperus odoratus*	Jg11	g	✓				
Poaceae	*Digitaria junghuniana*	Jg12	g	✓			✓	
Poaceae	*Eragrostis atrovirens*	Jg13	g	✓	✓	✓	✓	✓
Poaceae	*Imperata cylindrica*	Jg14	g	✓	✓	✓	✓	✓
Poaceae	*Leptochloa* sp.	Jg15	g	✓				
Poaceae	*Miscanthus floridulus*	Jg16	g	✓	✓	✓	✓	✓
Poaceae	*Panicum sarmentosum*	Jg17	g	✓			✓	
Poaceae	*Paspalum conjugatum*	Jg18	g	✓	✓	✓	✓	
Poaceae	*Pogonantherum crinitum*	Jg19	g	✓	✓	✓	✓	✓
Poaceae	*Setaria sphacelata*	Jg20	g	✓	✓	✓	✓	
Poaceae	*Thysanolaena latifolia*	Jg21	g	✓	✓	✓	✓	✓
Poaceae	*Bathriocloa* sp	Jg27	g	✓	✓		✓	
Thypaceae	*Thypa angustifolia*	Jg22	g	✓			✓	
Dicranaceae	*Campylopus umbellata*	Jg23	m			✓	✓	
Dowsoniaceae	*Dawsonia beccarii*	Jg24	m			✓		

Table 4. List of plant families occurring at the former Mamut Copper Mine

No.	Family	No. of Genera	No. of Species
1	Adianthacea	1	1
2	Anacardiaceae	1	1
3	Apocynaceae	2	4
4	Aquifoliaceae	1	1
5	Araceae	1	1
6	Araliaceae	2	5
7	Asteraceae	11 (1 indet)	13
8	Begoniaceae	1	1
9	Bignoniaceae	1	1
10	Blechnaceae (ferns)	1	1
11	Caprifoliaceae	1	1
12	Casuarinaceae	1	1
13	Cecropiaceae	1	2
14	Celastraceae	1	1
15	Clethraceae	1	1
16	Convolvulaceae	2	2
17	Crypteroniaceae	1	1
18	Cunoniaceae	1	1
19	Cyatheaceae (ferns)	1	1
20	Cyperaceae	8	8
21	Davaliaceae (ferns)	1	2
22	Dennstaedtiaceae (ferns)	3	3
23	Dicksoniaceae (ferns)	1	1
24	Dicranaceae (Mosses)	1	1
25	Dipteridaceae (ferns)	1	1
26	Dowsoniaceae (Mosses)	1	1
27	Elaeocarpaceae	1	2
28	Equisetaceae (ferns)	1	1
29	Ericaceae	3	12
30	Euphorbiaceae	2 (1 indet)	4
31	Fabaceae	10 (1 indet)	12
32	Gesneriaceae	2	2
33	Gleicheniaceae (ferns)	2	2
34	Hemerocallidaceae	1	1
35	Hypoxidaceae	1	1
36	Ixonanthaceae	1	1
37	Juglandaceae	1	1
38	Lauraceae	1 (1 indet)	1
39	Loganiaceae	2	2
40	Lycopodiaceae (ferns)	1	2
41	Lytraceae	1	1
42	Melastomataceae	2	4
43	Moraceae	2	5
44	Myricaceae	1	1
45	Myrsinaceae	2	2
46	Myrtaceae	5	5
47	Nepenthaceae	1	5
48	Nephrolepidaceae (ferns)	1	2
49	Orchidaceae	12	15
50	Pentaphylacaceae	2	5
51	Pinaceae	1	1
52	Pittosporaceae	1	2
53	Poaceae	15	15
54	Podocarpaceae	1	2
55	Polygalaceae	1	1
56	Polygonaceae	1	2

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Table 4. (Continued)

No.	Family	No. of Genera	No. of Species
57	Polypodiaceae (ferns)	5	8
58	Rosaceae	1	2
59	Rubiaceae	4	4
60	Schizaeaceae (ferns)	1	1
61	Schrophulariaceae	1	1
62	Smilacaceae	1	1
63	Sonneratiaceae	1	1
64	Theaceae	1	2
65	Thelypeteridaceae (ferns)	1	1
66	Thymelaeceae	1	1
67	Thypaceae	1	1
68	Ulmaceae	1	1
69	Urticaceae	3	3
70	Verbenaceae	1	1
71	Vitaceae	1	1
72	Winteraceae	1	1
73	Zingiberaceae	1	1
	TOTAL	**152**	**200**

Conclusions

This study has identified 25 plant species that are frequently found on the waste dumpsites and at the former mine. These species are: trees such as *Adinandra excelsa, Duabanga mollucana, Gymnostoma nobile, Litsea cubeba, Macaranga kinabaluensis, Neonauclea artocarpioides, Neonauclea gigantea, Pinus caribea, Pittosporum resiniferum, Tristaniopsis whaetiana* and *Wightia borneensis*; shrubs including *Blumea arnakidophora, Schefflera calyptrate* and *Vaccinium retivenium*; ferns namely *Aglaomorpha brooksii, Blechnum orientale, Christella arida, Dicranopteris clemensiae* and *Pityrogamma calomelanos*; orchids like *Arundina graminifolia, Dendrochillum crissum* and *Dilochia wallichii*; and other herbs namely *Nepenthes stenophylla, Polygala paniculata* and *Rhaucophica javanica*.

This information can be used for a rehabilitation programme of the former mine. The advantage of using existing plants is that they are pre-adapted to climatic and soil conditions at the site. Further assessments of these plants in the laboratory and field studies would be useful.

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Research Article

Ethnobotanical Study of Sasak Ethnic, East Lombok, West Nusa Tenggara

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Abstract
The ethnobotany study of the Sasak ethnic group who live in three villages in East Lombok, Lombok Island, West Nusa Tenggara is intended to reveal their knowledge about the diversity of useful plants including their utilization. This study was conducted through interviews and direct observation. The study recorded 103 species of plants which were used as food, traditional medicine, natural dyes and woven handicrafts. Plants collected were mostly from the wild and some were domesticated. Interviews showed that these days local communities rarely use uncultivated plants as food sources.

Keywords: Ethnobotany, Sasak ethnic, Lombok, Indonesia

Introduction
Indonesia is the world's largest archipelago country, consisting over 17,508 islands (LIPI, 2013), including Lombok Island. Located in West Nusa Tenggara province, the island is inhabited mostly by the Sasak ethnic group. Etimologically, according to Kawi language (ancient Java language), the word "Lombok" means "straight, honest"; whereas word "sasak" originates from the word "sah" which means "go" and "shaka" meaning "the elders." It is suggested that the Sasak ethnic people came from Java; this is supported by the use of Sasak inscription called "Jejawen," which has its origins in Java writings/alphabet in Sasak literature (Gratha, 2012).

Biodiversity, culture and nature tourism on Lombok Island has attracted local as well as international scientists and travellers. In addition, the increase in exploitation of natural resources, technological intervention into local practices, economic pressures, increasing population and decreasing areas for cultivation are some contributing factors leading to the shifting in ways of life of the Indonesian native people in general. As a result, local knowledge

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practised for years is disappearing, and this applies to the Sasak ethnic group as well.

Sasak is the largest ethnic group on Lombok. They constitute most of the island's population and numbered about 2.6 million at the turn of the 21st century. The Sasak speak Sasak or Sasak-flavoured Balinese, both of which are Austronesian languages. Originally the only inhabitants of Lombok, the Sasak were under the political domination of Bali from the 18th century until 1895, when the Dutch conquered the island. Concentrated most densely in the central third of the island, the Sasak are predominantly subsistence farmers of wet rice, coffee, vegetables, coconuts, bamboo, sugarcane and pandanus. They live in small villages of 5–20 families or in large villages with several thousand residents. Houses are built around a *kampu* (religious compound), where ceremonies take place (http://www.britannica.com/topic/Sasak).

The objective of this study was to document all traditional useful plants that are or have been used by the Sasak peope, and to ultimately document their traditional knowledge associated with local plant uses.

Methodology

The study was conducted in 3 villages representing accesses to abundant vegetation (Jeruk Manis village, situated on the border of Gunung Rinjani National Park, Figure 1), culture (Dusun Sade at Rambitan village, a Sasak cultural village, Figure 2), and craft centre (Loyok village, well known for its plaits craft, Figure 3). The majority of people in these areas are Muslim and are farmers.

A Prior Informed Consent (PIC) letter was sent in advance to the three village heads (Jeruk Manis, Sade and Loyok) through the local goverment at East Lombok, West Nusa Tenggara, before entering the village to seek their permission and agreement for this study to be conducted.

Data was collected in accordance to Vogl et al. (2004), Suminguit (2005) and Nolan & Turner (2011), with modification on non structural and "open ended" interviews followed by direct field observations. Interviews were conducted among "belian/dukun" or the elders who have familiarity on the use and benefits of plants in their villages.

Figure 1. Sasak people at Jeruk Manis village use traditional tools in their fields

Figure 2. Dusun Sade at Rambitan village, a Sasak cultural village; and one of the respondents at Dusun Sade spinning yarn for woven cloth material

Figure 3. Well known plaits crafts made by Loyok villagers

Criteria for selection of the respondents (17 people), such as native or have lived in the study area for at least 20 years, the age of respondents older than 35 years and are familiar with useful plants (Table 1). The local name and use of each plant wase catalogued; specimens were made into voucher of herbarium specimens and identification of each scientific name was conducted at the Botany Division, Research Center for Biology – Indonesian Institute of Sciences.

Table 1. List of characteristic respondents in three villages (Jeruk Manis, Sade & Loyok), East Lombok, West Nusa Tenggara

No	Characters of respondents	Number of respondents
1	Gender:	
	Male	9
	Female	8
2	Range of age:	
	35 – 50	3
	51 – 66	10
	67 – 82	4
3	Occupation:	
	Farmer	6
	Belian/Dukun (traditional priest)	4
	Craftmens	4
	Housewives	3
4	Education:	
	Elementary school	11
	Junior high school	4
	Senior high school	2

Results and Discussion

Cultivation system of the Sasak Ethnic

Similar to other ethnic groups in Indonesia, paddy or “pade” in Sasak is the most important source of carbohydrate. On average, each family owns about 0.5-1 ha of rice field. The paddy is usually planted in an even and wet land. The Sasak name rice fields or sawah as “bangket,” the activity of planting paddy is called “lowong.” Like other ethnicities practising rice cultivation, preparation for rice cultivation by the Sasak involves a series of ceremony from seedling preparation to harvesting.

The first activity is “mengampai” or preparing the paddy seedling. The paddy germinates between 10-14 days depending on the variety. Local paddy such as Buluh, Kanbo, Reket and Gadis require longer time to sprout compared high yielding varieties such as Pelita, IR 46, etc.

While waiting for the seedling to be ready for planting, farmers conduct “garu” or crumbling the soil through which land is prepared by ploughing using “tenggale” and garu. Land preparation is ended with “beririn” or clearing irigation around the paddy field. The day before planting, a ritual called “mamaon” is conducted by a “belian” or an elder. Traditionally, the best time to conduct the mamon is in the morning after the sun rises, around 7 or 8 am, on Mondays, Wednesdays or Thursdays. The offering consists of leafy *Jarak* stem *(Jatropha curcas)*, Green *Andong* (*Cordyline fruticosa)*, Bunut (*Ficus* sp.) and *Legu* stem (*Vitex trifolia*). The belian then says a mantra while circling the field to find a lucky spot, and then places these offerings on the spot. The purpose of this traditional ritual is to protect the planted rice from unsucessful harvesting.

Traditional cultivation generally involves ancestor rituals in which each ethnic group has its own specific way (Cooten, 1977). In the village of Wumbu Buro, Kabaena Island in Sulawesi Tenggara, the Moronene group starts paddy planting with the traditional ritual “kinanimbula” (Rahayu & Rugayah, 2010). The Mamaon ritual is now rarely practiced by the Sasak, however the role of the elder is still important and he is considered a wise man. His blessing is believed to allow the farmer’s effort to succeed and he can also prevent land disputes in the future.

The next activity is “ngume” or “nyeder” which involves clearing the field from weeds, and “rabuk” or application of fertilizer. These are done once or twice during the planting period when the paddy is 1 and 2.5 months old. The ngume is always conducted before the rabuk. The tool used for ngume is called “kis-kis” made from a long old bamboo stem about 2m in length and which has both ends that are bended; with a sharp metal like knife mounted to one end. The purpose of a long kis-kis is so that farmers can just stand and walk while clearing weeds without having to bend or squat. It is considered a Sasak local wisdom which involves efficiency of time and energy when carrying out the activity.

After paddy reaches 2.5-3 months, grains start to appear and the ritual “ngebuk” is then performed, usually on the same days as the Mamaon ritual. In this ritual, some paddy grains in all corners of the field are tied with “buk” leaves and covered with cotton. The purpose of this ritual is to stimulate grain development. The next traditional ritual performed is “nanares”, once the paddy grains start to ripen or are at 3 – 3.5 months old. The ritual is marked with the plugging of the Enau leaf (*Arenga pinnata)* covered with “ketan dan

pepesu" (*Paederia foetida*) on the same spot as the location of Mamaon offerings. This activity is then followed by fogging the field by burning paddy husks/hulls around the field. The significance of this ritual is to repel natural predators, such as rats and birds and other grain eaters; the nanares ritual is slightly similar with "sisiran" performed by Javanese farmers (Sutarno, 1995). One day before harvesting, the ritual "bebuntil" where paddy grains on corners are tied toward the right side, is performed. Its significance is to bind together the "essence" of the paddy. The "kucingan" offerings performed by farmers in Central Java (Sutarno, 1995), and "pamungkas" or "mipit" offerings practiced in West Java (Rahayu & Siagian, 2000) is considered to be similar to the "bebuntil" offering.

Harvesting is conducted using "awit" which is some sort of sickle and the paddy grain is then moulted using "perambet" and cleansed from dirt and hull using "kleong" or a bamboo basket. The refined grain is then sun-dried for two to three days and stored in the house. Unlike in West Java, no barns were spotted on rice fields in this area.

Paddy cultivation can be performed twice in a year. After two series of paddy planting, the land is then planted with crops or "tetanduran" including "antap" long bean *Vigna unguiculata*, corn *Zea mays*, "sebia" hot chili *Capsicum fructescens*, egg plant *Solanum melongena*, "terungacik", tomato *S. lycopersicon*, "botor" winged bean *Psophocarpus tetragonolobus* and snap/string bean *Phaseolus vulgaris*. On the ridge area in between two rice fields varieties of banana or "punti" *Musa* spp are planted, and these include varieties of "tolang," "sabe," "tombor," "bole," "telu," "lilin," "loma" and "ranggot." According to Ruthbenberg (1980) and Dove (1988), plant cultivation strategy as practised above are common in all communities within Southeast Asia. It is proven to be less intense and requires only low technology (Broolfield & Padoch, 1994).

Utilization of Plant Diversity

To meet their daily needs, the Sasak use various plants around their surroundings. It is noted that 102 species of plants are used for various purposes. Fifty seven species as sources of carbohydrate, vegetables and fruits, seven species as building materials, 57 species as source of medicine and cosmetics, seven species as firewood, eight species for ritual accessories, three species for woven materials, ten species as source of natural dyes, two species as natural pestisides and 14 species for other purposes. Some species might have more than one use (see Table 2).

