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Cover image:
Rhinolophus trifoliatus - (Photo credit: Faisal Ali Anwarali Khan)
Echinosorex gymnura – (Photo credit: Isham Azhar)
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Lecanorchis multiflora – (Photo credit: Edward Entalai Besi)
Etlingera metriocheilos - (Photo credit: Suganthi Appalasamy)
Etlingera fimbriobracteata - (Photo credit: Suganthi Appalasamy)

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Short Notes

Diversity of Odonata Species at Kangkawat, Imbak Canyon, Sabah

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Abstract

The Odonata fauna of Kangkawat Research Station in Imbak Canyon was surveyed during the Borneo Biogeographic Expedition from 28 September to 9 October 2018. A total of 56 species in 12 families were recorded – 18 species in Libellulidae, eight species in Platycnemididae, six species in Coenagrionidae, five species in Calopterygidae, four species each in Chlorocyphidae and Platystictidae, three species each in Euphaeidae and Gomphidae, two species in Synthemistidae and one species each in Devadattidae, Philosinidae and Aeshnidae. Of these, 10 species are new records for Imbak Canyon. The total number of species known from Imbak Canyon is now 83. Generally, Imbak Canyon is rich in Odonata, and it is a refuge for many uncommon species. Nevertheless, many more parts of the area still need to be explored for a more comprehensive picture of the Odonata of Imbak Canyon

Keywords: Biodiversity, Imbak Canyon, Kangkawat, Odonata, Sabah

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Introduction

Dragonflies and damselflies, collectively known as Odonata, form an important biological component of fresh water ecosystems. Their distribution is more concentrated in the tropics and subtropics. The adult insects are terrestrial while the nymphs are aquatic. Therefore, they could be found at various fresh water bodies such as streams, ponds, lakes and swamps. Many Odonata species are good biological indicators for water quality. Close to 6,000 Odonata species are distributed throughout the world (Dijkstra et al., 2013). In Malaysia, more than 400 species have been recorded (Choong et al., 2017), with the state of Sabah harbouring over 160 species (Dow per. com).

Imbak Canyon is located in the central part of Sabah, to the north of Maliau Basin. The canyon consists of ridges up to 1,120 m (Yayasan Sabah, 2014). The main part of Imbak Canyon is within the Imbak Canyon Conservation Area (ICCA) which has an approximate total area of 27,599 ha (Yayasan Sabah 2014). The published Odonata records for Imbak Canyon mainly come from a few recent publications (Choong, 2011; Dow & Orr, 2012; Chung et al., 2013; Choong & Chung, 2019). Choong (2011) recorded 38 species from Mt. Kuli Research Station (within ICCA), Dow & Orr (2012) mentioned the record of *Telosticta janeus* and Chung et al. (2013) recorded 24 species from Sungai Imbak Forest Reserve (adjacent to ICCA). The latest publication for Imbak Canyon came from Choong & Chung (2019), and they reported 61 Odonata species from Batu Timbang Research Station and Imbak Canyon Studies Centre. With the records from all the publications, 73 species are known from Imbak Canyon. It is always of immense interest to further survey the Odonata in different parts of Imbak Canyon to document the species richness of the area. In this paper we report the Odonata species found at Kangkawat Research Station, Imbak Canyon. At the same time, we produce an Odonata checklist for Imbak Canyon.

Methodology

Odonata of Imbak Canyon was surveyed during the Borneo Biogeographic Expedition from 28 September to 9 October 2018. The survey was done at aquatic habitats in the vicinity of Kangkawat Research Station (5°4’40.3”N, 117°3’27.3”E). The research station is situated by Sg. Kangkawat. During the expedition period, the water level of Sg. Kangkawat was low enough that the river could be crossed easily. Sampling was done at all types of aquatic habitats (streams, rivers, swamps, ponds, puddles, waterfalls etc.) at the research station and adjacent areas with an altitude range of 150–600 m above sea level. Adult insects were caught using an aerial net. Collected specimens were treated with acetone and then dried in silica gel. The identification of specimens down to species was done based on references and comparison with specimens from other places. The specimens are kept in Centre for Insect Systematics (Universiti Kebangsaan Malaysia), the Sabah Forestry Department and BORNEENSIS (Universiti Malaysia Sabah).