Table 2 Use of various Plants in East Lombok, NTB

No.	Scientific Name	Local Name	Plants Used	Usage
1	*Agave cantala*	Nanas hutan	Leaf	Woven material
2	*Ageratum conyzoides*	Bebembek	Leaf	To treat wound
3	*Aleurites moluccanus*	Lekong	Fruit Bark	Traditional cosmetic, spices Anti-bleeding agent
	Alocasia indica	Bira	Tuber	Staple food
5	*Ananas comosus*	Nanas	Leaf Fruit	Natural dyes Fresh fruit
6	*Aquilaria malaccensis*	Ketimunan	Stem	Incense in rituals
7	*Arenga pinnata*	Enau	Leaves Young leaves Stem. Branch Fruit sap	Cigar like material Used in paddy ritual Firewood Drink, source of sugar
8	*Azadirachta indica*	Mimba	Leaves	Remedy for wound, diabetes, malaria.
9	*Benincasa hispida*	Sonda	Young fruit Ripe fruit	Cooked as dish Fresh fruit
10	*Boenninghousenia albiflora*	Kelor bale	Leaves	Pesticide
11	*Borreria laevis*	Barabas	Leaves	Used to treat tumour
12	*Calotropis gigantean*	Rembiga	Sap	Used to treat tooth ache
13	*Canna edulis*	Sebet	Tuber Leaf	Staple food Food wrapping
14	*Carica papaya*	Gedang	Fruit Young fruit Leaf Flower	Fruit Used to shrink the abdomen To stimulate appetite After birth treatment, Contraceptive
15	*Cassia siamea*	Johar	Bark	To treat Malaria
16	*Ceiba pentandra*	Randu	Bark	To cure stiff muscle, headache and cramp abdomen
17	*Ceriops tagal*	Bakau	Bark Trunk Tree	Natural dye Building material, firewood Water retainer
18	*Citrus maxima*	Jeruti	Bark Fruit Fruit skin	Used for stomach ache and antibleeding agent. Fresh fruit Material for toy

(Continued on next page)

Table 2. (Continued)

No.	Scientific Name	Local Name	Plants Used	Usage
19	*Cinnamomum burmanii*	Kayumanis	Bark	Spices and traditional medicine
20	*Cleome viscosa*	-	Leaf	Used to treat wound
21	*Clerodendrum paniculatum*	Api-api	Leaf	To treat sore/red eye
22	*Cocos nucifera*	Nyiur	Leaf Trunk Leaf stem Fruit Fruit husk	Used for roof tile Building material, firewood Firewood Coconut milk/condiment Natural dye
23	*Coffea robusta*	Kopi	Fruit	Serve as drink, natural dye
24	*Cordyline fructicosa*	Andong	Young leaf	Used in paddy ritual
25	*Coriandrum sativum*	Ketumbar	Seed	Condiment, spice, traditional potion
26	*Cucurbita moschata*	Waluh	Leaf & fruit	Cooked as dish
27	*Curcuma longa*	Sekur	Aerial root	Used to treat head ache, potion after birth.
28	*Cymbopogon nardus*	Sesereh	All parts	Used to treat internal pain, spice
29	*Dioscorea alata*	Egal, Uwibonjor, Uwilengker, Uwi pit	Tuber	Staple food
30	*Dioscorea bulbifera*	Kalem	Tuber, fruit	Staple food
31	*Dioscorea esculenta*	Kembili	Tuber	Staple food
32	*Dioscorea hispida*	Gadungreket, Boyod	Tuber	Staple food
33	*Dioscorea* sp.	Gadung Kendit	Tuber	Staple food
34	*Dolichos lablab*	Komak	Fruit, Leaf	Food, natural dye
35	*Erechtites valerianifolia*	Gegook	Leaf	Used to treat fever and as cover on wound
36	*Eryngium foetidum*	Kesumbang Bewi	Root	Used to treat asphyxiate and flagging
37	*Eupatorium odoratum*	PKI	Leaf	Used to treat wound
38	*Euphorbia hirta*	Kungku-kungku	Sap	Used to treat wound
39	*Ficu srumphii*	Ancok	Leaf	Used to treat wound
40	*Ficus* sp.	Bunut	Leaf trunk	Used in paddy ritual
41	*Fleurya interrupta*	Serasah	Daun. Leaf	Itchy medicine
42	*Garcinia mangostana*	Manggis	Bark Fruit	Used to treat diarrhea, stiff muscle, and headache. Also as natural dye Served as fresh fruit
43	*Graptophyllum pictum*	Sembalekate	Leaf	Used to treat headache, afterbirth potion

(Continued on next page)

Table 2. (Continued)

No.	Scientific Name	Local Name	Plants Used	Usage
44	*Gynandropsis gynandra*	Lengkarang	Young leaf	Vegetable
45	*Hibiscus tiliaceus*	Tapen	Stem Leaf Tree	Building & boat material, firewood Used to reduce fever Shade plants
46	*Hydrocotyle sibthorpioides*	Bebele	All parts	Vegetable, lowering fever effect
47	*Hyptis brevipes*	Apur-apur, Teberate	Leaf Flower	Treatment for bruise Toxin
48	*Imperata cylindrica*	Re	Leaves Root	Used as roof cover To reduce fever, stiff muscle, curing head ache and stomach pain remedy.
49	*Indigofera* spp.	Taum	Leaves	Natural dye
50	*Ipomoea pes-caprae*	Leleda	Plant Leaf	Ornamental plant To treat haemorrhoid
51	*Jatropha curcas*	Ketangan	Seed Young bud Leaf Bark	As oil alternative Used on paddy ritual. Remedy for head ache, potion on birth Used to prevent bleeding
52	*Kalanchoe pinnata*	Sosor Bebek	Leaf	Reducing fever
53	*Lannaecoro mandelica*	Banten/ Kelor Jawa	Leaf Stem Tree	Remedy for wound and reducing fever Remedy for ulcer Used as living fence
54	*Leucaena leucocephala*	Lamtoro	Leaf	Remedy for ulcer
55	*Limnocharis flava*	Marembele	Leaf	Cooked as dish
56	*Luffa aegyptiaca*	Truwuk	Fruit Old fruit pulp	Cooked as dish Used as scrub
57	*Luffa cylindrical*	Truwuk Sagi	Fruit	Vegetable
58	*Lygodium circinnatum*	Ketak	Stem	Plaiting material
59	*Maranta arundinacea*	Marus	Tuber Leaf	Food staple Wrapper
60	*Momordica charantia*	Pria	Fruit Fruit	Vegetable Remedy for head ache
61	*Morinda citrifolia*	Pace	Leaf	Wrapper for broken bone
62	*Moringa oleifera*	Kelor	Leaves	Remedy for headache, to stimulate milk in lactation, natural dye

(Continued on next page)

Table 2. (Continued)

No.	Scientific Name	Local Name	Plants Used	Usage
63	*Muntingia calabura*	Singapur	Fruit Tree	Served as fresh fruit Shade plant
64	*Musa textilis*	Punti manila	Pseudo stem	Woven materials
65	*Musa* spp.	Punti	Leaf Fruit	Natural dye, used as wrapper Fruit
66	*Oxalis corniculata*	Empet-empet	All parts	Ointment for new wound
67	*Passiflora quadrangularis*	Pisa	Fruit & Seed	Fruit
68	*Persea americana*	Apokat	Bark Trunk Fruit	Anti-bleeding agent Building material, firewood Fruit
69	*Phaseolus lunatus*	Komak Kuning	Fruit	Food staple
70	*Paederia foetida*	Pepesu	Leaf, Stem	Used to treat shortness of breath, also on paddy ritual.
71	*Pilogyne repanda*	Dedilem	Leaf	Used during labour
72	*Piper betle*	Leko	Leaf	To treat fever
73	*Piper nigrum*	Sang	Seed	Spice, condiment, traditional potion
74	*Piper retrofractum*	Sembiatan	Fruit	Spice, condiment, traditional potion
75	*Piper umbellatum*	Umbe	Leaf	Remedy for rash
76	*Pluchea indica*	Beluntas, Ulet-ulet	Leaf All parts	Remedy for leucorrhoea used during labour Cattle feed
77	*Psophocarpus tetragonolobus*	Kecipir	Fruit Leaf	Dish Natural dye
78	*Pterospermum javanicum*	Bayur	Flower Trunk	Traditional cosmetic Building material; firewood
79	*Pueraria lobata*	Babaye	Tuber	Staple Food
80	*Rorippa heterophylla*	Jaong	Leaf	Served as dish
81	*Picrasma javanica*	Prian	Bark	Remedy for malaria, to expel flea
82	*Pillogyne repanda*	Bebikam	Leaf	Lowering fever
83	*Rubus rosafolius*	Murbei	Fruit	Served as fresh fruit
84	*Sandoricum koetjape*	Sentul	Bark Trunk Bark	Remedy for diarrhea Building material, firewood Remedy for diarrhea
85	*Sauropus androgynus*	Sager	Leaf	To stimulate lactation process.
86	*Schefflera elliptica*	Ketandandedangang	Bark Young leaf	Remedy for stiff muscle, treatment during labour Stimulating toddler to walk

(Continued on next page)

Table 2. (Continued)

No.	Scientific Name	Local Name	Plants Used	Usage
87	*Sechium edule*	Jepang	Fruit	Served as dish
88	*Sesbania grandifolia*	Ketujur	Young leaf, flower Leaf	Served as dish To treat broken bone, stimulant during lactation
89	*Sida rhombifolia*	Tengasigangan	Leaf	Remedy for tooth ache, to cover wound
90	*Sonchus arvensis*	Tetai	Leaf	To treat diabetics
91	*Syzygium aromaticum*	Cengkeh	Fruit	Condiment, ingredient of traditional potion
92	*Syzygium polianthum*	Jukut	Young leaf	For vegetable and condiment
93	*Syzygium*sp.	Jukutgawa	Fruit	Served as fruit
94	*Tamarindus indica*	Bage	Fruit Trunk	Condiment Building material, firewood.
95	*Trevesia sundaica*	Penggeng	Young stem Young leaf	Ingredient for chilli sauce Vegetable
96	*Tridax* sp.	Rebuletu	All parts	Cattle feed
97	*Vitex trifolia*	Lage, legu	Leaf Bark	To treat itch, used as deodorant, treatment during labour Natural dye
98	*Zyziphus* sp.	Daun Berduri	Fruit Leaf	Served as fresh fruit Used to cleanse corpse
99	?	Pepauh	Leaf	Vegetable
100	?	kembangkulur	Flower	Mosquito repellent
101	?	Sereget	Fruit	Served as fresh fruit, Ink
102	?	Kenebele	Tuber	Food staple
103	?	Tandan Bikam	Leaf Young leaf	Remedy for sore throat, high fever Vegetable

Plants commonly found in the forest and widely used by the Sasak include "sembalekate" *Graptophyllum pictum* (traditional medicine, used on traditional rituals), bayur *Pterospermum javanicum* (used as building materials, firewood, and traditional cosmetics), "ketandandedangang" *Schefflera elliptica* (traditional medicine), "lage" or "legu" *Vitex trifolia* (medicine and natural dye), "sentul" *Sandoricum koetjape* (fresh fruit) dan "prian" *Picrasma javanica*(medicine).

At present, modern cultivation that focuses less on pre and post harvest processing has slowly replaced some indigenous plants. An example of this are some carbohydrate-source plants such as *Dioscorea* spp., *Maranta arundinacea* and *Pueraria lobata* which are replaced by *Oryza sativa*, "ambonjama" ubijalar *Ipomoea batatas* and "ambon jawa" ubikayu *Manihot esculenta*. In the same way, uncultivated crops have been replaced with cultivated crops such as from Cucurbitaceae and Fabaceae families. Some fruit trees such as Manggis *Garcinia mangostana*, Duren *Durio zibethinus* and Rambutan *Nephelium lapppaceum* are intensively cultivated and become a significant additional income for people in East Lombok and West Lombok.

The Sasak community use a spell/mantra of plain water for their main traditional medication practice. The patient is then given this water. There are not many plants that are used for medication purpose except for after birth treatment. On the research location, the local name "bebele" is applied to *Hydrocotyle sibthorpioides* whereas Sasak community at the village Sembalun applied "bebele" to *Centella asiatica* which is applied to reduce fever and to obtain a healthy womb. These two species have similar morphology and belongs to the Apiaceae family. A phytochemical analysis is required to determine type and concentration of the active compounds on those two species.

The use of "kelor bale" *Boeninghousenia albiflora* as bio-insecticide needs further study on its active ingredients. According to Perry & Metzger (1980), steeped root of the plant is used as remedy for malaria in China and its dried leaves as an anti bleeding agent in Taiwan. However this knowledge does not seem familliar to the Sasak and the plant grows on the research location in abundance. The plant has not been listed as a source of natural pesticide.

Culture and the distinct woven cloth of Lombok are well known to many foreign countries. There are at least four weaving techniques known to Lombok people, the simple methods include "songket," "tenun ikat" and "sulam." The

simple weaving technique uses cotton thread called "beberut." Cotton (*Gossypium arboreum*) was first cultivated in Lombok in the early 19th century, its thread was then coloured using natural dyes (Gratha, 2012). Nowadays, with the development of technology, apart from using cotton thread, Sasak people also use fibres made from the stem of *Musa textilis* (Pisang Manila) and leaf of *Agave cantala* (wild ananas). The wild ananas is obtained from its habitat in the forest. The plant originated from Mexico and was introduced by the Spanish who initially used it as life-fence (Utomo, et al. 2003). Interviews with the Sasak revealed that of three species, the fibre of wild ananas was the most difficult to process. Its fibre is stiff and easily broken and thus requires a painstaking process to finally produce yarn.

Although synthetic dyes were introduced over the decades, the demand for natural dyes has increased. The Sasak use natural dyes from plants found in their surroundings, these include leaves of *Indigofera* spp, or "taum" to produce blue, "antek" black – bean to produce purple colours, "oma" leaf (*Psophocarpus tetragonolobus)* or Kelor (*Moringa oleifera*) for green colour, "luking kenyaman" or coconut fibre (*Cocos nucifera*) and coffee grains (*Coffea robusta*) for brown, and bark of "lage" (*Vitex trifolia*) for red. The length of soaking the yarn in the dye affects the colour produced. The longer the soaking, the deeper the colour will be.

The cloth "ulopdoyo" which is a distinctive woven cloth of the Dayak Benuaq, East Kalimantan Island is produced using fibers from the leaf of doyo, *Curculigo latifolia*. Its dominant traditional colours are black (from leaf of "sopaakng" *Archidendron* sp), red (from seed of "gilinggam" Bixa *orellana*), yellow (from the root of Curcuma *longa* and "siraakng" *Codiaeum variegatum*), and green (from the leaf of "blowo" *Cordyline fruticosa*). Blue dye originating from the leaf of *Indigofera tinctoria* is brought from outside Kalimantan (Zakorka, 2012). In Lombok Island, *Codiaeum variegatum* dan *Cordyline fruticosa* are used only as ornamental plants, their use as source of natural dyes is not known.

One of the well known souvenirs from Lombok is plaits from stem of "ketak" *Lygodium circinnatum*. In Bali island ketak is known as "pakuata" and is a handicraft material that contributes significantly in increasing income of the local people (Astuti et al. 2000). It is important to start cultivating this species extensively to ensure availability, as at the present it is wildly grown.

Conclusion

Etnobotany study of the Sasak ethnic in East Lombok revealed 103 useful species. These are used as stapple food, remedy for various illnessess, building materials, fruits, vegetables, source of natural dyes, and handicraft material. Fifty seven species are sources of carbohydrate, vegetables and fruits, seven species are building materials, 57 species are a source of medicine and cosmetics, seven species are used as firewood, eight species for ritual accessories, three species for woven materials, ten species as source of natural dyes, two species as natural pestisides, and 14 species for other purposes. Some species might have more than one use. Ketak as a potential source of additional income for local people merits further study, and extensive cultivation. This would ensure availability of raw material and thus preserving local knowledge and culture.

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Research Article

Brief Mist-netting and Update of New Record of Bats at Tumunong Hallu in Silam Coast Conservation Area (SCCA), Lahad Datu, Sabah, Malaysia.

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Abstract

A bat survey was conducted at Tumunong Hallu in Silam Coast Conservation Area (SCCA), Lahad Datu, Sabahfollowing the Silam Scientific Expedition 2015 from 7th July until 5th August 2015. A total of nine bat species belonging to two families were captured at SCCA. Among the noteworthy species recorded from this survey were *Rhinolophus sedulus* and *Pteropus vampyrus*, which are listed as Near Threatened in the IUCN Red List.

Keywords: Chiroptera, Sabah, Tumunong Hallu, Silam Coast Conservation Area (SCCA).

Introduction

Silam Coast Conservation Area (SCCA) is one of the conservation areas managed by Yayasan Sabah Group along with Danum Valley Conservation Area (DVCA), Maliau Basin Conservation Area (MBCA) and Imbak Canyon Conservation Area (ICCA). Initially, the area covered 580 hectares before it was expanded to 2,770 hectares in 2014 after its management was handed over to Yayasan Sabah Group in 1997. The SCCA is located in Darvel Bay, which is globally known as a region with marine-rich biodiversity and also a part of the Priority Conservation Area of the Sulu-Sulawesi Marine Eco-region. It is mainly covered by mixed swamp and beach vegetation, secondary forest and mangrove forest. From land to the sea, the diversity and the mix of flora and fauna in SCCA makes it an ideal conservation area for both the marine and terrestrial environments.

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A scientific expedition was carried out from the 10th to 18th May 2015, to officiate scientific data collection prior to designing a holistic Conservation and Management Plan for SCCA. To complement the data of this scientific expedition and the previous study by Ketol et al. (2009), another bat survey was conducted at various areas in SCCA including Pandanus Beach, Sungai Dewata and few orchard plots within the conservation area to update the list of bat species in SCCA. Currently, six newly-recorded species have been documented and the results of the survey are presented herein.

Material and Methods

Study area

The bat surveys were conducted in selected localities (Table 1) Sungai Dewata, Pandanus Beach and two orchard plots within SCCA (Figure 1). Most sampling occasions were done in orchard-based habitats with presence of local fruit

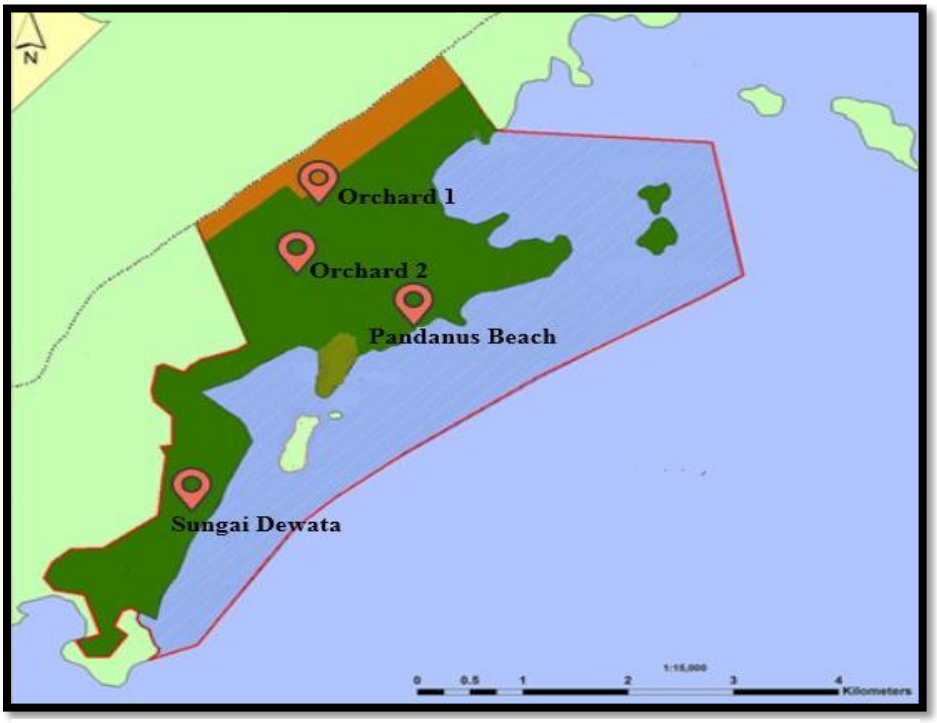

Figure 1. Map of Silam Coast Conservation Area (SCCA) with sampling sites.

trees such as mango (*Mangifera indica*), durian (*Durio zibethinus*), tarap (*Artocarpus odoratissimus*), kuini (*Mangifera odorata*), rambutan (*Nephelium lappaceum*) langsat (*Lansium domesticum*), jackfruit (*Artocarpus heterophyllus*) and longan (*Dimocarpus longan*) except for the sampling site at Pandanus Beach. The areas with orchard vegetation were split into three sites which are Orchard 1, Orchard 2 and Sungai Dewata. Orchard 1 is near the main road and human settlements whereas in Orchard 2, there is a small flowing stream. Meanwhile, the site in Sungai Dewata was surrounded with an oil palm plantation. The sampling site at Pandanus beach is near the coastline and the habitat includes beach vegetation, secondary forest, and few patches of mangroves and rattans. There are also flowering fig trees (*Ficus* sp.) scattered around the survey areas.