Results

A total of 56 species in 12 families were recorded during the Borneo Biogeographic Expedition 2018: 18 species in Libellulidae, eight species in Platycnemididae, six species in Coenagrionidae, five species in Calopterygidae, four species each in Chlorocyphidae and Platystictidae, three species each in Euphaeidae and Gomphidae, two species in Synthemistidae and one species each in Devadattidae, Philosinidae and Aeshnidae (Table1; column E). Of these, 10 species are new records for Imbak Canyon, i.e. *Vestalis amabilis*, *Libellago phaethon*, *Libellago semiopaca*, *Rhinocypha cucullata*, *Dsyphaea dimidiata*, *Pseudagrion pillidorsum*, *Drepanosticta rufostigma*, *Macromidia fulva*, *Megalogomphus* sp. and *Phaenandrogomphus safei*. Some of the species photographed at Kangkawat Research Station are shown in Figure 1. All the published records were compiled to produce a checklist of Odonata for Imbak Canyon. The total number of species known to Imbak Canyon is now 83 (Table 1).

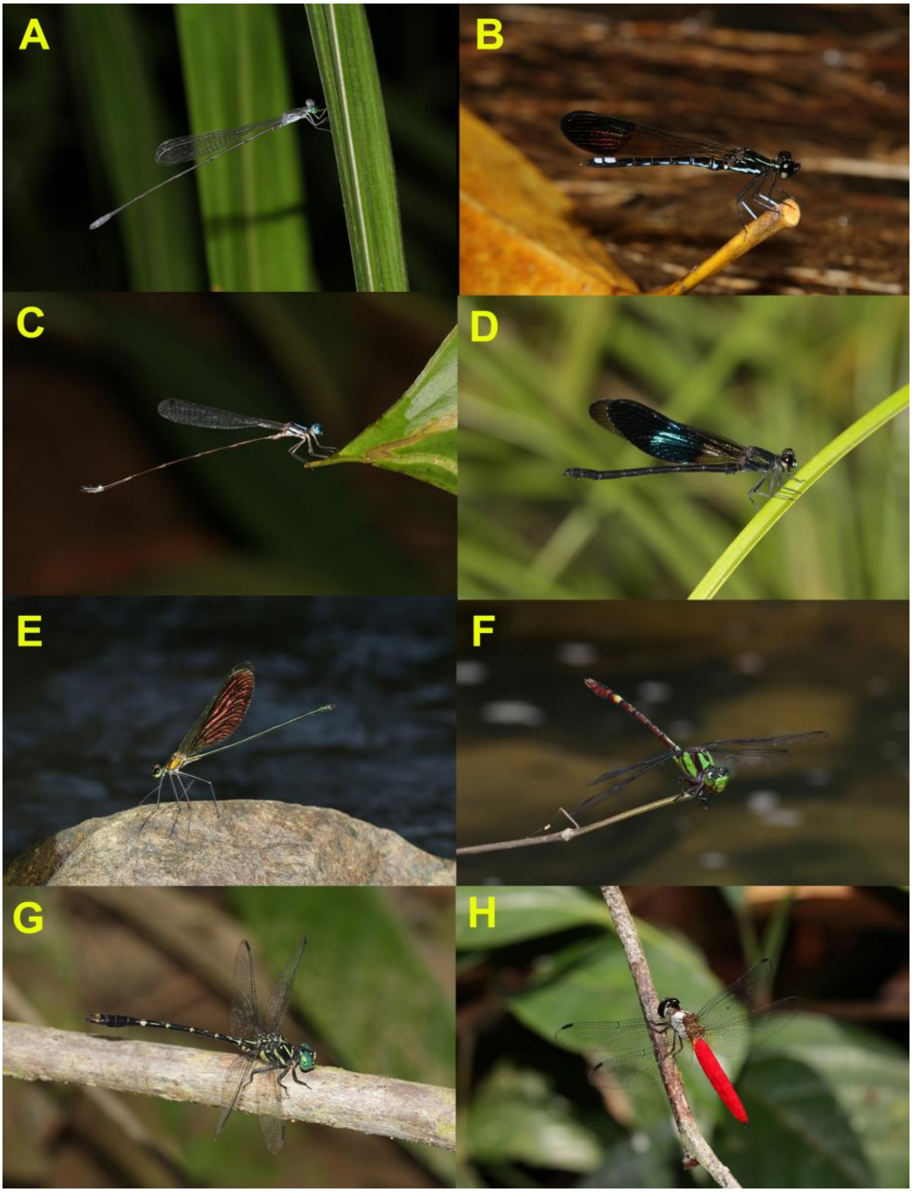

Figure 1. Some of the Odonata species photographed at Kangkawat Research Station. A. *Teinobasis laidlawi*, B. *Rhinocypha cucullata*, C. *Telosticta janeus*, D. *Euphaea subcostalis*, E. *Neurobasis longipes*, F. *Megalogomphus* sp., G. *Phaenandrogomphus safei* and H. *Lyriothemis biappendiculata*.

Table 1. Odonata species recorded at Imbak Canyon. Column A: data from Choong (2011), B: data from Chung et al. (2013), C: records for Imbak Canyon Studies Centre, D: records for Batu Timbang Research Station (Choong & Chung, 2019); E: records for Kangkawat Research Station. * indicates new records for Imbak Canyon.