Table 1. List of study areas, habitat types and GPS readings.

No.	Study Area	Habitat	GPS reading
1.	Orchard 1	Orchard plots	N 04°55'0'' E 118°09'52.1''
2.	Orchard 2	Orchard plots and a small flowing stream	N 04°55'53.0'' E 118°09'11''
3.	Sungai Dewata	Oil palm plantation; riverine and orchard plots	N 04°54'9'' E 118°10'9''
4.	Pandanus Beach	Beach vegetation, few patches of mangroves, rattan, *Pandanus* sp., secondary forest and few individual fig trees (*Ficus* sp.)	N 04°55'03.6''E118°10'38.3''

Field method

The survey was carried out using four-shelves mist nets (9 m x 2.5 m, 25 mm mesh size) that were erected at areas identified as potential bat flyways. In order to enhance the species list of SCCA, high nets (12 m above the ground) were also used to catch high flyers or open-spaced bats. Mist nets were set up from 1700 hours and monitored until 2100 hours at an interval of 15 to 30 minutes. Before the last inspection at 0600 hours, mist nets were re-opened to capture bats that are active towards the dawn. Additional methods include using aerial nets to opportunistically catch bats that were observed roosting in old buildings. Captured bats were immediately removed from the nets to avoid casualties and to reduce stress induced from mist nettings. Each bat were kept inside separate cloth bags, weighed, measured and identified before being released.

Species identification

All individuals were identified following Payne et al. (1985) and Francis (2008). Standard measurements such as forearm (FA), ear (E), tibia (TB), hind-foot (HF), tail (T), head-body (HB) and weight (Wt) were taken using digital calliper (Mitutoyo 500 - 133 CD-6"B) prior to species identification based on Abdullah et al. (2010) and weighed using a Camry portable weighing scale. Selected individuals were taken as voucher specimens (wet specimen; preserved in 70 % alcohol) and deposited at the Yayasan Sabah Museum. Photographs of chosen species were taken for reference.

Results

A total of 91 individuals of bats, represented by two families and nine species were recorded from this survey (Table 2).

Table 2. Taxonomic list of chiropterans recorded from Silam Coast Conservation Area, Lahad Datu, Sabah.

No.	Family Species	Common name	IUCN Red List status	Relative abundance (%), N
	PTEROPODIDAE			
1	*Cynopterus brachyotis*	Lesser dog-faced fruit bat	LC	61.5 (56)
2	*Eonycteris spelaea*	Dawn bat	LC	9.9 (9)
3	*Eonycteris major*	Greater dawn bat	DD	1.1 (1)
4	*Macroglossus minimus*	Dagger-toothed long-nosed fruit bat	LC	2.2 (2)
5	*Penthetor lucasi*	Lucas's short-nosed fruit bat	LC	8.8 (8)
6	*Pteropus vampyrus*	Large flying fox	NT	1.1 (1)
7	*Rousettus amplexicaudatus*	Geoffroy's rousette bat	LC	13.2 (12)
	RHINOLOPHIDAE			
8	*Rhinolophus borneensis*	Bornean horseshoe bat	LC	1.1 (1)
9	*Rhinolophus sedulus*	Lesser woolly horshoe bat	NT	1.1 (1)
No. individuals		**91**		
Total number of families		**2**		
Total number of species		**9**		
Trapping effort (Net/trap-nights)		**56**		
Capture rate (Bats/effort)		**1.625**		

Note: LC- Least concern, DD- Data deficient and NT- Near threatened

Cynopterus brachyotis was the most abundant species captured in the Silam Coast Conservation Area (61.5 %) followed by *Rousettus amplexicaudatus* (13.2 %). Although *Pteropus vampyrus* were observed abundant in the area, only one individual was captured with the height of ground level mist net ranging from three to four metres height. Other than that, *Eonycteris major*, *Rhinolophus borneensis* and *Rhinolophus sedulus* were caught as singleton species. The recorded species were mostly pteropodid bats while capture of insect-eating bats was very poor, representing only 2 % of the total observed species. Based on previous studies done in SCCA and Gunung Silam (Ketol et al., 2009; Azniza et al., 2015) there are seven species recorded in these areas. Overall, six newly-recorded species have been added into the list of chiropteran species found in SCCA (Table 3).

Table 3. Comparison of chiropteran data in this study and other authors.

FAMILY Species	This study	Ketol et al. (2009)	Azniza et al. (2015)
PTEROPODIDAE			
Cynopterus brachyotis	✓	✓	✓
Cynopterus horsfieldii	0	0	✓
Eonycteris spelaea	✓	✓	0
Eonycteris major	✓	0	0
Macroglossus minimus	✓	✓	0
Penthetor lucasi	✓	0	0
Pteropus vampyrus	✓	0	0
Rousettus amplexicaudatus	✓	0	0
HIPPOSIDERIDAE			
Hipposideros diadema	0	0	✓
RHINOLOPHIDAE			
Rhinolophus acuminatus	0	✓	0
Rhinolophus borneensis	✓	0	0
Rhinolophus sedulus	✓	0	0
Rhinolophus trifoliatus	0	0	✓
No. of family	**2**	**2**	**3**
No. of species	**9**	**4**	**4**

Figure 2. Photo of **A** *Rhinolophus borneensis*, **B** *Rhinolophus sedulus*, **C** *Pteropus vampyrus*, **D** *Eonycteris major*, and **E** *Rousettus amplexicaudatus*

Species Account

FAMILY PTEROPODIDAE

Cynopterus brachyotis (Müller, 1838)

Short-nosed fruit bat (Cecadu Pisang)

Cynopterus brachyotis had the highest capture of all chiropterans (56 individuals) and was netted in all sampling areas in this study. This species is one of the common fruit bats in Southeast Asia which occupies a broad variety of habitats from primary forests to disturbed forests and orchards, mangrove forests, cultivated areas, gardens, urban areas and even in anthropogenic settings (Lim, 1966; Medway, 1983; Payne et al., 1985; Boon & Corlett, 1989; Francis, 1990, 1994; Zubaid, 1993, 1994; Tan et al., 1997, 2000; Abdullah, 2003; Mohd Ridwan et al., 2011). Apart from the Payne et al. (1985) description of *C. brachyotis* diet which comprised nectars and fruits, a few authors have suggested that their diet also includes leaves and particular insects (Boon & Corlett, 1989; Funakoshi et al., 1993; Tan et al., 1998; Mohd Ridwan et al., 2011). The individuals caught during the survey were the large-sized *C. brachyotis* that was genetically resolved by Abdullah et al. (2000), Abdullah (2003), Campbell et al. (2004; 2006) and Jayaraj et al. (2004; 2005a).

It is listed as a 'Least Concern' species in the IUCN Red List with an unknown population trend (Csorba et al., 2008a).

Eonycteris spelaea (Dobson, 1871)

Cave Nectar Bat (Cecadu Gua Kecil)

In this study, *Eonycteris spelaea* was netted mainly in the orchard areas similar to previous studies by Lekagul & McNeely (1977), Heideman & Heaney (1989), Kitchener et al. (1990) and Bumrungsri et al. (2013). The largest individual in this study was identified with FA= 73mm measurement. A distinct feature of this species includes the absence of its second digit (Payne et al., 1985). This species can travel as far as 38 km to forage and feeds on at least 31 species of plants (Start & Marshall, 1976; Bumrungsri et al., 2013). It is listed as a 'Least Concern' species in the IUCN Red List with an unknown population trend (Francis et al., 2008a).

Eonycteris major K. Andersen, 1910

Greater Nectar Bat (Cecadu Gua Besar)

Eonycteris major was netted in an orchard within Sungai Dewata. It was the first and only individual captured during the fourth survey (24th July 2015). Its physical features were more or less alike *E. spelaea*, but with darker body fur and larger in size. The individual caught in this study had FA=81.06mm measurement. Although this species is related to primary forest and its distribution is limited to areas with higher elevations (Jayaraj et al., 2011), capture of singleton *E. major* in the present study showed a new encounter of this species in the coastal area as a previous study in Lambir Hills National Park recorded this species in highland localities (Jayaraj et al., 2005b; 2011; Fukuda et al., 2009). It is listed as a 'Data Deficient' species in the IUCN Red List with an unknown population trend (Bates et al., 2008a).

Macroglossus minimus (É. Geoffroy, 1810)

Long-tounged Nectar Bat (Cecadu Madu Bakau)

Macroglossus minimus was netted in the orchards but with a lower occurrence in the mist nets compared to *C. brachyotis, E. spelaea*, and *P. lucasi*. Only two individuals were recorded throughout this study. The first individual was caught on 8th July 2015 and the second individual was captured on 10th July 2015. They were often caught in mist nets together with *C. brachyotis* (Payne et al., 1985). Their diet mainly consists of nectar and pollen, however they also suck juices of soft fruits occasionally (Nowak, 1991). This species is also recorded in coastal mangroves in Malaysia which are present and abundant in SCCA, especially with the presence of *Sonneratia* sp. where the buds also act as their food source (Nowak, 1991). *M. minimus* needle-like teeth, small-sized body and narrow muzzle enabled it to be easily distinguished from the other fruit bats in Borneo (Payne et al., 1985). It is listed as a 'Least Concern'

species in the IUCN Red List with a stable population trend (Francis et al., 2008b).

Penthetor lucasi (Dobson, 1880)

Dusky Fruit Bat (Cecadu Hitam Pudar)

Penthetor lucasi was commonly netted in areas where fruiting and flowering trees are present. Their roosting preference includes sites which are close to total darkness, remote caves and rock shelters (Payne *et al.*, 1985; Francis, 2008; Mohd Ridwan & Abdullah, 2012). In this study, they were found in orchards and also at Pandanus beach where the *Ficus* sp. was fruiting. The largest individual had FA=68.00mm measurement while the smallest individual had FA= 56.51mm measurement. Their morphological variation is suggested to be caused by the possible factors of breeding, crowding effect, foraging behaviour, resource availability, sexual dimorphism and selective pressure (Abd Rahman & Abdullah, 2010). They were usually caught alongside *C. brachyotis* and can be distinguished by observing the number of incisors present. *P. lucasi* has one pair of lower incisor whereas *C. brachyotis* has two pairs (Payne et al., 1985). It is listed as a 'Least Concern' species in the IUCN Red List with a decreasing population trend (Bates et al., 2008b).

Pteropus vampyrus (Linnaeus, 1758)

Large Flying Fox (Keluang Besar)

This species was netted near a rambutan tree (*Nephelium lappaceum*) in Orchard 2. Most of the rambutans were ripe and the canopy level of the rambutan tree was quite low (three to four metres) thus, forcing the *P. vampyrus* to fly closer to ground and was netted using an understorey mist net. Although recorded in orchard areas, it is commonly seen in mangrove or nipah palm areas, typically roosting in large colonies on trees with open branches (Payne et al., 1985). This species is able to fly up to 50 km overnight for foraging (Lim, 1966). Unfortunately, the population is declining due to extensive hunting for its meat, which is believed to have medicinal properties (Fujita & Tuttle, 1991; Mohd-Azlan et al., 2001). It is listed as a 'Near Threatened' species in the IUCN Red List with a decreasing population trend (Bates et al., 2008c).

Rousettus amplexicaudatus (É. Geoffroy, 1810)

Geoffroy's Rousette (Cecadu Besar)

Rousettus amplexicaudatus was also netted mainly in orchard compounds. The highest number of capture for this species was on 31st July 2015 during the morning inspection, for the seventh survey. Eleven individuals of *R. amplexicaudatus* were captured in the mist nets deployed five to six metres from the ground without the occurrence of other bat species. Previously, echolocation in family Pteropodidae has been exclusively described in a few

species of genus *Rousettus* bats by their production of audible clicking sounds (Payne et al., 1985). However, recent studies managed to show echolocating calls demonstrated by other pteropodids such as *E. spelaea*, *C. brachyotis* and *M. minimus* through wing clapping motion (Boonman et al., 2014). Records from Fukuda et al. (2009) showed the presence of this species in primary and secondary forests at Lambir Hills National Park. *R. amplexicaudatus* is listed as a 'Least Concern' species in the IUCN Red List with an unknown population trend (Csorba et al., 2008b).

FAMILY RHINOLOPHIDAE

Rhinolophus borneensis Peters, 1861

Bornean Horseshoe Bat (Kelawar Ladam Borneo)

Rhinolophus borneensis was caught using an aerial net while roosting in one of the public toilets at Pandanus beach. The individual captured in this study has brown to reddish body fur. Regardless of the distribution across Malaysia, this species is more likely to be found in Borneo compared to Peninsular Malaysia (Biotani et al., 2006). It is reported to roost in large colonies in caves (Payne et al., 1985) and also in bamboos, tree cavities, rock crevices and young foliage of banana plants (Mohd Ridwan et al., 2011). *R. borneensis* also lacks extra lappets or flaps on its noseleaf, and its connecting process varies from slightly rounded to bluntly pointed (Payne et al., 1985). It is listed as a 'Least Concern' species in the IUCN Red List with an unknown population trend (Hutson et al., 2008).

Rhinolophus sedulus K. Andersen, 1905

Lesser Woolly Horseshoe Bat (Kelawar Ladam Bulu Halus)

Rhinolophus sedulus was caught using an aerial net while roosting in a changing room at Pandanus Beach. It has been observed that this particular individual still roosts at the same spot in the changing room even after several unsuccessful attempts to capture it. This species has body fur that is greyish, dark grey ears and noseleaf with lateral lappets at the base of its sella (Payne et al., 1985). It is listed as a 'Near Threatened' species in the IUCN Red List with a decreasing population trend (Hutson & Kingston, 2008).

Discussion

This study recorded nine species, of which six are additional records for SCCA. The survey from this study recorded the highest number of species compared to previous studies by Ketol et al. (2009) and Azniza et al. (2015). Among the potential factors that might affect the abundance of bats are food availability, temporal disparity, sampling efforts, sampling methods, duration of study,

forest types and the intensity of area disturbance which then may influence the difference in data between these studies (Abdullah et al., 1997; Hodgkison et al., 2004; Mohd-Azlan et al., 2005, 2008; Jayaraj et al., 2011).

Consistent with results of most previous studies, *C. brachyotis* is a common species, usually recorded in high number in most bat surveys (Francis, 1994; Abdullah & Hall, 1997; Fukuda et al., 2009; Jayaraj et al., 2011; Nur Juliani et al., 2011; Noor Haliza et al., 2012). This is due to their ability to adapt and tolerate to a broader range of environments (Nur Juliani et al., 2011). Moreover, the stability of *C. brachyotis* populations is also aided by tree species that have extended fruiting periods or that fruit constantly throughout the year (Tan et al., 2000). It is speculated that the high number of pteropodids species were influenced by the fruiting season during the survey due to higher availability of food source as fruits and floral resources are part of their main diet. Thus, temporal disparity affects the gap of data between this survey and previous studies despite the brief sampling period. Furthermore, pteropodid bats often travel to areas where food is available (Nelson, 1965; Thomas, 1982, 1983; Hodgkison et al., 2004) in response to temporal variation. The presence of individual fig trees (*Ficus* sp.) in SCCA is another factor that contributes to the stable pteropodids population as *Ficus* sp. is also an essential food source for bats in Southeast Asia (Lambert & Marshall, 1991; Bhat, 1994; Funakoshi & Zubaid, 1997; Marshall, 1985; Boon & Corlett, 1989; Tan et al., 1998, 2000; Mohd Ridwan et al., 2011).

Gunung Madai is the nearest cave and is 44.8km away from SCCA. This might explain the capture of a few cave-dwelling species such as *R. amplexicaudatus, P. lucasi, E. spelaea,* and also *R. borneensis* that were previously recorded by Payne et al. (1985) in Gunung Madai. In this study, only the mist-netting method was applied to capture chiropterans because of equipment shortage, which affects the results of this survey. This method is more effective for pteropodids sampling. Insectivorous bats tend to chew and damage the mist nets, enabling them to escape in an instant if they are not removed upon capture (Abdullah et al., 1997). Apart from that, insectivorous bats echolocation call has empowered their flight capacity to avoid mist nets where it reflects stronger resonance due to higher material density (Abdullah et al., 1997; Berry et al., 2004; Schnitzler et al., 2003; Ramli & Hashim, 2009). Hence, the usage of four-bank harp traps will increase sampling competency and the likelihood of capturing insectivorous bats (Laval & Fitch, 1977; Francis, 1989; Tidemenn & Woodside, 1989; Mohd-Azlan et al., 2000, 2005; Ramli & Hashim, 2009; Mohd Ridwan et al., 2011). Likewise, extended duration added

with extra frequency of sampling may possibly lead to a higher number of recorded species. There are still areas in SCCA that are not explored for bats surveys.