No.	Species	A	B	C	D	E	IUCN status
	Family Devadattidae						
1	*Devadatta tanduk* Dow, Hämäläinen & Stokvis 2015	/		/	/	/	DD
	Family Calopterygidae						
2	*Neurobasis longipes* Hagen, 1887	/	/	/	/	/	LC
*3	*Vestalis amabilis* Lieftinck, 1965					/	LC
4	*Vestalis amaryllis* Lieftinck, 1965	/		/	/	/	LC
5	*Vestalis amoena* (Hagen, 1853)			/		/	LC
6	*Vestalis anacolosa* Lieftinck, 1965	/		/	/	/	LC
7	*Vestalis beryllae* Laidlaw, 1915	/			/		LC
	Family Chlorocyphidae						
8	*Heliocypha biseriata* (Selys, 1859)		/				LC
*9	*Libellago phaethon* (Laidlaw, 1931)					/	NT
*10	*Libellago semiopaca* (Selys, 1873)					/	LC
11	*Rhinocypha aurofulgens* Laidlaw, 1931	/	/		/		LC
12	*Rhinocypha stygia* Förster, 1897		/				NT
*13	*Rhinocypha cucullata* Selys, 1873					/	LC
14	*Rhinocypha humeralis* Selys, 1873	/	/	/	/	/	LC
	Family Euphaeidae						
*15	*Dysphaea dimidiata* (Selys, 1853)					/	LC
16	*Euphaea impar* (Selys, 1959)		/			/	LC
17	*Euphaea subcostalis* (Selys, 1873)	/	/	/	/	/	LC
	Family Lestidae						
18	*Lestes praevius* Lieftinck, 1940			/			NA
19	*Orolestes wallacei* (Kirby, 1889)	/		/			LC
	Family Philosinidae						
20	*Rhinagrion elopurae* (McLachlan, 1886)	/	/	/		/	LC
	Family Coenagrionidae						
21	*Agriocnemis femina* (Brauer, 1868)			/		/	LC
22	*Argiocnemis rubescens rubeola* Selys, 1877			/			LC
23	*Argiocnemis* sp.	/		/		/	-
24	*Ceriagrion bellona* Laidlaw, 1915			/			LC
25	*Pseudagrion microcephalum* (Rambur, 1842)			/			LC
*26	*Pseudagrion pillidorsum* Brauer, 1868					/	Draft LC
27	*Stenagrion dubium* (Laidlaw, 1912)	/		/	/	/	LC
28	*Teinobasis laidlawi* Kimmins, 1936	/		/	/	/	LC

29	*Teinobasis rajah* Laidlaw, 1912			/		/	LC
30	*Xiphiagrion cyanomelas* (Selys, 1876)		/	/			LC
	Family Platycnemididae						
31	*Coeliccia nigrohamata* Laidlaw, 1918	/		/	/	/	LC
32	*Coeliccia* cf *nemoricola* Laidlaw, 1912	/		/	/	/	NA
33	*Coeliccia arcuata* Lieftinck, 1940	/		/	/	/	LC
34	*Copera vittata* (Selys, 1863)	/		/	/	/	LC
35	*Prodasineura dorsalis* (Selys, 1860)	/				/	LC
36	*Prodasineura hosei* (Laidlaw, 1913)	/				/	LC
37	*Prodasineura hyperythra* (Selys, 1886)	/				/	LC
38	*Prodasineura verticalis* (Selys, 1860)			/		/	LC
	Family Platystictidae						
39	*Drepanosticta actaeon* Laidlaw, 1934	/			/	/	LC
40	*Drepanosticta versicolor* Laidlaw, 1913	/		/	/	/	LC
*41	*Drepanosticta rufostigma* (Selys, 1860)					/	LC
42	*Protosticta joepani* Dow, Phan & Choong, 2020				/		Draft VU
43	*Telosticta janeus* Row & Orr, 2012	/			/	/	NT
	Family Aeshnidae						
44	*Anax panybeus* Hagen, 1867			/			LC
45	*Indaeschna grubaueri* (Forster, 1904)	/		/	/	/	LC
46	*Tetracanthagyna degorsi/brunnea* (female)				/		-
	Family Corduliidae						
47	*Epophthalmia vittigera* (Rambur, 1842)			/			LC
	Family Synthemistidae						
48	*Idionyx* sp. (female)	/				/	-
*49	*Macromidia fulva* Laidlaw, 1915					/	LC
	Family Macromiidae						
50	*Macromia corycia* Laidlaw, 1922	/			/		NT
	Family Gomphidae						
*51	*Megalogomphus* sp.					/	-
52	*Microgomphus chelifer* (Selys, 1858)	/				/	LC
*53	*Phaenandrogomphus safei* Dow & Luke, 2015					/	VU
	Family Libellulidae						
54	*Agrionoptera insignis* (Rambur, 1842)			/		/	LC
55	*Agrionoptera sexlineata* Selys, 1879			/		/	LC
56	*Brachydiplax chalybea* Brauer, 1868			/			LC
57	*Camacinia gigantea* (Brauer, 1867)		/	/			LC
58	*Cratilla lineata* (Brauer, 1878)			/	/	/	LC

59	*Cratilla metallica* (Brauer, 1878)	/		/	/	/	LC
60	*Diplacodes trivialis* (Rambur, 1842)			/			LC
61	*Hylaeothemis clementia* Ris, 1909			/			LC
62	*Lyriothemis biappendiculata* (Selys, 1878)	/		/	/	/	LC
63	*Lyriothemis cleis* Brauer, 1868	/				/	LC
64	*Nesoxenia lineata* (Selys, 1868)			/		/	LC
65	*Neurothemis fluctuans* (Fabricius, 1793)			/	/	/	LC
66	*Neurothemis ramburii* (Brauer, 1866)		/	/	/	/	LC
67	*Neurothemis terminata* Ris, 1911		/	/	/		LC
68	*Orthetrum chrysis* (Selys, 1891)	/	/	/	/	/	LC
69	*Orthetrum glaucum* (Brauer, 1865)	/	/	/	/	/	LC
70	*Orthetrum pruinosum schneideri* Forster, 1903	/	/	/	/	/	LC
71	*Orthetrum sabina* (Drury, 1773)		/	/			LC
72	*Orthetrum testaceum* (Burmeister, 1839)		/	/	/	/	LC
73	*Pantala flavescens* (Fabricius, 1798)		/	/	/		LC
74	*Rhyothemis phyllis* (Sulzer, 1776)		/				LC
75	*Rhyothemis regia regia* (Brauer, 1867)		/				LC
76	*Rhyothemis triangularis* Kirby, 1889		/	/			LC
77	*Tetrathemis* cf *irregularis hyalina* Kirby, 1889	/		/		/	LC
78	*Tramea transmarina euryale* Selys, 1878		/	/			LC
79	*Trithemis aurora* (Burmeister, 1839)	/		/		/	LC
80	*Trithemis festiva* (Rambur, 1842)	/	/	/	/	/	LC
81	*Tyriobapta torrida* Kirby, 1889	/		/	/	/	LC
82	*Zygonyx iris errans* Lieftinck, 1953	/			/	/	LC
83	*Zyxomma petiolatum* Rambur, 1842			/			LC
	Total number of species	**38**	**23 +1#**	**54**	**35**	**56**	

Chung et al. (2013) identified a taxon (female) as *Vestalis* sp. This taxon could be any of the four *Vestalis* species with similar abdominal length found at Imbak Canyon (*V. amabilis*, *V. amaryllis*, *V. amoena* and *V. anacolosa*).

Discussion

The number of species recorded from the Borneo Biogeographic Expedition was moderately high (56 species), representing 35% of the species known to Sabah. This is partly due to the various types of aquatic habitats found at the Kangkawat Research Stations and its surrounding areas – river, streams, streamlets, swamps and waterfalls. The number of species recorded was equivalent to that from Batu Timbang Research Station (Choong & Chung, 2019) but much higher than Mt. Kuli Research Station (Choong, 2011) and Imbak Canyon Studies Centre (Choong & Chung, 2019), indicating the richness of Odonata fauna in Kangkawat Research Station.

Some interesting species recorded during the expedition were *Telosticta janeus*, *Protosticta joepani*, *Libellago phaethon*, *Rhinocypha cucullata*, *Megalogomphus* sp. and *Phaenandrogomphus safei*. All of these species are endemic to Borneo. *Telosticta janeus* was also recorded at Mt. Kuli Research Station (Choong, 2011) and Batu Timbang Research Station (Choong & Chung, 2019). So far, this species is endemic to Sabah and only known from Danum Valley and Imbak Canyon (Dow & Orr, 2012), and also SAFE project area (Dow per. comm.). *Protosticta joepani* was treated as *Protosticta* cf. *kinabalunensis* in Choong & Chung (2019), and it was recently described as a new species (Dow et al. 2020). *Libellago phaethon* is a rare and localized species which is only recorded in Sabah and also in the adjacent part of Kalimantan, Indonesia (Dow, 2020). In the expedition, only two male individuals of *L. phaethon* were spotted at the riverbank of Sg. Kangkawat. *Rhinocypha cucullata* was found to be abundant at two of the small tributaries to Sg. Kangkawat (Figure 1B). At the small streams, males of *R. cucullata* were frequently observed engaging in territorial fighting. The taxonomy of *Megalogomphus* from Sundaland is being revised (Dow per. comm.), and the *Megalogomphus* species recorded here is treated as *Megalogomphus* sp. Two individuals of *Megalogomphus* sp. were spotted at Sg. Kangkawat (Figure 1F). *Phaenandrogomphus safei* is one of the most interesting findings from the expedition (Figure 1G). Two males *P. safei* were spotted hovering over the surface of a small rapid at Sg. Kangkawat. This species was described from a specimen collected at Kalabakan Forest Reserve, Sabah (Dow & Luke, 2015), and later on it was found at two locations in Lanjak Entimau Wildlife Sanctuary, Sarawak (Dow et al., 2018). Therefore, Sg. Kangkawat is the fourth location of this rare species.