Insectivorous bats in this study were captured opportunistically using aerial nets while they were roosting in old public toilets and a changing room at Pandanus Beach. Hence, testing different approaches to sample faunal diversity was positive, not only in generating extensive data but also in leading to unanticipated discoveries. The presence of a forest interior bat such as *R. sedulus* leads to the speculation that the forest could sustain the survivability of fragile species, which are very susceptible towards habitat conversion (Kingston et al., 2003). Therefore, trappings with proper equipment such as harp traps and ultrasonic bat detectors coupled with increased sampling efforts might yield additional species of insectivorous bats and reveal more information regarding the species composition in a sampling site.

Habitats in SCCA include mangrove forest, beach vegetation, orchards, secondary forest and oil palm. Each of these habitats has a unique ecosystem that can accommodate a variety of bat species. It was observed that there are patches of forests logged in some parts of the forest and also remnant of cleared rattan trees and bamboo which are abundant in SCCA. There are also some housing settlements at the edge of this area near the main road. Regardless of the environmental disturbance, SCCA is able to support a few vulnerable species such as *P. vampyrus* and *R. sedulus*. However, bat populations in SCCA might be affected and decline if the intensity of disturbance increases (Mohd Ridwan et al., 2011). Excessive clearing of bamboo and rattan may result in habitat loss for a few species of bats in genus *Tylonycteris, genus Kerivoula* and genus *Rhinolophus* that are known to roost in these vicinities (Payne et al., 1985; Francis, 2008).

Conclusion

Nine species of chiroptera from two families were documented within Silam Coast Conservation Area (SCCA). Though the newly recorded species are higher than previous studies, data suggests that the species diversity of chiropteran in SCCA has not been fully reflected and greater efforts and coverage are essential to obtain complete chiropteran data in this conservation area. For future surveys, advanced trapping equipment such as ultrasonic bat detectors and harp traps could be used to improve sampling efficiency. The sampling

period could also be prolonged by taking into account spatial and temporal factors including forest phenological changes.

Being the only conservation area that is involved in the management of coastal and marine ecosystems, SCCA harbours a bountiful combination of unique terrestrial and marine biota. Thus, they need to be properly assessed and conserved for future generations.

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Appendix 1

Table 4. Morphological measurements of chiroptera (maximum and minimum ranges). **N**= total individuals, **FA**= forearm, **E**= ear, **TB**= tibia, **HF**= hind foot, **T**= tail, **HB**= head-body and **WT**= weight.

Family	Morphological measurements							
Species	N	FA (mm)	E (mm)	TB (mm)	HF (mm)	T (mm)	HB (mm)	WT (g)
PTEROPODIDAE								
Cynopterus brachyotis	56	59.00 - 67.87	11.61-16.21	20.73-25.63	6.53-12.28	6.51-14.27	64.48-92.95	25.00-46.00
Eonycteris spelaea	9	61.00 -73.00	15.37-25.00	26.81-30.39	10.27-21.00	11.50-22.00	87.00-116.00	32.00-49.00
Eonycteris major	1	81.06	21.06	38.02	16.34	20.65	95.01	80.00
Macroglossus minimus	2	43.00- 47.00	17.00 - 22.00	29.00	12.00-15.00	-	67.00-69.00	10.00-14.00
Penthetor lucasi	8	56.51-68.00	15.00-25.00	20.73-34.00	8.92-20.00	10.33-17.00	67.00-82.00	14.00-29.00
Pteropus vampyrus	1	190.81	43.38	92.76	40.32	-	235.41	567.00
Rousettus amplexicaudatus	12	83.87 - 96.00	17.24 - 27.00	40.00 - 49.00	11.09 - 23.00	16.12-29.00	104.37 - 119.00	49.00-91.00
RHINOLOPHIDAE								
Rhinolophus borneensis	1	45.79	17.94	19.57	4.55	21.68	45.60	7.00
Rhinolophus sedulus	1	45.26	18.49	22.96	5.36	20.04	48.34	12.00

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Short Notes

A Note on *Selliguea murudensis* (C. Chr.) Parris (Polypodiaceae), a New Record of Fern for Mount Alab, Crocker Range Park, Sabah

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Abstract
A rare fern species, *Selliguea murudensis* was found in the lower montane forest of Mount Alab. The species was previously observed in several localities, on Mount Kinabalu in Sabah and on Mount Mulu and Mount Murud in Sarawak. Mount Alab is the second locality of *Selliguea murudensis* to be recorded in Sabah, making it a new record for Mount Alab. Coincidentally, this was also the first record of the species to occur in higher altitude at 1,725 - 1900 m asl. The species is an epiphytic fern and was found growing on the trunk of a fallen tree. A single elongated fertile frond was observed with one series of sori on either side of the midvein. It thrives in cool, moist and shaded environment with air temperature and relative humidity of 15.5 ± 0.6 ^{o}C and 99.0 ± 2.1 %, respectively. The fern is believed to occur in abundance at Mount Alab and in the other localities of its limited distribution.

Keywords: *Selliguea murudensis*, Polypodiaceae, new record, Mount Alab, Crocker Range Park

Introduction
Polypodiaceae is a widely distributed family that occurs throughout the world extending from the tropics to the northern and southern latitudes. *Selliguea*, a fern member of the Polypodiaceae family has a pantropical distribution, occurring mostly in Asia, from India eastward to Japan and southward to New Guinea (Kramer & Green 1990). To date, there are about 78 taxa in the Malesian region (data obtained from http://portal.cybertaxonomy.org/flora-malesiana/), of which nearly all species are epiphytes. A montane species, *Selliguea murudensis* is endemic to Borneo and was first collected at Mount Murud and Mount Mulu in Sarawak. The species was first described as *Pycnoloma murudense* from a specimen collected from Mount Murud, Sarawak. The collection of this species has been done at these localities since 1931 (Parris et al. 1992). In Sabah, specimen of this species was collected at Mount Kinabalu in a range of altitude between 1200-1600m asl (Beaman & Edwards

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2007). It has limited distribution; however, it may occur in high abundance within the localities of its previous collection. *Selliguea murudensis* commonly inhabits mossy rock, fallen logs or stumps and shaded areas, and may occur as lithophyte and epiphyte in lower montane forests.

This short note presents information on the current distribution of *Selliguea murudensis* in Sabah based on records of herbarium collections as well as specimens collected at Mount Alab, the new locality record. In addition, the microclimate environment of the species in its habitat at Mount Alab is described to add information on its ecology.

Materials and Methods

The specimen was collected at the Minduk Sirung trail in Mount Alab and the voucher specimen was deposited at the Borneensis Herbarium(BORH), Universiti Malaysia Sabah. The duplicate was deposited at Kinabalu Park herbarium. The specimen was compared with six specimens of *Selliguea murudensis* found on Mount Kinabalu as well as other localities in Crocker Range Park (Table 1). The morphology of our specimen (BORH 1549) matched with the morphology exhibited by the *Selliguea murudensis* specimens at Kinabalu Park herbarium.

Table 1. Localities of the examined *Selliguea murudensis* specimens

Collector & ID number	Localities & Habitat	Altitude
Luiza Majuakim & Florina Anthony BORH 1549 26 Feb 2013	Crocker Range Park, Mount Alab, Minduk – Sirung trail. On fallen tree trunk.	1725 m
Hovenkamp, P.H. PH 136 21 Sept. 2012	Crocker Range Park, Mount Alab, Minduk – Sirung trail. On branch of fallen tree.	1900 m
P.S. Shim SNP A 18454 9 May 2010	Km. 32, Kota Kinabalu-Tambunan road.	1580 m
P.S. Shim SNP A 18443 11 April 2010	Crocker Range Park, Alab. Epiphytes in upper montane forest.	Data not available
T. Nakamura, S. Matsumoto, Ebihara, Diwol S., A. Sugawara & Hendry M. BORH 140 2 Feb. 2007	Kinabalu Park, Silau-silau trail. Roadside, on mossy mound, epilithic.	1500 – 1600 m
A. Sugawara AS 245 7 Jan 2006	Crocker Range Park, Mount Alab, forest between Alab substation and Telecom tower. On trunk of liana.	1900 m
Geofarry G. SP No. 08198 7 Aug 1997	Mile 19, Kimanis-Keningau road. In open area, by roadside, on rock.	1100 m
Geofarry G. SP 09704 22 July 1999	Ulu Tikolod river, Tambunan, riverbank forest	850 m

In addition, microclimate of the species was monitored for a period of approximately three weeks at the location where the species was found at Mount Alab. Atmospheric temperature and relative humidity were captured using Hobo data loggers which were installed at the location.

Results and Discussion

Description of specimens collected at Mount Alab

Rhizomes: The rhizomes of this species are long-creeping and the colour is golden brown. The scale is peltate, narrowly lanceolate and long-attenuate and stipes is articulated to rhizome.

Stipes: c. 1.5 – 4 cm long on sterile fronds, and much longer to 9 cm on fertile fronds. Fronds erect, simple, glabrous, ovate-spathulate and strongly dimorphic. The lamina of the sterile frond is 1.5 – 3 cm long and 1.5 – 2 cm wide. Sterile fronds have 4 – 9 conspicuous lateral veins and margin inconspicuously notched. Veins are distinctly raised on the upper surface, forked once near the margin. The lamina in fertile fronds is linear with 8 cm long and 0.3 cm wide.

Sori: Elongate, forming a series of parallel band on either side of midvein, and superficial.

Ecology and distribution

The distribution of *Selliguea murudensis* is restricted to the northern part of Borneo (Hovenkamp, 1998); this species was observed on Mount Mulu and Mount Murud in Sarawak, and on Mount Kinabalu and Mount Alab in Sabah. This species may be found in other areas that share similar ecological features as the localities in which this species was found in Borneo. There have been no official reports of the species in Kalimantan and Brunei. Several collections of *Selliguea murudensis* have been made in Kinabalu Park and Crocker Range Park at various localities (Table 1). Our specimen was the third collection of this species to be made at Mount Alab. Previous collections were done in 2006 and 2012, but the findings were not officially reported. Hovenkamp (1998) reported the species to be distributed at an altitude from 150 m to 1700 m asl. However, based on the localities of the examined specimens, no collection of this species was ever made or reported below 850 m asl in Sabah or Sarawak. The lowest altitude recorded was at 850 m asl when the specimen was collected in riverbank forest growing as epiphytes. The distribution of this species is confined to lower montane forest zone in Sabah and Sarawak. At this altitude, the forest at Mount Alab is persistently covered with cloud from mid-

day until night-time, and often throughout the day. The presence of cloud enhances moisture retention in the atmosphere and promotes the growth of mosses in abundance on the ground and vegetation. Because of such conditions, Mount Alab has been referred to as mossy forest.

The specimen collected from Mount Alab was present in a closed canopy environment and growing on fallen tree trunk, using accumulated decaying organic matter on the tree trunk as substrate. There was minimal daily fluctuation of the microclimate measurements of the habitat of *Selliguea mururdensis* in Mount Alab (Figure 1). The air temperature fluctuated between a minimum of 14.3 ^{o}C to 16.3 ^{o}C. The mean air temperature and relative humidity of the habitat were 15.5 ± 0.6 ^{o}C and 99.0 ± 2.1 %.

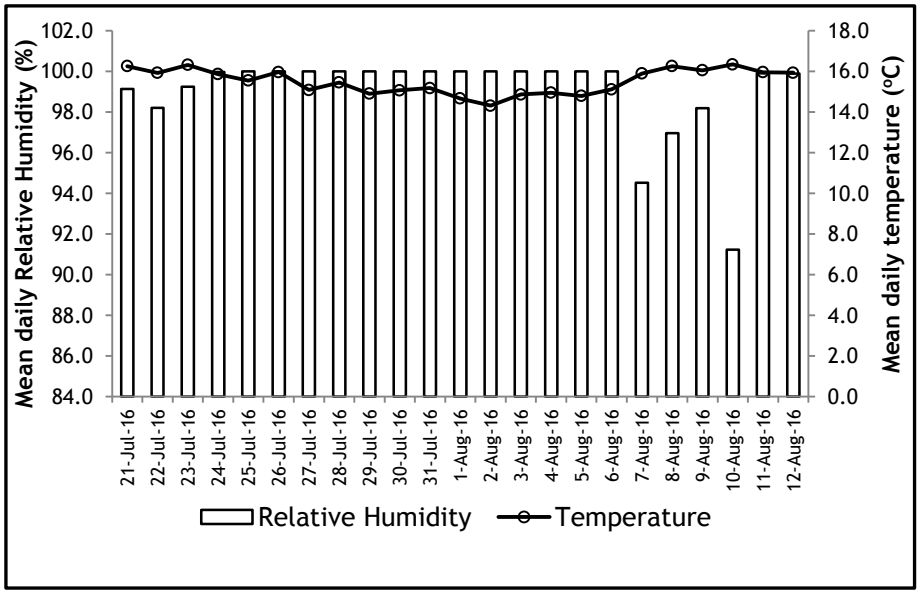

Figure 1. Daily microclimate measurements recorded at Mount Alab locality of *Selliguea murudensis*

The species of *Selliguea murudensis* occurred in both epiphytic and terrestrial habitats. *Selliguea murudensis* was observed growing on fallen tree trunks and branches, lianas, mossy rocks and on trunks of standing trees. On several occasions, we observed the unfertile individuals of this species growing on mossy rocks at Mount Alab. *Selliguea murudensis* grows in shady, cool and moist habitat. Although specimens of the species were collected mostly from high moisture and cool habitat, at one instance, it was found in an exposed habitat as evidenced by the specimen collected at the roadside along the Kimanis – Keningau road (SP No. 08198; Table 1). It probably benefited from some form of shade and moisture from the forest nearby, and at such altitude, clouds may occasionally cover the area.

Selliguea murudensis may be a versatile species that can cope with higher temperatures and thus desiccation, unlike the filmy fern, Hymenophyllaceae. With the current emerging signs of climate change, this species may provide insights on the impact of a changing climate on its population dynamics and adaptability.

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Short Notes

Short Notes on Fireflies of Sungai Kawang, Sabah

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Abstract

A survey on the congregating fireflies located in the mangrove forest of Sungai Kawang, Kinarut, 20 kilometers south of Kota Kinabalu was conducted from September to October 2015. The dominant firefly species was *Pteroptyx bearni* Olivier. Out of 133 male *Pteroptyx* fireflies collected, 131 individuals belong to this species. The less common species *Pteroptyx malaccae* Gorham was collected on a mangrove tree that is away from the jetty. Most of the fireflies were collected from the dominant mangrove species, *Rhizophora mucronata*, while some were collected from *Aegiceras floridum* and *Lumnitzera littorea*. With a high population of congregating fireflies and the geographical advantages of Sungai Kawang, it has the potential to be developed as a tourist attraction. Proper development planning associated with a system for population monitoring and habitat conservation are essential for sustainable ecotourism.

Keywords: Congregating fireflies, *Pteroptyx bearni*, *Rhizophora mucronata*, population monitoring system, sustainable ecotourism, mangrove forest

Introduction

The intriguing beauty of wildlife has engrossed humans for centuries. The bioluminescence emitting ability of fireflies has fascinated people across geographical regions. A renowned writer, W. Somerset Maugham, described the congregating fireflies he saw during his trip heading up the river of Borneo back in 1922 as sparkling candles that lit up the mangrove trees that resemble an alluring Christmas tree (Maugham, 1977). It is really an uplifting experience to view the congregating fireflies at night, with the tiny flashing pixies gregariously lighting up mangrove trees on the riverine.

In Sabah, there are several places that are famous for firefly watching, for example, Sungai Klias (Chey, 2004) and Weston near the Beaufort District. Both are some 100 kilometers south of Kota Kinabalu. For tourists who spend most

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of their time in the capital of Sabah, it is inconvenient to travel far away from Kota Kinabalu for firefly watching. The high population of *Pteroptyx* fireflies and the geographical advantage of Sungai Kawang 20 kilometers south of Kota Kinabalu is an appropriate site to be developed for ecotourism.

Materials and Methods

A survey was conducted at nightfall in Sungai Kawang. The mangrove forest here is well concealed from artificial lighting; light pollution is suggested to deplete the *Pteroptyx* firefly population. Sampling was conducted on 21 September, 13 October and 27 October 2015. Fireflies on the display trees were collected using sweep-nets and placed in a plastic bag. The fireflies were later killed with ethyl acetate and preserved in vials with 70 % ethanol.

Results and Discussion

Two species of *Pteroptyx* fireflies were sampled throughout three sampling occasions. They were confirmed to be *Pteroptyx bearni* Olivier and *Pteroptyx malaccae* Gorham (Ballantyne & Lambkin, 2013). There were a total of 217 individual fireflies collected with the ratio of 133 males to 84 females. The dominant firefly species in Sungai Kawang was *Pteroptyx bearni*; out of 133 males collected, 131 individuals belonged to this species. According to estimation, around 90 % of the mangrove species found on the riverine of Sungai Kawang belongs to the species *Rhizophora mucronata* (Rhizophoraceae), where most of the *Pteroptyx* fireflies congregated. By referring to the data collected, it is suggested that *Pteroptyx bearni* is not specific when it comes to display tree selection. Its predilection seems to be determined by tree availability and suitability rather than certain species of mangrove trees. Some fireflies can be found congregating on *Aegiceras floridum* (Primulaceae) and *Lumnitzera littorea* (Combretaceae). Several mangrove species coexist at the riverine, including *Avicennia alba* (Acanthaceae) and *Hibiscus tilliaceus* (Malvaceae). There was no visible *Nypa fruticans* (Arecaceae) along the riparian region, which is commonly found in a mangrove ecosystem. Table 1 summarizes the data collected from three sampling occasions.

Table 1. Firefly species sampled in the mangrove forest and their display tree species.

Date of sampling occasion	Firefly species	Display Tree species	Individual number of male fireflies	Individual number of female fireflies	Total
21 Sept 2015	*Pteroptyx bearni* & *Pteroptyx malaccae*	*Rhizophora mucronata* & *Aegiceras floridum*	15	19	34
13 Oct 2015	*Pteroptyx bearni*	*Rhizophora mucronata* & *Lumnitzera littorea*	36	19	55
27 Oct 2015	*Pteroptyx bearni* & *Pteroptyx malaccae*	*Rhizophora mucronat, Aegiceras floridum* & *Lumnitzera littorea*	82	46	128
		Total	**133**	**84**	**217**

Ecotourism potential and conservation of fireflies

World-renowned entomologist and writer, Edward O. Wilson, introduced and popularized the Biophilia hypothesis in his book in 1984. The Biophilia hypothesis suggests that there is an inborn connection between human beings and other forms of life. This natural behaviour of humans led to the rapid development of ecotourism. Sinha (2001) in his conference paper on wildlife tourism mentioned many conservationists and natural resource managers proposing that wildlife tourism can bring harm to the integrity of ecosystems, more specifically wildlife population dynamics and their behaviour. However, properly managed ecotourism should be able to benefit the ecosystem and local communities (Ondicho, 2012). Non-consumptive ecotourism should be emphasized in Sungai Kawang. As narrated by boatmen and local communities, tourists tend to collect some of the fireflies and place them into a container for viewing or to bring them out of their natural habitat. In addition, light pollution that acts as a significant disruptor in the firefly mating ritual (Mahadimenakbar et al., 2009), must be minimized in order to sustain a healthy population of fireflies (Chey, 2009). Sungai Kawang which is near Kota Kinabalu has the potential to be developed as an ecotourism site. However, proper development planning associated with population monitoring system and habitat conservation must be implemented in order to achieve sustainable utilization of natural resources.

Conclusion

The most common congregating firefly species found in Sungai. Kawang is *Pteroptyx bearni* while *Pteroptyx malaccae* can also be encountered. Sungai Kawang serves as a firefly watching option for tourists who do not want to travel for several hours from Kota Kinabalu to enjoy the elegant beauty of congregating fireflies. The habitats for congregating fireflies are rapidly degrading due to anthropogenic activities. This would eventually lead to the local extinction of the firefly population. Non-consumptive ecotourism is essential for the sustainability of the *Pteroptyx* firefly population in Sungai Kawang. Ecotourism development projects must be well planned in order to sustain the integrity of the ecosystem.

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Short Notes

First Record of the Female of the Praying Mantis *Mythomantis serrata* (Order: Mantodea) from Sabah, Borneo

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Abstract

We present the first record of the female of *Mythomantis serrata,* collected from Imbak Canyon Conservation Area, Sabah. This species was described by Schwarz & Helmkampf in 2014 based on male specimens collected from Gunung Mulu, Sarawak and Danum Valley, Sabah, Borneo. This species can be distinguished from the other *Mythomantis* species, *M. confusa* and *M. gracilis*, based on the presence of sawtooth-like lobes along the sides of the pronotum, and the concave margins of its supra-anal plate. The female individual of this species possesses similar morphological characters like those seen in males. The description of the female specimen follows Schwarz & Helmkampf (2014).

Keywords: Mantodea, *Mythomantis serrata*, female, Borneo, taxonomy

Introduction

The praying mantis genus *Mythomantis* was first described by Giglio-Tos in 1916 and currently comprise three Sunda species, namely *M. confusa* (Westwood, 1889), *M. gracilis* Werner, 1922 and a recently described species, *M. serrata* Schwarz & Helmkampf, 2014. To date, both sexes are only known in *M. confusa*. *M. gracilis* and *M. serrata* have been described based on male specimens with no information on their females. *M. serrata* was described based on a series of male specimens collected in Gunung Mulu, Sarawak and Danum Valley, Sabah, Borneo, the description is based on these additional specimens. These specimens are deposited in collections such as the Natural History Museum, London (NHM), the Muséum National d'Histoire Naturelle, Paris (MNHN), the Cleveland Museum of Natural History (CMNH), and the Sarawak Museum of Natural History (SMNH).

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M. serrata can be easily distinguished from the other two species based on its prominent triangular lobes along its pronotal sides (Figure 1C), and the concave margins of its supra-anal plate (Figure 1B). Additionally, its body length exceeds those of *M. confusa* and *M. gracilis*. This paper reports on the first female of *M. serrata* collected from Imbak Canyon Conservation Area, Sabah.

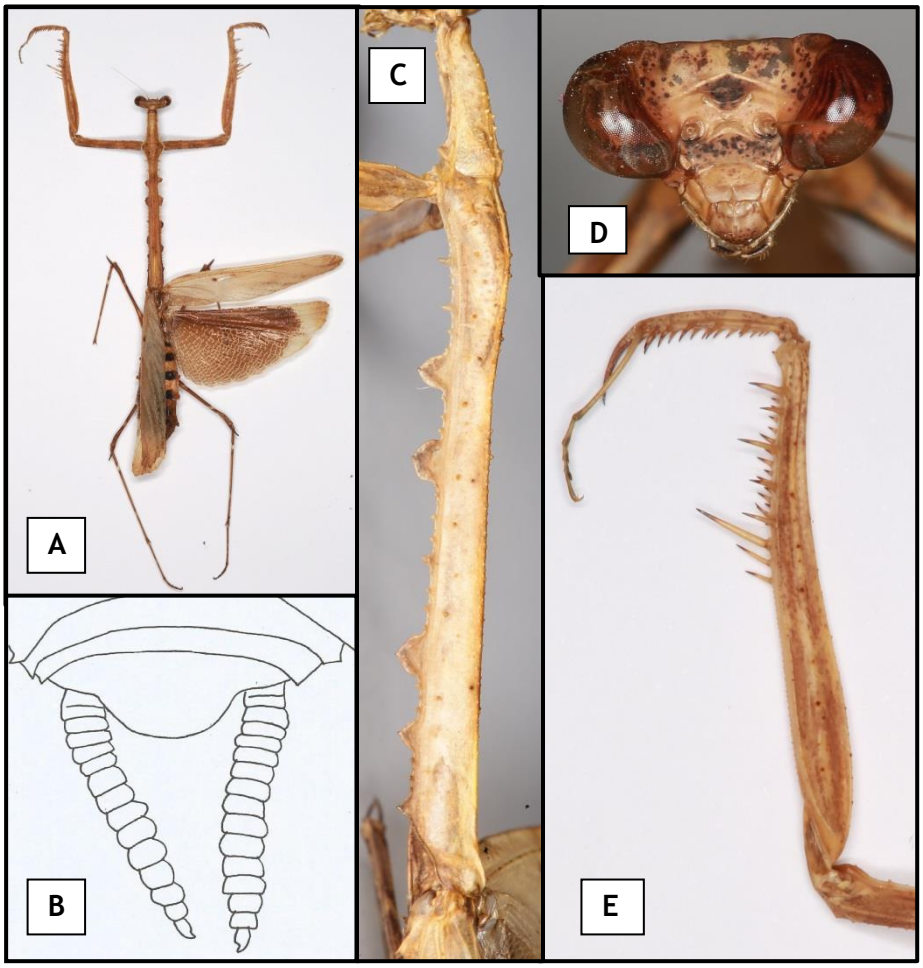

Figure 1. *Mythomantis serrata*, ♀. **A.** Habitus, dorsal view. **B.** Illustration of supra-anal plate with cerci, dorsal view. **C.** Pronotum, lateral view **D.** Head, anterior view. **E.** Left fore femur and tibia, posterior view.

Materials and Methods

A single female specimen of *M. serrata* (Figure 1A) has been collected from Mount Kuli Research Centre located within the Imbak Canyon Conservation Area (ICCA), Sandakan, Sabah (Figure 2). ICCA is a Class 1 protected lowland dipterocarp forest that consists of approximately 30,000 ha of conserved forest, including two nearby Virgin Jungle Reserves. Mount Kuli is the lower montane section of the conservation area.

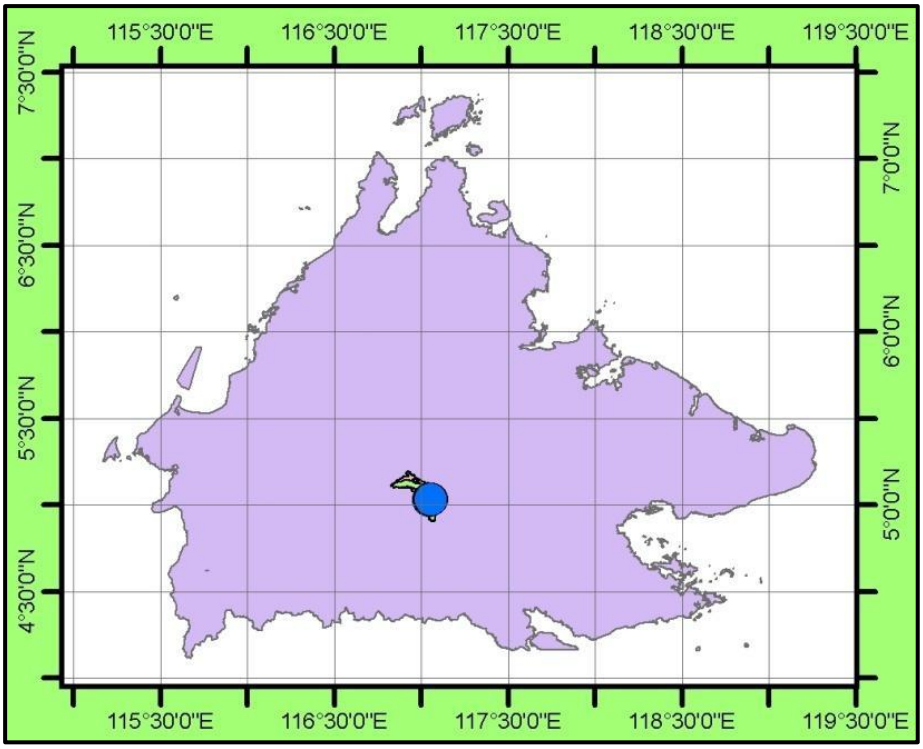

Figure 2. Map of Sabah showing the location of Imbak Canyon Conservation Area (ICCA).Source: Nurain (2012)

This specimen was collected during a short term study of praying mantis diversity ICCA (conducted by the corresponding author), where the sampling was carried out for three weeks (between January and February 2012). The specimen was caught by using a light-trap consisting of a white linen sheet and a bulb powered by a portable petrol generator which was set up at an understorey of the forest. The trapping was conducted between 6:30pm to 12:00am. The female *M. serrata* specimen is deposited in BORNEENSIS, a

collection centre at the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah.

Figure 3. Light-trap was set-up in the sampling site.Source: Nurain (2012)

Results

Abbreviation

BORNEENSIS Insect Collection, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah - BOR.

Material examined

♀, Sabah, Imbak Canyon Conservation Area, 28.i.2012. Light Trap, Nurain Musi (BOR).

Description (after Schwarz & Helmkampf 2014)

***Female*.** Length of body 70mm, head 5mm, pronotum 35mm, forewing 36mm, hindwing 31mm, width of head 6.5mm, pronotum 2mm.

Head as in males (Figure 1D); ocelli smaller than in males; antennae shorter than in males but similar in colour; palpi as in males. Pronotum features as in males except the lateral margins of metazone with 5 large, triangular, sawtooth-like lobes interspersed with smaller teeth (Figure 1C). Prosternum as in males.

Forecoxae 15mm long with 5 teeth along anterior margin and the colour as in males; forefemora measurement 20mm in length, with the same features as found in males (only 4 posteroventral spines on the left side and 5 posteroventral spines on the right side of this specimen); foretibiae 8 mm long, with 5 posteroventral and 13 anteroventral spines (Figure 1E).
Middle and hind legs have similar colour as males. Middle and hind femur measurement 15 mm and 17 mm long respectively, with the same features found in males. Middle tibia is about the same length as femur. Hind tibia measurement is 20 mm long, which is longer than the corresponding femur.

Forewing has the same pattern as found in males. Supra-anal plate is similar to males (Figure 1B). Ovipositor short, but its tips protruding from the genital chamber.

Discussion

The island of Borneo is well known as one of the world's biodiversity hotspots (Struebig et al., 2015). Borneo is reported as an area with the highest number of mantid species so far with 118 species and 56 genera (Schwarz & Konopik, 2014). New species of praying mantis are discovered from time to time in the course of studies conducted on various aspects of praying mantid biology, including their biodiversity and taxonomy.

Mythomantis serrata is rarely found and assumed to be confined to mature dipterocarp forest. This information is in agreement with the collection of the female specimen, which had been sampled from the dipterocarp forest in Imbak Canyon Conservation Area (ICCA), Sabah. Morphological examination revealed that sexual dimorphism is not very accentuated in the genus *Mythomantis*. Apart from differences in the external reproductive organs, body size dimorphism is very apparent in this species, with body, pronotum, legs and abdomen being generally longer in females than in males, except the wings which are comparatively shorter among females when compared to males.

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Research Article

Diversity and Geographical Ranges of Insects in Crocker Range Forest Reserve, Sabah, Malaysia

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Abstract

An insect diversity survey was carried out in May, 2011 in the Crocker Range Forest Reserve. This is a Class VI Forest Reserve (Virgin Jungle Reserve), gazetted in 1967 and then regazetted in 1984. It comprises an area of 3,279 ha. The nocturnal insect diversity was very high, with an average of 148 insect species from 207 individuals in a square metre of the light-trapping cloth. The mean Shannon, Simpson and Fisher Alpha indices are H' = 4.77 (>3.0), D = 322.49 and S = 417.04 respectively. Apart from having the highest diversity of nocturnal insects in all the 20 forest reserves surveyed within the Heart of Borneo area in Sabah, it has also recorded a number of endemic species. Some beetles are hyper-endemics, such as *Cyclommatus chewi*, *Odontolabis schenki* and *Odontolabis katsurai* (all Lucanidae beetles) which are found only in Mt. Alab of the Crocker Range F.R. At least 10 butterfly species are known to be confined to the Crocker Range, including the Kinabalu Tiger, *Parantica crowleyi*, which was sampled during the survey. A stick insect, *Orthonecrosia felix*, was recorded and it is only confined to the Crocker Range. New species are still being described. Such interesting scientific insect data from this survey and also from past records support the need to enhance biodiversity conservation in this Virgin Forest Reserve. In view of the high diversity and intriguing insect fauna, Crocker Range F.R. has potential in nature tourism for special interest tourists who contribute to Sabah's economy. A private initiative, Kipandi Park set up adjacent to the forest reserve, not only showcases the diversity of insects in Sabah but is also doing its part in studying the life cycle of rare and endemic insects which contributes towards insect conservation. The park also cooperates with government agencies in promoting conservation of biodiversity. In this paper, some of the issues pertaining to insect diversity and conservation are discussed.

Keywords: Insect, diversity, Crocker Range Forest Reserve, endemic, Heart of Borneo

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Introduction

Insects are among the most diverse and abundant organisms in tropical ecosystems and they are ecologically important in the tropics (Chung, 2013). It has been estimated that some 6,000 insect species can be found in one acre of rainforest (Williams, 2012). In terms of biomass, insects are also overwhelming (Holldobler & Wilson, 1994). Insects in the Bornean rainforests are interesting, rare and many are only confined to this island. Hence, biodiversity conservation is important.

Various efforts have been taken to document the diversity of flora and fauna in Sabah, including insects. Among the key contributions towards the success of Sabah's efforts in conservation is the implementation of the Heart of Borneo (HoB) Initiative. It is the epitome of Sabah's high profile and phenomenal achievement in the management and conservation of its old world tropical rainforests. Initiated by WWF, the three countries, namely Indonesia, Malaysia and Brunei have committed through the HoB Declaration in 2007 to a common conservation vision to ensure the effective management of forest resources and the creation of protected area networks, sustainable-managed forests and land-use zones across the 22 million hectares. Following this declaration, the Sabah State Government with support from the Federal Government through the Ministry of Natural Resources and Environment, is very committed in the implementation of the HoB Initiative, with the Sabah Forestry Department taking the lead. The Sabah State Government has designated about 39,000 km^2 of the state's landmass, comprising mainly the important inland and highland forest ecosystems, as part of HoB (Nilus et al., 2014).

The insect diversity survey in the Crocker Range Forest Reserve was one of the programmes on biodiversity documentation under HoB. Apart from documentation, the study was also carried out to investigate issues affecting insect diversity, as well as to provide recommendations that would contribute towards biodiversity conservation of the study area.

Study Area

Crocker Range Forest Reserve is a Virgin Jungle Reserve (VJR) Class VI, located at N 05^o 53' E 116^o 16', at the western part of Sabah. It is conveniently situated along the right hand side of the Tambunan-Kota Kinabalu highway. This dragon-like shape reserve extends from 16 km southeast of Kota Kinabalu city to 16 km north of Tambunan town.

The forest was first gazetted in 1967 and then regazetted in 1984 (SFD 2015). It covers an area of 3,279 ha (Figure 1) which forms a small part of the Crocker Range. The bulk of the Crocker Range encompassing 139,919 ha has been gazetted as the Crocker Range Park (Taman Banjaran Crocker), managed by Sabah Parks. The Crocker Range serves as the water catchment area for the west coast and interior of Sabah. In the district forest management, Crocker Range F.R. is located mostly within the Kota Kinabalu district and only a small portion in the south is under Tambunan district.