It is worthwhile to note that 10 of the species recorded from Kangkawat Research Station are new records for Imbak Canyon (Table 1, marked with *). Nevertheless, some of these new records are common species such as *Vestalis amabilis*, *Libellago semiopaca*, *Dysphaea dimidiata* and *Drepanosticta rufostigma*. These new records were compiled together with the existing published records to give a tally of 83 species known to Imbak Canyon (Table 1). This represents more than 50% of the species known to Sabah, indicating the extremely high diversity of Odonata fauna of Imbak Canyon. It must be noted that only a small part of Imbak Canyon has been surveyed for Odonata. Therefore, further surveys on other parts of the canyon are vital for a more comprehensive database.

Conclusion

At present the Odonata checklist of Imbak Canyon has 83 species, and a few are novel species to Borneo. It must be stressed that this species list is far from complete. Nevertheless, it provides baseline data for a future strategic management plan to manage Imbak Canyon, and it also acts as a reference for the study of Odonata diversity of Sabah.

Acknowledgements

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Short Communication

Review of Malaysian black flies (Diptera: Simuliidae): note on new record on *Simulium kalimantanense* from Sabah

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Abstract
Black flies are the two-winged, small-bodied (3mm to 6mm) and blood-sucking insects of medical and veterinary importance. Female of certain species play a role as a vector of several disease agents including, *Onchocerca volvulus*, causative agent of human onchocerciasis. Despite their medical significance, the biodiversity of black flies in the Borneo part of Malaysia as well as other Southeast Asian countries (except Thailand, Vietnam and Indonesia) are unknown. Our recent visit to the Kangkawat Reserve within the Imbak Canyon Conservation Area (ICCA) has successfully discovered one new record from Malaysia, *Simulium kalimantanense* of the *S. banauense* species-group and one from Sabah, *Simulium sarawakense* of the *S. epistum* species-group. Based on these current findings, the total number of species and species-group of black flies inhabiting Malaysia has increased to 96 and 22 respectively.

Keywords: black fly, Simuliidae, Malaysia, Sabah, biodiversity, vector, Onchocerciasis

Introduction
To date, there are 2,335 black fly species of five genera discovered worldwide (Adler & Crosskey, 2018). The genus *Simulium* is the most diverse group containing the largest species number (1,919) and occurs in almost all places, however, it represents the only genus in the Oriental region. Black flies are the two-winged, small-bodied (3mm to 6mm) and blood-sucking insects of medical dan veterinary importance.

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Female of certain species in the genus *Simulium* play a role as a vector of filaria parasites including *Onchocerca volvulus*, an agent of human Onchocerciasis in Sub-Saharan Africa, Latin America and Yemen (Ishii et al, 2008; Adler et al. 2010).

Black flies in the order Diptera and family Simuliidae is widely distributed across all zoogeographical regions and the preimaginal black flies generally inhabit unpolluted running water (Takaoka, 1995; Currie & Adler, 2008). In fact, preimaginal black flies are important components of the stream ecosystem (Hamada et al., 2002; Currie & Adler, 2008; Pramual & Kuvangkadilok, 2009). They act as the keystone species in the ecology of running water because they are usually present as a major component of stream macroinvertebrates (Malmqvist et al., 2004) and have the ability to filter dissolved organic matter and make it available in the food chain (Currie & Adler, 2008). Black flies are also important in the monitoring of freshwater contamination because larvae and pupae are susceptible to both organic and inorganic pollutions (i.e. insecticides and fertilizers) (Currie & Adler, 2008).

Despite their medical and ecological significance, the biodiversity of black flies in most parts of the Southeast Asian region, except Thailand, Vietnam and Indonesia are unknown. In 2014, led by our team, University of Malaya Simuliidae Research Project (UMSRP), a comprehensive survey on the biodiversity of black flies was conducted across the west (Peninsular Malaysia) and partly in the east (Sabah) Malaysia. As an outcome, 30 new species have been discovered (23 and seven in the west and east Malaysia respectively), bringing the total number of Malaysian species to 95 (see Table 1).

Biodiversity of black flies in the Borneo part of Malaysia (Sabah and Sarawak) is understudied. Currently, there are only 28% of the total Malaysian black fly species from 11 species-groups recorded in Sabah (see Table 1 and Table 2). Owing to various bio-geographical landscapes in the Borneo part of Malaysia and Indonesia, we hypothesized that more significant species are yet to be explored which may consequently, contribute to increased biodiversity of black flies and identification of vector of human and animal onchocerciasis. Therefore, in this scientific expedition, we aim to explore the biodiversity of black flies residing in a remote area in Kangkawat Reserve within the Imbak Canyon Conservation Area (ICCA) in the state of Sabah. The outcome of this entomological survey would provide updated biodiversity data for further scientific research in related disciplines (i.e. breeding habitat preference, vector-borne diseases and epidemiology).

Table 1. The updated list of black fly species from Malaysia

Classification	Total	West Malaysia	East Malaysia	
		Peninsular Malaysia	Sabah	Sarawak
Genus				
Simulium Latreille	94	63	27	25
Subgenus				
Daviesellum Takaoka & Adler	1	1	0	0
Gomphostilbia Enderlein	47	35	9	15
Nevermannia Enderlein	7	5	3	1
Simulium Latreille	39	22	15	9

Table 2. Diversity of black fly species in Malaysia based on species-group level

Genus	Subgenus	Species-group	Total	West Malaysia	East Malaysia	
				Peninsular Malaysia	Sabah	Sarawak
Simulium	*Daviesellum*	-	1	1	0	0
	Gomphostilbia	*Asakoae*	8	8	1	1
		Batoense	14	12	2	4
		Ceylonicum	5	4	2	2
		Darjeelingense	2	0	1	1
		Epistum	11	4	2	6
		Gombakense	3	3	0	0
		Varicorne	4	4	0	1
		Banauense	1	0	1	0
	Nevermannia	*Feuerborni*	4	2	2	0
		Ruficorne	1	1	1	1
		Vernum	2	2	0	0
	Simulium S. str.	*Argentipes*	2	1	1	1
		Christophersi	3	3	0	0
		Crocinum	2	2	0	0
		Griseifrons	1	1	0	0
		Grossifilum	1	1	0	0
		Melanopus	10	1	8	4
		Multistriatum	3	3	0	0
		Nobile	2	1	1	0
		Striatum	3	3	0	0
		Tuberosum	11	5	5	4
		Variegatum	1	1	0	0

Methodology

Sample collection

Streams were chosen based on the presence of flow and accessibility. The stream was sampled from downstream to upstream (20 m). Larvae and pupae attached on aquatic substrates such as grasses, leaves and stems, twigs, plant roots and rocks were collected by hand using fine forceps. These sampling protocols could represent the species occurrence in a locality (McCreadie et al. 2005; McCreadie & Colbo, 1991). Pupae attached on similar substrates were individually kept alive in vials until emergence. The adults, together with their pupal exuviae and cocoons were preserved in 80% ethanol for identification at the subgenus, species-group or species level. The methods of collection and identification followed those of Takaoka (2003) and Adler et al. (2010).

Stream measurement

For ecological data collection, the following stream physicochemical parameters were measured at the time of each collection: depth (m), width (m), velocity (m/s) (one to three measurements along the collection path), water temperature (°C), acidity (pH), conductivity (mS/cm) and dissolved oxygen (mg/l). The values of pH, temperature, conductivity and dissolved oxygen were taken using a portable multi-probe parameter (Hanna HI 9828). Meter tape and steel ruler were used to measure stream width and depth respectively, while cork and a timer watch were used to measure stream velocity; the time is taken for a cork to move one meter in distance. Velocity, depth and width measurements were used to estimate discharge (McCreadie et al. 2006). The ecological and physicochemical measurement protocols including those for major streambed particles, riparian vegetation, and canopy cover followed those of McCreadie et al. (McCreadie et al. 2016). For each fixed-stream site, the latitude and longitudinal coordinates were taken once and recorded using a hand held global positioning system (GPS) instrument (Garmin International Inc., Olathe, KS).

Table 3. Details of sampling sites from the Kangkawat Reserve within the Imbak Canyon Conservation Area (ICCA), Sabah, Malaysia.