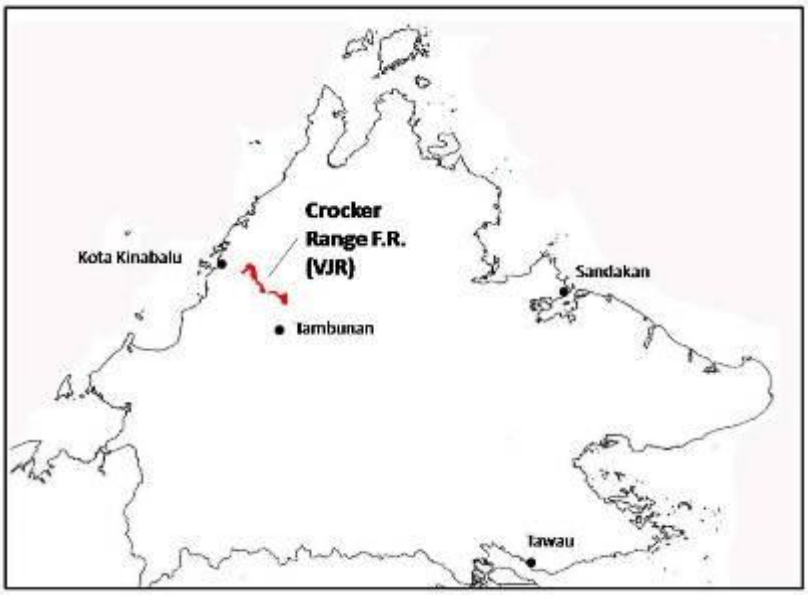

Figure 1. Location of Crocker Range Forest Reserve in Sabah.

Two major forest formations occur in the reserve, i.e. upland mixed dipterocarp forest (MDF) and lower montane forest. The differentiation of these formations is approximately at 1,000 m whereby beyond this elevation, the forest is classified as montane. Between 500 to 1,000 m, it is classified as upland MDF. However, most of the lowland and upland and some of the montane areas are degraded and overgrown by secondary plant species. The heavy clearing through nomadic agricultural practices by villagers living at the surrounding area of the forest reserve have had a major impact to the surrounding landscape (CAIMS, 2005).

This study was conducted from 11th to 21st of May, 2011. The expedition base camp was at the Rafflesia Forest Reserve (N 05° 46'25.3" E 116° 21'00.2" at 1,274 m.a.s.l.), adjacent to the Tambunan District Forestry Office and the Crocker Range F.R., located beside the Tambunan-Kota Kinabalu highway.

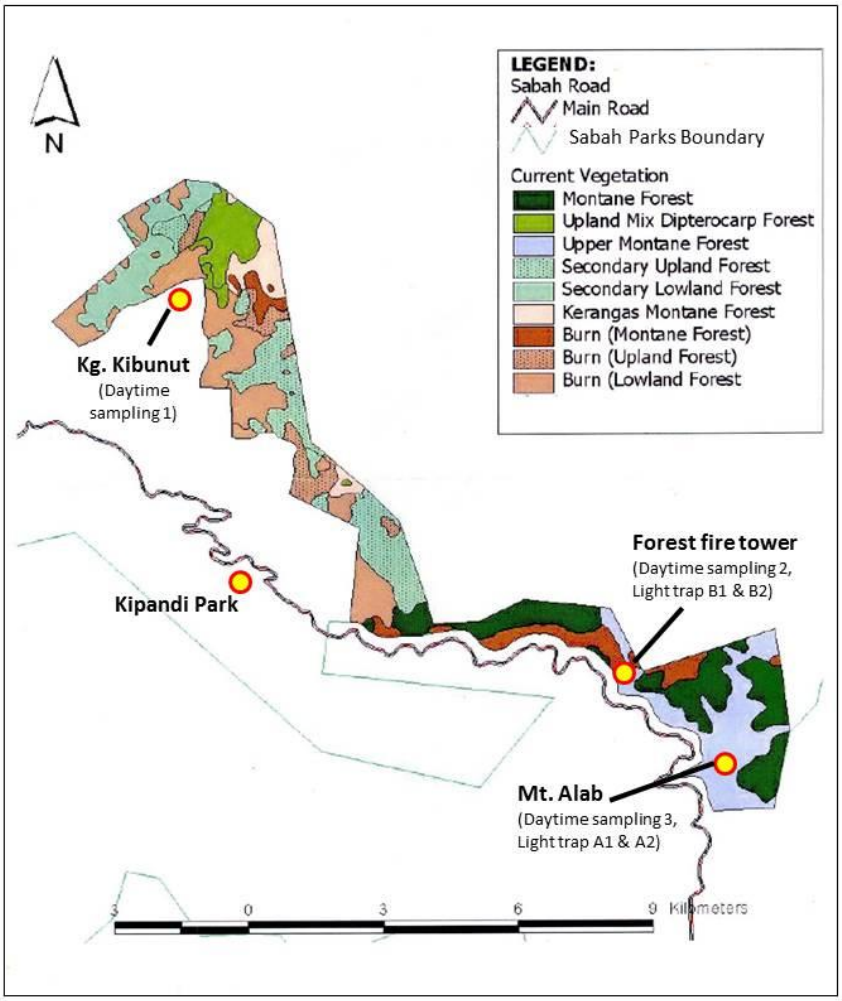

Figure 2. The forest types of Crocker Range F.R. and sampling sites during the survey.

Materials and Methods

Light trap was used to sample nocturnal insects while sweep net 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. It was set up in an open area facing the forest reserve, from 7:00 to 9:00 p.m. for four nights as indicated in Table 1. Enumeration for insect species and abundance ($\geqslant$ 5 mm in length) within the 1 X 1 m square was carried out from 8:30 to 9:00 pm, to evaluate diversity of the sampling area. This is a standardized enumeration for half an hour (towards the end of the two-hour light trapping) that was also applied to other samplings in the past. It is a rapid biodiversity assessment method because by the end of the sampling time, species and individual numbers could be obtained, and the data could be used to calculate diversity indices. This method is simple, fast and can be carried out by a 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 1 and Figure 2. A GPS (Model: Garmin GPSMAP 60CSx) was used to determine the coordinates of each sampling site. Temperature and humidity were recorded using a digital gadget from Oregon Scientific (model no. ETHG-912).

Diversity indices

The diversity indices, namely Shannon Wiener, Simpson and Fisher Alpha were calculated through a diversity analysis software by Henderson & Seaby (1998), based on Magurran (2004) and Southwood and Henderson (2000).

Shannon Wiener Index (H')

This index is calculated in the following way:

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

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:

$$D_s = \Sigma\ p_i^2$$

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

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

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:

$$ax,\ ax^2/2,\ ax^3/3,\ \ldots\ ax^n/n$$

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.

Table 1. Light-trapping sites in Crocker Range F.R.

Sampling site	Coordinates	Elevation (m)	Temp. (°C)	Humidity (%)	Sampling date	Remarks
A1	N 05° 49'48.2" E 116° 0'30.1"	1,957	15	85	16 May	Light trap was set up next to the TM telecommunication tower on Mt. Alab.
A2	N 05° 49'45.7" E 116° 0'29.5"	1,955	18	89	19 May	Light trap was set up next to the Digi transmission tower on Mt. Alab.
B1	N 05° 50'55.4" E 116° 9'21.9"	1,600	18	94	17 May	Light trap was set up next to the forest fire tower.
B2	N 05° 50'55.6" E 116° 9'21.7"	1,600	19	91	18 May	Same as above but facing different direction.

Sweep net and manual collection

Sweep nets were used to collect flying insects, such as butterflies and dragonflies 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 along the road, open and riverine areas within the forest, and also along trails established by the Botany and Ecology teams of the Forest Research Centre. Details of the daytime sampling sites are listed in Table 2 and Figure 2.

Table 2. Daytime sampling sites in Crocker Range F.R.

Sampling site	Starting point coordinates	Elevation (m)
1 (Kg. Kibunut)	N 05° 55'55.3" E 116° 14'20.0"	692
2 (Forest fire tower area)	N 05° 51'10.8" E 116° 19'15.1"	1,588
3 (Mt. Alab area)	N 05° 49'48.2" E 116° 20'30.1"	1,957

Insect specimens and identification

In this survey, focus was given to certain insect groups, i.e. butterflies, moths, beetles, ants and dragonflies. Only interesting and potential indicator insect species were sampled to minimize the workload at the laboratory in preparing the specimens for identification. Photographs were taken with a DSLR Nikon D300 and a compact Nikon Coolpix to facilitate identification. Common insects were not sampled but photographs were taken for record purposes.

Selected specimens were dry-mounted and sorted to family and some to the generic and species level. The specimens sampled from this study 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 Corbet & Pendlebury (1992) for butterflies; Holloway (1983, 1985, 1986, 1988, 1989, 1993, 1996a, 1997, 1998a & b, 1999, 2001, 2003, 2005, 2008 & 2009) and Robinson et al. (1994) for moths; Mizunuma & Nagai (1994), Makihara (1999) and Tung (1983) for beetles; Orr (2003) and Tang et al. (2010) for dragonflies.

Results and Discussion

Overall insect diversity

The nocturnal insect diversity was exceptionally high, compared to the diversity recorded from Gn. Lumaku F.R. in Tenom and Bukit Hampuan F.R. in Ranau and Milian Labau F.R. in Keningau (Table 3). An average of 148 insect species from 207 individuals were recorded in a square metre of the light-trapping cloth. The mean Shannon, Simpson and Fisher Alpha indices are 4.77, 322.49 and 417.04 respectively. All light-trapping sites recorded more than 130 insect species, with Site A2 recording the highest number with 170 species in one square metre. In terms of individuals, Site A2 also recorded the highest, with 310 individuals. In diversity values, however, Site A2 was the lowest among all the Crocker Range sampling sites. This is because of the high abundance of a few dominant species (see Figure 3). It is also significantly reflected in the Simpson's diversity index which is sensitive towards dominant species.

Table 3. Insect diversity within a one-square-metre, as sampled through light-trapping in Crocker Range F.R. (Sites A1, A2, B1 & B2) compared to selected sites of Milian Labau, Bukit Hampuan and Gn. Lumaku F.Rs.

No.	Sampling site	Species	Ind.	Shannon (H')	Simpson (D)	Fisher Alpha (S)
1	A1	131	146	4.81	392.04	614.91
2	A2	170	310	4.59	61.25	154.35
3	B1	159	178	5.03	716.05	717.3
4	B2	131	192	4.65	120.63	181.59
	Mean	148±20	207±72	4.77±0.2	322.49±299.3	417.04±290.8
5	Milian Labau (Site 1)	79	122	4.05	45.56	97.03
6	Bukit Hampuan (Site 2)	119	142	4.61	111.23	346.35
7	Gn. Lumaku (southern part - Site 5)	124	163	4.56	90.43	236.60

Most of the montane and upper montane forests in the light-trapping sites are still intact although certain parts were burnt or disturbed in the past before 2003 (Figure 2). Hence, the condition of the forest would have improved when the survey was carried out in 2011. Light trapping was not conducted in the more disturbed area, i.e. in Kg. Kibunut area, due to logistics difficulties at night and distance from the base camp.

The high insect diversity shows that the Crocker Range F.R. provides a conducive environment with an elevation from 1,500 to 2,000 m a.s.l. (based. on light-trapping sites) and a cool atmosphere of 15-19 ^{o}C and relatively high humidity of 85-91 %, suitable for nocturnal insects. The distribution of nocturnal insect species from the light-trapping sites is reflected in the species-rank abundance curves in Figure 3.

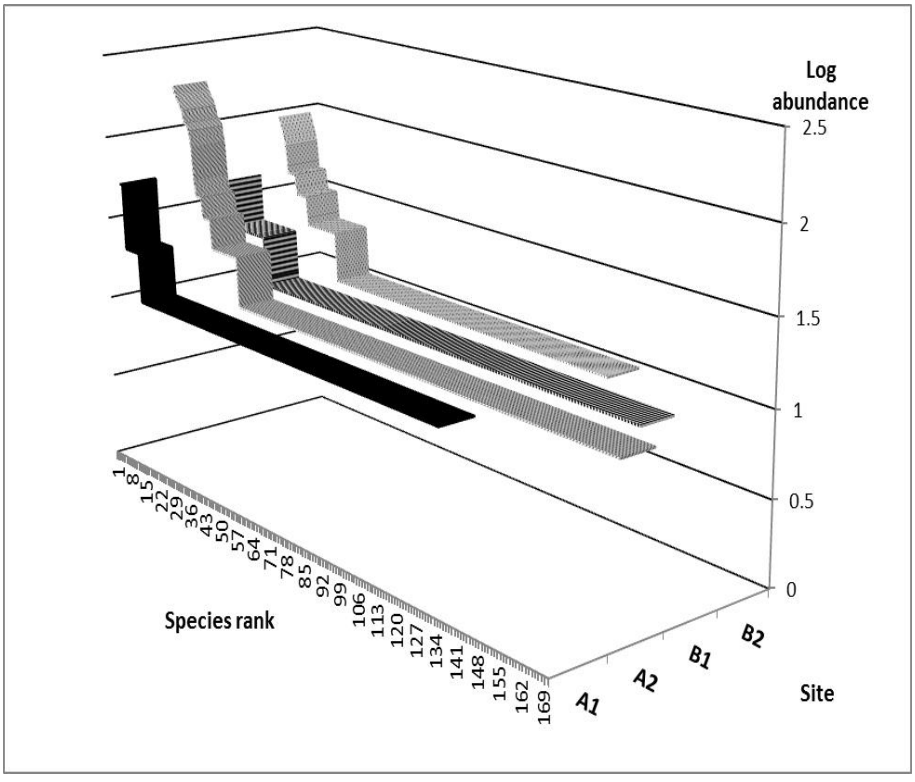

Figure 3. Species-rank abundance curves of the light-trapping sites in Crocker Range F.R.

Butterfly (Lepidoptera) diversity

Despite the high diversity of nocturnal insects, not many butterflies were sampled during the survey. Only 20 species were recorded, including the Bornean endemic Kinabalu Tiger, *Parantica crowleyi* which was frequently seen foraging at Mt. Alab area. The low butterfly number was partly due to erratic weather during the sampling period. Too much rain and the lower-than-usual temperature had adversely affected about 50 % of the butterfly population in the Kipandi Park (Steven Bosuang, pers. comm.). Some eggs were not able to hatch and some pupae could not emerge as adults due to the drastic microclimatic changes. Besides *P. crowleyi*, there are nine other species of Bornean endemic butterflies that are confined to the Crocker Range, as listed in Appendix 1.

Moth (Lepidoptera) diversity

Various moth species were attracted to the light trap set up at two locations facing the Crocker Range F.R. at 1,955 m (Sites A1 & A2) and 1,600 m a.s.l. (Sites B1 & B2) respectively. From observation, the species richness was very high, surpassing those at other forest sites sampled under the Heart of Borneo (HoB) programme in Sabah. At least 24 Bornean endemic moth species were recorded from this survey, as listed in Appendix 1.

Beetle (Coleoptera) diversity

A total of 23 species of macro-beetles were recorded. The most spectacular species was the Stag Beetle, *Cyclommatus montanellus* (Lucanidae) which is endemic to Borneo and is only confined to the Crocker Range. Measuring up to 70 mm, it is a handsome beetle with conspicuously long antler-like mandibles. There are also various variations of the mandibles. Another species which is somewhat similar to *C. montanellus* is *Cyclommatus chewi*. This hyper-endemic and rare species is only found in Mt. Alab of the Crocker Range. Other hyper-endemic species of Mt. Alab are *Odontolabis schenki* and *Odontolabis katsurai*. These species, however, were not sampled during the survey but their presence were recorded previously (Steven Bosuang, pers. comm.). A list of the Bornean endemic beetles (25 species) that are found in the Crocker Range is provided in Appendix 1.

Other interesting beetles sampled from the Crocker Range F.R. were the Giant Weevil, *Protocerius* sp. (Curculionidae) and the Trilobite Larva, *Platerodrilus* sp. (Lycidae). The elytra and pronotum of the Giant Weevil are almost entirely red. The male was larger, with a body length up to 8.5 cm while the female was about 6 cm. The forelegs of the male were longer than the mid and hind

legs. When disturbed, the weevil would raise and widely open its forelegs as a defensive posture. It looks similar to *Macrochirus praetor* Gyllenhal, found in Peninsular Malaysia (Tung, 1983). They were not attracted to the light trap but a few adult weevils were entangled on the mist nets for trapping birds and bats set up by the villagers at Kg. Kibunut, about 690 m a.s.l. The Trilobite Larva is so called because of the wingless larva-like female which resembles the extinct trilobite. It glows in the dark to attract the flying male which is smaller in size at about 8-9 mm. This sluggish insect can be seen moving slowly over the moist forest floor, feeding on rotten wood.

Other insects

The Green-banded Cicada, *Tacua speciosa*, was among the interesting montane forest insects sampled from the Crocker Range F.R. It is a magnificent cicada, measuring about 5-6 cm long. The band is sometimes yellow in colour. This species was not attracted to the light trap but was sampled in the daytime, perching on tree branches or shrubs.

Various ant species were sampled and the most common group was from the genus *Myrmicaria*. Bakhtiar et al. (2009) noted that *Myrmicaria* ants are found at high altitudes above 1,500 m where the temperature is generally low throughout the year and fluctuates during the day. Other ant species sampled were from the genera *Polyrhachis*, *Crematogaster* and *Dolichoderus*.

A pair of Stalk-eyed Flies was spotted at the forested area of Site 2 (forest fire tower) at about 1,570 m a.s.l. They belong to a very small family of peculiar flies (Diopsidae), found mainly in East Africa and South-east Asia; only seven species were recorded from Borneo. The eyes are borne on long, lateral stalks. The larvae are phytophagous or saprophagous. *Diopsis* is the most common genus found in South-east Asia (Hill & Abang, 2005).

Only a few dragonfly species were recorded from this survey. Montane forest habitats for dragonflies are confined to small streams, and the number of species restricted to the zone at 1,000-2,000 m are few (Orr, 2003). Those recorded in this study were from Kg. Kibunut area at about 700 m a.s.l. which included *Orthetrum sabina*, *O. glaucum*, *O. testaceum*, *O. pruinosum* and *Cratilla metallica*.