Trail (stream code)	Latitude Longitude	Riparian vegetation	Streambed particle	Canopy cover	Specimen collected
Nepenthes (St-1)	05°04.928'N 117° 03.099'E	Forest	Boulder	Partial	Larvae
Nepenthes (St-2)	05°05.005'N 117° 03.046'E	Forest	Pebble	Complete	Larvae and Pupae
South Rim (St-3)	05°04.056'N 117°03.049'E	Forest	Pebble	Complete	Larvae and Pupae
South Rim (St-3/2)	05°04.056'N 117°03.049'E	Forest	Pebble	Partial	Larvae
Pelajau (St-4)	05°05.007'N 117°03.545'E	Forest	Pebble	Complete	Larvae and Pupae
Kangkawat (St-5)	05.07704° 117.05758°	Forest	Sand/mud	Complete	Larvae

Table 4. Physicochemical characteristics of surveyed streams

Stream Code	Width (m)	Depth (m)	Flow (velocity)	pH	Temperature (°C)	Conductivity (μS/cm)
St-1	4.00 – 5.00	0.50	Moderate	6.37	24.4	41.3
St-2	5.00	0.30	Moderate	5.86	24.3	25.2
St-3	4.50	0.50	Moderate	6.53	24.0	54.1
St-3/2	2.00	0.07	Slow	6.54	23.9	50.8
St-4	2.00	0.05	Moderate	5.58	23.9	10.7
St-5	1.50	0.20	Slow	6.69	25.5	67.4

Results and Discussion

A total of 81 black fly specimens consisting of two stages, larvae and pupae of three species (Table 4) were successfully collected from streams inside the Kangkawat Forest Reserve within the Imbak Canyon Conservation Area (ICCA). *Simulium kalimantanense* was the most abundantly collected species (69.1%) followed by *S. sarawakense* (28.3%) and *S. tahanense* (2.5%).

Table 5. Total species and the specimen collected from Kangkawat Forest Reserve, ICCA.

Species	Larvae	Pupa	Total specimen
Simulium (*Gomphostilbia*) *sarawakense*	5	18	23
Simulium (*Gomphostilbia*) *kalimantanense*	50	6	56
Simulium (*Gomphostilbia*) *tahanense*	2	-	2
Total	**57**	**24**	**81**

Table 6. The diversity and abundance of three black fly species collected from Kangkawat, Imbak Canyon Conservation Area (ICCA), in the state of Sabah, Malaysia

Stream	Species					
	Simulium kalimantanense		***Simulium sarawakense***		***Simulium tahanense***	
	Larva	Pupa	Larva	Pupa	Larva	Pupa
St-1	2	-	-	-	-	-
St-2	10	2M	-	-	-	-
St-3	17	3M, 1F	2	1M, 1PS	2	-
St-3/2	8	-	-	-	-	-
St-4	10	-	3	8M,3F, 5F		-
St-5	3	-	-	-	-	-

Notes on newly recorded species

***Simulium (Gomphostilbia) kalimantanense* Takoaka & Sofian-azirun, 2016: 798-806 (female, male, pupa and larva)"**

Simulium kalimantanense was originally described on the basis of females, males, pupae, and mature larvae from East Kalimantan, Indonesia. This species is assigned in the *Simulium banauense* species group and is the first member reported from Malaysia. There are only 15 members of the *S. banauense* species-group recorded worldwide. Of these, 13 were reported in the Philippines, and one species each from Sulawesi and Kalimantan, Indonesia (Adler & Crosskey 2018).

Simulium kalimantanense is distinct with all existing species in Malaysia by the pupal gills composed of only four long filaments on each side. Both adults of this species are characterized by their lack of hairs on the pleural membrane or its vicinity and medium-sized female claw tooth. Pupal of this species have conical terminal hooks while larva with a medium-sized postgenal cleft (Takaoka et al. 2016).

***Simulium (Gomphostilbia) sarawakense* Takaoka, 2001: 247-250 (female and pupa).**

This study also discovered a new locality record from Sabah, *Simulium sarawakense* of the *S. epistum* species-group. It was originally described from Mount Pueh, Sarawak. Current data has provided new distribution information of this species which extends to the heart of Sabah region. *Simulium sarawakense* can be distinguished with other existing species through the pupa gill with one long and seven short filaments which are about half the length and thickness of the longer filament (Takaoka 2001). This species is closely similar to *Simulium pegalanense* however, differ by pupal terminal hooks not serrated (Takaoka, 2001).

Distributions of preimaginal black flies (i.e. larva and pupa) are highly influenced by their associated stream habitats (Ya'cob et al. 2016a, b). Therefore, an abnormal stream discharge due to heavy rainfall might wash all stream inhabitants including pupae and larvae of black flies. Due to this limitation, the aim of the current study was not fully achieved in terms of recording the actual biodiversity of black flies inside the Kangkawat reserve forest. Further entomological observations need to be carried out outside the monsoon period in order to reveal its actual biodiversity from various landscapes and habitat types.