A colourful stick insect was sampled at Site 2 during the day, about 1,570 m a.s.l. It was identified as *Orthonecrosia felix*, and it is endemic to the Crocker Range (Francis Seow Choen, pers. comm.).

Insect geographical ranges

The Crocker Range F.R. is a haven for insects. Besides having the highest diversity of nocturnal insects in all the 20 forest reserves surveyed within HoB, it has also recorded the highest number of endemic species (Chung et al., 2015; Chung et al., 2013). More than 27 insect species were documented during the survey compared to 19 endemic species from Bukit Hampuan F.R. From previous records and references, there are a number of insect species which are confined to the Crocker Range (including Crocker Range Park and Kinabalu Park under the management of Sabah Parks). These are hyper-endemics since they do not occur in any other parts of Borneo. A few are restricted to certain areas in the Crocker Range, such as *Cyclommatus chewi*, *Odontolabis katsurai* and *Odontolabis schenki* found only at Mt. Alab. At least seven endemic species of lantern bugs were recorded in the past in Crocker Range. The endemic insect species from previous records and also those from this survey are listed in Appendix 1.

Apart from endemic species, many new species have been described from the Crocker Range quite recently. For example, 14 new species of flower beetles (Scarabaeidae: Cetoniinae) have been described by Legrand & Chew (2010), and 7 new species of long-horned beetles (Cerambycidae: Callichromatini) have been described by Vives et al. (2009). All the new species are endemic to Borneo, and many are found in the Crocker Range. A long-horned beetle, *Gressittichroma sammannani* was named after Sabah Forestry Department Director, Datuk Sam Mannan while *Gressittichroma tengkuadlini* was named after former Sabah Tourism Board Chairman, Datuk Tengku Zainal Adlin. *Heudepoliana masidimanjuni* is another long-horned beetle named after the Sabah Minister of Tourism, Culture and Environment, Datuk Masidi Manjun.

Current issues on insect diversity and conservation in Crocker Range F.R.

Crocker Range is home to many rare and endemic species, and various new species have been and are still being described for this area. Although the erratic weather (too much rain and drastic change in temperature) had adversely affected some of the insect populations in the first quarter of 2011, the conducive cooling temperature and high elevation (650-2,000 m a.s.l.) are generally suitable for various insect species. This is reflected in the highest species richness and insect diversity values assessed from the nocturnal insects in this survey, surpassing all those recorded from previous HoB forest surveys. In view of the high insect diversity with many rare, endemic and interesting species, it is subjected to **illegal encroachment and collection of specimens** since the Crocker Range F.R. is conveniently located along the Tambunan-Kota

Kinabalu highway. The encroachment issue is not on insects alone but also on plants and other wildlife, such as mammals (bats) and birds. At some of the forest ridges, the vegetation was cleared to set up mist nets and light traps to collect birds, bats and insects. Under the Sabah Forest Enactment 1968, it is illegal to enter a forest reserve and to take its resources without permission from the Director of the Sabah Forestry Department. Collection for scientific purposes is allowed, with approval from the Forestry Director. The Forestry Department is monitoring the situation and warnings have been issued to suspects. Some traps, however, were set up outside the forest reserve, within villages and state land.

During the survey, it was observed that 'Forest Reserve' signages had been erected at certain locations to denote the **boundary of the forest**. It is important to have more of such signages, especially at areas adjacent to the villages which are prone to encroachment. **Public awareness and environmental education** are crucial in educating villagers and the younger generation on the importance of conservation of biodiversity and forest services to mankind. The Crocker Range is the water catchment area for the west coast and interior of Sabah. Any disturbances on the streams and riverine areas would affect the quality of the water, and this will also affect the butterfly population. Various public awareness and environmental education activities have been conducted by the Sabah Forestry Department, Sabah Parks as well as NGOs, and should be continued and further enhanced.

The high diversity of insects in Crocker Range attracts special interest tourists from all over the world to visit Sabah, and this **nature tourism** contributes to the economy of the state. The Kipandi Park located beside the Crocker Range F.R., some 40 minutes' drive from Kota Kinabalu, was set up by a Sabahan, Dr Steven Bosuang. The park showcases the diversity of insects in Sabah and also studieses the life cycle of various rare and endemic insect species. Understanding the life cycle and food plants of these insects would enable **conservation of insects** to be more effective. For example, *Aristolochia* spp. which are food plants for many birdwing butterflies (including the Rajah Brooke's Birdwing, *Trogonoptera brookiana*) are not only propagated in the park but are also planted at various areas outside the park to increase the population of the birdwing butterflies. About 30% of butterflies from the park are released back to their natural habitat. These are some of the conservation efforts carried out by Kipandi Park. The Sabah Forestry Department is working with Kipandi Park on beetle diversity and conservation in Sabah, as well as plant diversity. A memorandum of understanding was signed in 2014 to

enhance such collaboration (SFD, 2014). This is a **smart partnership** between a private initiative and the State Government in the conservation of biodiversity.

Various new species of insects were discovered from Crocker Range, in collaboration with international researchers. **Discovery of new species** (which is part of biodiversity documentation) is utmost important and is a piece of hallmark information to support and enhance the need for conservation of an area, e.g. in preparation of the Forest Management Plan (FMP). This confirms the wealth of biodiversity in Sabah's rainforests and would significantly elevate their conservation status, and one such example is the Crocker Range.

Forest fire is a threat to any forest reserves and the Crocker Range F.R. is no exception, especially in areas adjacent to villages. Previously, there were slash-and-burn problems caused by villagers along the highway for agricultural purposes (see Figure 2, CAIMS 2005). For monitoring purposes, a forest fire tower was built some 10 years ago at about 1,600 m a.s.l. overlooking the Crocker Range F.R. In the recent years, the incidences of forest fires in the Crocker Range F.R. are less compared to forest reserves in the lowlands. The high humidity and rainfall in the reserve reduce the risk of forest fires.

Conclusion

From the survey, the nocturnal insect diversity in Crocker Range F.R. was very high, surpassing all those recorded from previous HoB forest surveys. In addition, there are a number of rare and endemic insect species from this forest and the surrounding areas. Various new insect species have been described. As such, these are important scientific information to support the need and effort in biodiversity conservation of the Crocker Range F.R. The diurnal insect species richness during the survey, e.g. butterflies, was below expectation. This was due to the unconducive weather during the sampling period which had adversely affected many of the insect populations.

In view of the high diversity and interesting insect fauna, Crocker Range F.R. has potential in nature tourism for special interest tourists who contribute to the state's economy. A private initiative, Kipandi Park set up adjacent to the forest reserve not only showcases the diversity of insects in Sabah but is also doing its part in studying the life cycle of rare and endemic insects which provides salient information for insect conservation. The park also works hand-in-hand with the Sabah Forestry Department in promoting conservation of biodiversity.

Due to the interesting fauna and flora of Crocker Range, illegal encroachment and collection of specimens are among threats within this forest reserve. The Forestry Department is aware of this matter and is monitoring the situation. Based on feedback from some people staying adjacent to the Crocker Range F.R., the boundary of some parts of the reserve is still not clear. Hence, it is important to have more signboards to denote the forest reserve boundary. Public awareness and environmental education plays an important role among so that local communities understand the significance of biodiversity conservation of forest resources. Forest fires were a problem in the past. In recent years, however, the incidences of forest fires are under control.

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Appendix 1. Endemic insect species from Crocker Range (Crocker Range National Park, Crocker Range F.R. & Kinabalu Park)*.

No.	Species	Author	Family	Subfamily / Common Name	Remarks
	Butterflies (source: Steven Bosuang)				
1	*Elymnias pellucida*	Fruhstorfer	Nymphalidae	Kinabalu Palm Fly	Endemic of Crocker Range
2	*Parantica crowleyi*	Jenner-Weir	Nymphalidae	Kinabalu Tiger	Endemic of Crocker Range
3	*Graphium procles*	Grose-Smith	Papilionidae	Kinabalu Bluebottle	Endemic of Crocker Range
4	*Graphium stratiotes*	Grose-Smith	Papilionidae	Kinabalu Sword Tail	Endemic of Crocker Range
5	*Papilio acheron*	Grose-Smith	Papilionidae	Bornean Memnon	Endemic of Crocker Range
6	*Troides andromache andromache*	Staudinger	Papilionidae	Bornean Birdwing	Endemic of Crocker Range
7	*Delias cinerascens*	Mitis	Pieridae	Kinabalu Jezebel	Endemic of Crocker Range
8	*Delias eumolpe*	Grose-Smith	Pieridae	Bornean Jezebel	Endemic of Crocker Range
9	*Ixias undatus*	Butler	Pieridae	Yellow Orange Tip	Endemic of Crocker Range
10	*Prioneris cornelia*	Vollenhoeven	Pieridae	Bornean Sawtooth	Endemic of Crocker Range
	Beetles (source: Steven Bosuang)				
1	*Chewchroma nayani*	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Crocker Range
2	*Gressittichroma sammannani*	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Sabah
3	*Gressittichroma tengkuadlini*	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Crocker Range
4	*Huedepoliana masidimanjuni*	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Crocker Range
5	*Stenochroma cheyi*	Vives, Bentanachs & Chew	Cerambycidae		Endemic of Sabah
6	*Cyclommatus chewi*	Mizunuma	Lucanidae		Endemic of Mt. Alab
7	*Cyclommatus montanellus*	Mollenkamp	Lucanidae		Endemic of Crocker Range
8	*Hexarthrius parryi elongatus*	Jordan	Lucanidae		Endemic of Borneo
9	*Odontolabis cypri*	Didier et Seguy	Lucanidae		Endemic of Crocker Range
10	*Odontolabis hitam*	Nagai	Lucanidae		Endemic of Crocker Range
11	*Odontolabis katsurai*	H. Ikeda	Lucanidae		Endemic of Mt. Alab
12	*Odontolabis leuthneri*	Boileau	Lucanidae		Endemic of Crocker Range
13	*Odontolabis schenki*	Schenk	Lucanidae		Endemic of Mt. Alab
14	*Odontolabis vollenhoveni*	Parry	Lucanidae		Endemic of Crocker Range
15	*Prosopocoilus tigrinus*	Didier	Lucanidae		Endemic of Crocker Range
16	*Pseudochalcothea spathulifera*	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
17	*Pseudochalcothea viridipes*	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range

(Continued on next page)

Appendix 1. (continued)

No.	Species	Author	Family	Subfamily / Common Name	Remarks
18	*Taeniodera ditissima*	Bates	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
19	*Taeniodera kinabaluana*	(Arrow)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
20	*Theodosia magnifica*	Rothchild & Jordan	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
21	*Theodosia nobuyukii*	Nagai	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
22	*Theodosia telifer*	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
23	*Theodosia viridiaurata*	(Bates)	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
24	*Xenoloba nagaii*	K. Sakai	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
25	*Xenoloba speciosa*	Bates	Scarabaeidae	Cetoniinae	Endemic of Crocker Range
	Lantern Bug (source: Steven Bosuang)				
1	*Pyrops whiteheadi*	Distant	Fulgoridae		Endemic of Sabah
2	*Pyrops heringi*	Schmidt	Fulgoridae		Endemic of Crocker Range
3	*Pyrops sultana*	Adam & White	Fulgoridae		Endemic of Borneo
4	*Polydictya chewi*	Nagai & Porion	Fulgoridae		Endemic of Crocker Range
5	*Polydictya ornata*	Chew, Porion & Audibert	Fulgoridae		Endemic of Crocker Range
6	*Polydictya tanjiehoei*	Bosuang, Audibert & Porion	Fulgoridae		Endemic of Crocker Range
7	*Saiva karimbujangi*	Chew & Porion	Fulgoridae		Endemic of Sabah
	Moths (all recorded during the survey from Crocker Range F.R.)				
1	*Barsine euprepia*	Hampson	Arctiidae	Arctiinae	Endemic of Borneo
2	*Lemyra bornemontana*	Holloway	Arctiidae	Arctiinae	Endemic of Borneo
3	*Nyctemera kinabaluensis*	Reich	Arctiidae	Arctiinae	Endemic of Crocker Range
4	*Spilosoma rubriventris*	Talbot	Arctiidae	Arctiinae	Endemic of Borneo
5	*Cyana cruentata*	Talbot	Arctiidae	Lithosiinae	Endemic of Borneo
6	*Garudinia simulana*	Walker	Arctiidae	Lithosiinae	Endemic of Borneo
7	*Lyclene mesilaulinea*	Holloway	Arctiidae	Lithosiinae	Endemic of Sabah
8	*Lyclene obscurilinea*	Holloway	Arctiidae	Lithosiinae	Endemic of Crocker Range
9	*Mustilia dierli*	Holloway	Bombycidae		Endemic of Borneo
10	*Ozola submontana*	Holloway	Geometridae	Desmobathrinae	Endemic of Crocker Range
11	*Abraxas intervacuata*	Warren	Geometridae	Ennominae	Endemic of Borneo
12	*Amblychia cavimargo*	Prout	Geometridae	Ennominae	Endemic of Borneo

(Continued on next page)

Appendix 1. (continued)

No.	Species	Author	Family	Subfamily / Common Name	Remarks
	Moths (all recorded during the survey from Crocker Range F.R.)				
13	*Dalima mjoebergi*	Prout	Geometridae	Ennominae	Endemic of Borneo
14	*Ourapteryx incaudata*	Warren	Geometridae	Ennominae	Endemic of Borneo
15	*Oenospila altistrix*	Holloway	Geometridae	Geometrinae	Endemic of Borneo
16	*Spaniocentra apatelloides*	Holloway	Geometridae	Geometrinae	Endemic of Borneo
17	*Problepsis borneamagna*	Holloway	Geometridae	Sterrhinae	Endemic of Borneo
18	*Rhypotoses ?maculutea*	Holloway	Lymantriidae		Endemic of Borneo
19	*Sundaroa ?transflava*	Holloway	Lymantriidae		Endemic of Borneo
20	*Asota kinabaluensis*	Rothschild	Noctuidae	Aganainae	Endemic of Borneo
21	*Hypersypnoides fenella*	Swinhoe	Noctuidae	Catocalinae	Endemic of Borneo
22	*Diehlea ducalis*	Bryk	Nolidae	Chloephorinae	Endemic of Borneo
23	*Tyana marina*	Warren	Nolidae	Chloephorinae	Endemic of Borneo
24	*Antheraea alleni*	Holloway	Saturnidae		Endemic of Borneo
	Stick Insect (recorded during the survey from Crocker Range F.R.)				
1	*Orthonecrosia felix*	Redtenbacher	Heteronemiidae		Endemic of Crocker Range

*Geographically, Crocker Range includes Crocker Range National Park, Crocker Range Forest Reserve and Kinabalu Park (Tangah & Wong, 1995).

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Research Article

Nest density of the Black-and-Red Broadbill (*Cymbirhynchus macrorhyncos*) along the Kinabatangan River, in Relation to Riverine Habitat Reduction

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Keywords: Black-and-Red Broadbill, *Cymbirhynchus macrorhyncos*, Kinabatangan River, riverine habitat reduction

Abstract

In Borneo, the forest type that supports the largest number of species, the tropical lowland rainforest, is decreasing rapidly. To estimate what is the general effect of this habitat degradation and loss on birds, this study looks at the easily visible Black-and-Red Broadbill nests that were surveyed along the Kinabatangan river in eastern Sabah, Malaysian Borneo, and answers the following questions: (i) what is the current density of the population of the Black-and-Red Broadbill between Batu Putih and Bilit, along the Kinabatangan river, (ii) is the abundance of nests correlated with the surrounding habitat type (forest or disturbed area), and (iii) do Black-and-Red Broadbills need and/or use the riparian zone at the riverbank for nesting sites. During this study, a 55.6 kilometre river transect was surveyed for 3 days, and nests that were found were recorded. This study found that Black-and-Red Broadbills nests were significantly more often located in areas with a higher proportion of forest habitat type (compared to disturbed habitat type). Furthermore, this study shows that Black-and-Red Broadbills need branches and sticks at the river's edge to build their nest on, so they are profiting from the riparian zones along the river. Therefore we recommend enhancement of nesting opportunity by artificially providing above-water nesting sites along the river edge.

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Introduction

Every year, the amount of rainforest in the world is reduced by approximately 21 million hectares, as the combined consequence of logging for timber and clearing land for agriculture (Laurance, 1999). For organisms more or less restricted to the rainforest habitat, this forest cover reduction means a great loss and fragmentation of distribution area (Estes et al., 2012; Pahl et al., 1988; Wich et al., 2008). One of the main forest types that has been cleared is the Southeast-Asian lowland forest. In Sabah, the northern state in the Malaysian part of Borneo, approximately 40 % of the forest was lost during the 20th century (Estes et al., 2012). In Sabah, in the tropical floodplain of the lower Kinabatangan, the oil palm plantation land coverage has dramatically increased from 9,735 ha in 1975 to 156,848 ha in 1994 (Azmi, 1998). Today, 250,617 ha (of a total area of 520,269 ha) is cultivated with oil palm (Abram et al., 2014).

In Borneo, some species are strongly influenced by such habitat reduction, and it has had disastrous consequences for certain large-bodied vertebrates, such as the Bornean elephant (*Elephas maximus borneensis*), of which there are approximately 300 individuals left in the Lower Kinabatangan Managed Elephant Range (Estes et al., 2012). Other affected species are the Bornean orangutan (*Pongo pygmaeus*), which cannot live in the monoculture landscape of oil palm plantations (Ancrenaz et al., 2015; Wich et al., 2015), and certain bird species like hornbills, terrestrial insectivores, and bark-gleaning insectivores, which depend on unlogged forests for foraging (Cleary et al., 2007). Other species, on the other hand (e.g., tailorbirds (*Orthotomus*), munias (*Lonchura*) and certain sunbirds (Nectariniidae), are adapted to naturally occurring forest edges and they may thrive in the more disturbed areas that are created by clearing the lowland forests (Myers, 2016; Cleary et al., 2007).

It may be very hard to properly assess the impact of disturbance on bird populations that live in the lowland forest. This is due to the difficulty of accurately estimating numbers of breeding pairs in densely vegetated habitats with a high canopy, especially since this may need to be done by ear, and it may be hard to distinguish one species among many competing calls and songs. Selecting a bird species that has unique nesting locations and that can be nearly exhaustively sampled, such as the Black-and-Red Broadbill (*Cymbirhynchus macrorhyncos*), can circumvent these difficulties. This bird almost exclusively builds its nest on a stick or branch along the waterside and the bird is brightly coloured and easily visible when at or near the nest

(Smythies, 1999; Phillipps & Phillipps, 2009). Building a nest on a stick in the water could be a strategy to avoid egg predation by vertebrates, which is one of the major limitations for forest bird populations (Cooper & Francis, 1998).

During this study, we therefore investigated the nest density of the Black-and-Red Broadbill along the Kinabatangan in Sabah. With this information we could determine the effect of habitat fragmentation for this species. When we know more about the needs of the bird, conservation measures can be taken to prevent a decrease in this and other bird species that have similar ecological requirements.

Specifically, in this study we try to find out (i) what is the current density of the population of the Black-and-Red Broadbill along the 55.6-km-long river transect between Batu Putih and Bilit, (ii) whether the abundance of nests is correlated with the surrounding habitat type (forest or disturbed area), and (iii) whether Black-and-Red Broadbills need and/or use the riparian zone at the riverbank as nesting sites.

Materials and Methods

Study species

Black-and-Red Broadbills belong to the family Eurylaimidae, which is a small family distributed in tropical Africa and Asia, reaching South-East Asia in Central Myanmar, Thailand, Southern Indochina, Sumatra, and Borneo (Smythies, 1999). There are 15 species in the world and they are very well represented in Borneo, which is a hot spot of broadbill diversity with eight species including two endemics, namely Whitehead's Broadbill and Hose's Broadbill (Phillipps & Phillipps, 2009; Myers, 2016). The adult Black-and-Red Broadbills are 20-24 cm in length and have a distinctive plumage consisting of black, white and maroon-red, and a turquoise/yellow bill (Smythies, 1999; Robson, 2008; Phillipps & Phillipps, 2009). Black-and-Red Broadbills are found throughout the lowlands of Borneo up to 750 m elevation (Myers, 2016). They can be found in primary and secondary lowland dipterocarp forests, near water in riverine and peat swamp forest, mangroves, and overgrown plantations (Myers, 2016). Generally, Black-and-Red Broadbills are not very vocal (Phillipps & Phillipps, 2009). They are well known for river-haunting habits (Smythies, 1999). Black–and-Red Broadbills are substrate-gleaning insectivores, and their diet includes beetles, crickets, grasshoppers, snails and hemipterans (Smythies, 1999). They also have frugivorous habits, feeding on large-stoned berries, small white seeds, and leaves (Lambert & Woodcock, 1996; Myers,

2016) and in addition, small riverine animals such as small fishes, small crustaceans (Sheldon et al., 1992), and small crabs (Smythies, 1999). Their breeding season spans from January to September (Smythies, 1999). The birds particularly build their nests at the banks of rivers or streams, where the gigantic, pear-shaped nests can be found suspended from branches over water. The nests appear to mimic the bunches of flood-debris that are commonly found hanging from the ends of the branches of trees or sticks along rivers (Smythies, 1999). All other broadbill species build differently shaped or differently situated nests. The nests are highly characteristic and, in our opinion, cannot be confused with the nests of other species. The (two or rarely three) eggs of the Black-and-Red Broadbill are densely flecked chestnut on a pinkish-buff ground (Smythies, 1999). The conservational status of the Black-and-Red Broadbill in Sabah, as categorized by the IUCN (International Union for Conservation of Nature) Red List (www.redlist.org) is 'least concern'. This is mainly because of the extremely large range of the bird; the current population trend is, however, decreasing (BirdLife International, 2012).

Study Site

The Kinabatangan River is at 560 kilometres, the second longest river in Malaysia. It has a total catchment area of 16,800 km^2 (Azmi, 1996). Along the river, a large area of forest has been cleared for oil palm since 1975 (Azmi, 1998. The Lower Kinabatangan Wildlife Sanctuary contains riparian forest, seasonally flooded forest, swamp forest, dry dipterocarp forest, estuary nipa palm (*Nypa fruticans*) and mangrove (Estes et al., 2012). During this study, we recorded all the nests along the Kinabatangan River between Batu Putih (5°24'25"N, 117°57'4"E) and Bilit (5°29'49"N, 118°12'25"E), a distance of about 55.6 km. We chose this length based on a rough estimate for the number of nests per km along the Menanggul tributary as given in Smythies (1999), namely four per 2.6 km.

Survey Procedure

From the 29th of February until 2nd of March 2016, three to five persons identified nests by cruising along the river and scanning potential nesting sites along the banks with binoculars or with the naked eye. We surveyed on the first day from 7:00 am until 4:00 pm with 3 persons, the second day from 8:00 am until 1:00 pm with 5 persons, and the third day from 7:00 am until 11:00 am with 3 persons. Each day, a different part of the transect was covered. Per potential nest found, we recorded the coordinates, left or right side of the river (defined by the direction of the current), the height above the water (estimated) and we roughly estimated the nest size in centimetres. Once a

nest was found, we started a 15-minute survey of the nest to determine the occupancy status (yes/no) of the nest. The 15 minutes survey time was determined based on the time available for the entire project. As soon as a Black-and-Red Broadbill was seen emerging from the nest or entering into it, or perching within 5 m from the nest, we considered the nest occupied and stopped the 15-minute watch. In addition, we recorded the types of vegetation along the entire riverbank; we distinguished (i) reedland and/or grassland and (ii) forest.

Coordinates

For the coordinates we used two different devices: the iPhone compass application for nest numbers 16-28, 26, 35 and 38-42, and a Garmin Oregon 600 GPS device for nest numbers 1-15, 29-33, 37, and 43-69. For the coordinates from the GPS device we applied Timbalai as map datum, which required us to correct the coordinates by shifting all 3.65" east and 9.54" south. In addition we needed to correct numbers 5, 6, 15, 25, 33, and 66 slightly to place them in the correct place, according to our notes. The coordinates derived from the iPhone compass application proved less precise than the ones from the GPS device but they were accurate enough to show in which habitat type the nests were situated.

Nest Categories

We categorized the nests in three categories (see figure 1). Category 1 nests did not (yet) have the right size or structure to function as a nest. These nests could be old nests or nests that are still under construction or even non-nest debris. Category 2 nests had the right size and structure and could be nests that were in use at the time of the survey, but no bird was seen during the 15-minute watch. Category 3 nests were nests at which we observed one or two birds during the 15 minutes of observation. For each nest, we recorded the type of riverbank vegetation in which it was present.

Data Analysis

We plotted all nest locations (of all three categories) in Google Earth (see figure 2 and figure 3). We projected a pattern of 100 m x 100 m plots on an area ranging 500 m from the river, on both sides and determined if the plot was composed of (more than 50 %) (1) river, (2) forest or (3) disturbed area, namely oilpalm plantations, roads, and villages. We did the same for circles of 1 kilometre diameter around the nests. Then, we counted the different blocks and compared the habitat types around the nests with a baseline habitat type distribution around the entire river transect, using a Pearson's Chi-squared test with Yates' continuity correction. For the statistics we have used RStudio (Rstudio 0.99.484).

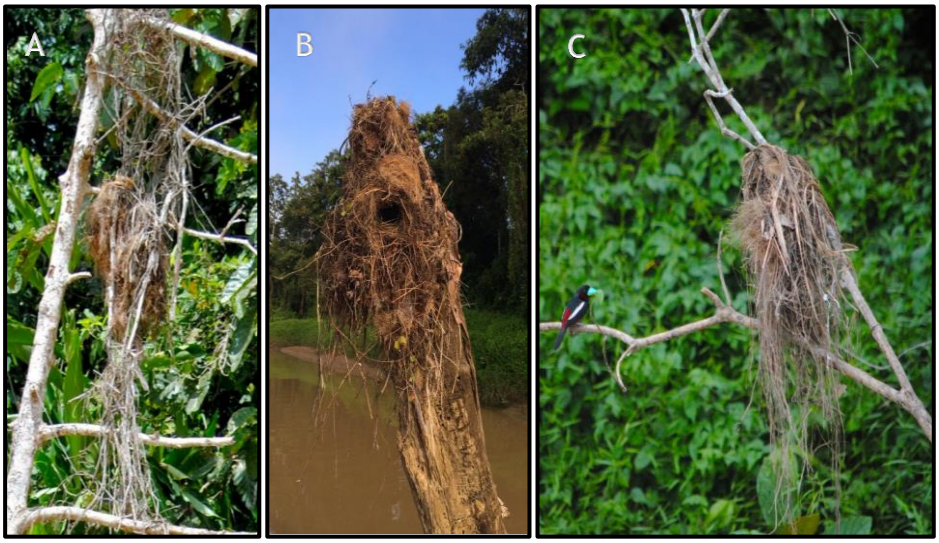

Figure 1. Examples of the different nest categories used in this study. **A** Category 1 nest **B** Category 2 nest **C** Category 3 nest

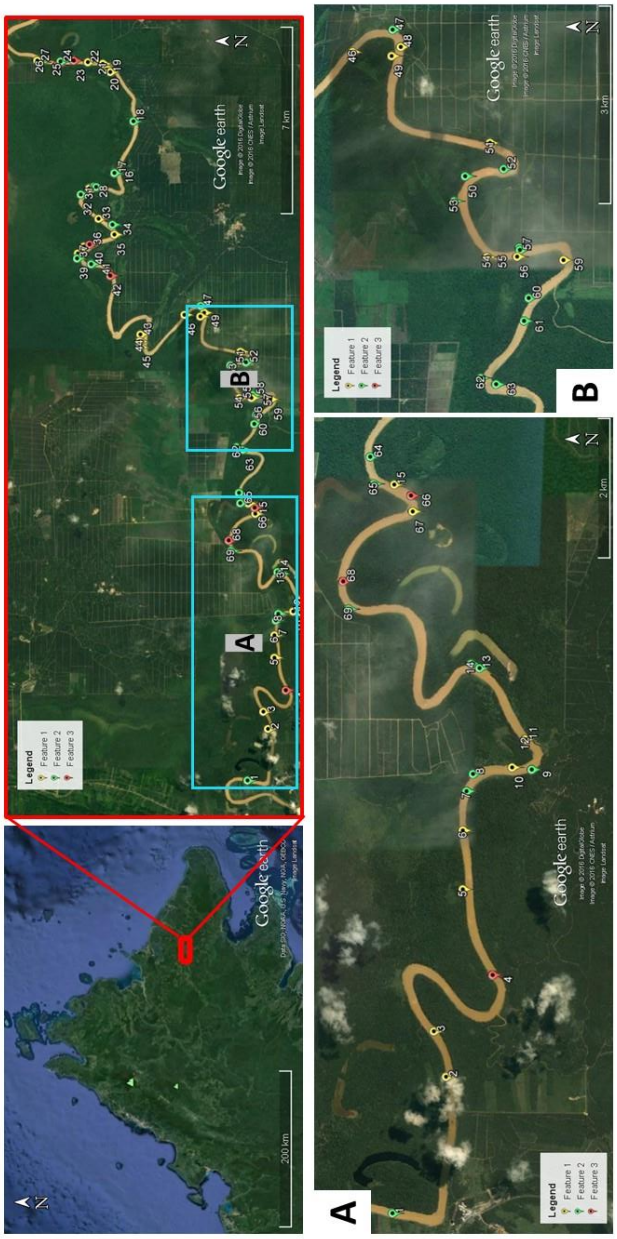

Figure 2. Nest location plotted on Google Earth image of the area

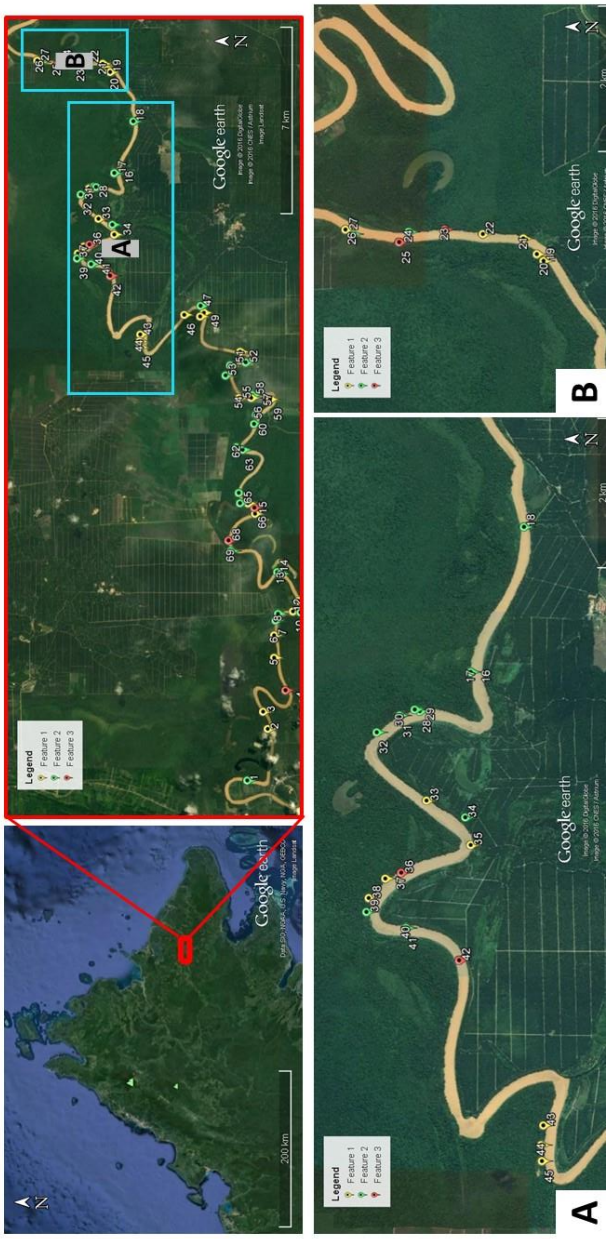

Figure 3. Nest location plotted on Google Earth image of the area

Results

Nest abundance

During the three days of survey, we registered 69 potential nests of the Black-and-Red Broadbill of which eight were in category 1; 30 in category 2; and 31 in category 3. For this area, we found 2 occupied nests per 3.6 kilometres of river, which is a lower abundance than along the Menanggul tributary as given in Smythies (1999).

Association with surrounding habitat type

Our study found that the nests are not randomly distributed among habitat types (see table 1). With the chi-square test, we found that these results are significant ($p<0.001$), which suggests that the Black-and-Red Broadbill prefers building its nest in areas with a lot of forest.

Table 1. The numbers in the cells are the numbers of 100m x 100m plots counted in a map. The first row represents the null hypothesis as it shows the overall area around the river[1], the second row shows the deviations from the null hypothesis for the areas around all nests[2].

	River[(i)]	Forest[(ii)]	Disturbed[(iii)]	**Total**
Habitat type along the river[1]	656	2672	1971	**4643**
Habitat type around the nests[2]	906	3022	1385	**5313**

Riparian zone

We found that all the nests were situated at the waterside where there is some form of tree coverage or dead wood. There were no nests in riverside sections where the banks were covered by reed or grass. At these sides, there was a lack of strong branches for attaching nests to.

Discussion

Nest abundance

It is not possible to say much about the population density of the Black-and-Red Broadbill based only on this study because we only surveyed a very short part of their nine-months breeding season (Smythies, 1999). Moreover, our surveying method did not allow us to cover oxbow lakes and tributaries, which also are likely to contain nesting sites. To tell if the population is increasing or decreasing with habitat degradation of the forest, one requires data over many years. So, with this study we can only give an indication of the population at the time of the survey. We recommend a multi-year monitoring of the

population to document the population trends. It could be tempting to advocate the monitoring of Black-and-Red Broadbill nests as a quick method to assess habitat quality. However, if population density for this bird species depends strongly on the availability of nesting sites (Cooper & Francis, 1998), its use as a habitat quality indicator may be limited.

Correlation with surrounding habitat type

During this study we found a clear preference in habitat type for the nesting location of the Black-and-Red Broadbills. Whether this is due to the need for nesting material, food or other resources has not been looked at in this study, but is definitely interesting to investigate in the future.

Riparian zone

When land in low-lying floodplains is cleared and converted to agricultural lands, such as oil palm plantations, a riparian zone at the riverbank can be a conservation measure taken to reduce river siltation and to function as a corridor for migrating animals (Goossens et al., 2005), or as a refuge (Sieving et al., 2000) for others. For the Black-and-Red Broadbill, the riparian zone can be useful when it comes to finding a suitable place to build a nest. It might be possible that the Black-and-Red Broadbill does not rely on the actual tree zone, and that just some dead trees in the water or artificial sticks close to the waterside would be sufficient. Therefore, we recommend enhancement of nesting opportunity by artificially providing above-water nesting sites along the river edge. It might also be that the birds are relying on the forest for foraging, as they consume different food types (Myers, 2016) but this was not taken into account during this study.

General Conclusion

Black-and-Red Broadbills build their nests along the river on branches and sticks that are standing in the water or hanging above the water. They prefer to build their nests in an area with more forest as a habitat type compared to the alternative: disturbed habitat type. They might profit from the riparian zones when it comes to finding a branch or stick to build their nests on but it also might work to just provide these branches or sticks artificially. The preference shows that the Black-and-Red Broadbills might rely on forest habitat and riparian zone for other resources than just the nest location but further research is necessary to provide this information.

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