Conclusion

In conclusion, this one-time black fly survey has provided new insight into the black fly species composition in Malaysia. *Simulium kalimantanense* of the S. *banauense* species-group is officially added to the list of the fauna of black flies in Malaysia which brings the total number of species and species-group to 96 and 22 respectively. Basic information obtained in this study will be useful in predicting more species, including those new to science, and yet to be discovered in Malaysia. Additionally, this first survey will be the stepping stone to promote more black fly studies including identification of vector species and its associated pathogens from Sabah as well as in Borneo Island as a whole.

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Short Notes

Termite Fauna of Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA), Sabah

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Abstract
Termites are important inhabitants of the tropical rain forest, and they are commonly found in tropical soils. They have great importance in tropical terrestrial ecosystems especially in the decomposition process, mediate ecosystem processes and facilitate to improve the structure and quality of the soil. This study was conducted to identify the termite fauna of Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA). Termites were collected using a standardized 100mx2m line transect at South Rim Trail and also through casual collection around the study site. A total of 31 termite species were recorded in this study. The termite assemblage comprises two families namely, Rhinotermitidae and Termitidae. Family Termitidae dominated the termite assemblage with 87.1% (27 species). The collected termite species in this study comprises 30% of recorded termite species of Sabah. Seven subfamilies that are commonly recorded in the tropical forest were identified in this study. Subfamily Termitinae and Nasutitermitinae from family Termitidae dominated the termite assemblage of Sungai Kangkawat with 12 species and ten species respectively. The previous study conducted at ICCA recorded 29 species which have 43.9% similarity with the current study. A total of 12 species were identified as new records for ICCA through this study. Hence, the total number of termite species of ICCA is 41. This study has provided the checklist of termite fauna in Sungai Kangkawat and updated the termite checklist of ICCA.

Keywords: Blattodea, Transect, Wood feeder, Termitidae, Imbak

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Introduction

Sabah is a state in Malaysia which has a total area of 7,487,564 ha (Sabah Forestry Department, 2010). This state is diverse with flora and fauna where, 48.17% of the total land has been gazetted under Permanent Reserve Forests (Sabah Forestry Department, 2010). Various studies have been conducted in these forests to identify the diversity of flora and fauna including termites. Eventhough economically termites can cause serious damage to wood and wood products (Kirton, 2005; Gibb & Oseto, 2006; Kuswanto et al., 2015), termites are important members of soil macrofauna in the tropical forest as they provide ecosystem services. They have a high contribution in improving structure and quality of soil, decomposition of organic matters and also recycling nutrients in an ecosystem (Jones et al., 1998; Bignell & Eggleton, 2000; Jones & Prasetyo, 2002; Elzinga, 2004; Inoue et al., 2006; Brune, 2014). Termites use physical and chemical defences to protect their colonies from enemies (Prestwich, 1984; Chuah, 2010; Alia diyana et al., 2019).

Imbak Canyon Conservation Area (ICCA) is one of the protected forests in Sabah managed by Kumpulan Yayasan Sabah. In 2010, a termite study was conducted at Riverine Trail and Ridge Trail of ICCA (Homathevi & Johar, 2011). The study recorded 29 termite species from 20 genera and two families (Rhinotermitidae and Termitidae). The current study was focused at Sungai Kangkawat basecamp of ICCA. This paper provides the checklist of termites at Sungai Kangkawat and updates the termite checklist of ICCA.

Methodology

Termite sampling was conducted at two main trails at Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA) from 29 September to 2 October 2018 during the Borneo Geographic Expedition 2018. South Rim Trail and Pelajau Trail were the two trails focused on in this study.

Termites were collected at South Rim Trail (N05^{0}04.499’ E117^{0}03.448’) using a standardized line transect (100 mx2 m) method (Eggleton et al., 1997; Eggleton et al., 1999; Nivaarani & Homathevi, 2015). The transect was divided into 20 contiguous sections and each section was searched by two people for 30 minutes. All possible microhabitats of the termites were explored such as carton runways on tree trunks, leaf litter, soil, dead wood and nests (Arumugam et al., 2019). Termites were also searched casually at South Rim Trail and Pelajau Trail.

All collected termites were preserved in 80% ethanol for further identification (Kori & Arumugam, 2017). The identification was done at the Natural Resources Laboratory, Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli Campus with the aid of Thapa (1981); Collins (1984) and Tho (1992). Feeding groups were allocated according to Collins (1984), Eggleton et al. (1997), Jones & Brendell (1998) and Donovan et al. (2001). Identified termites deposited at BORNEENSIS, Universiti Malaysia Sabah. A duplicate specimen was deposited at Natural Resources Museum, Universiti Malaysia Kelantan, Jeli Campus.

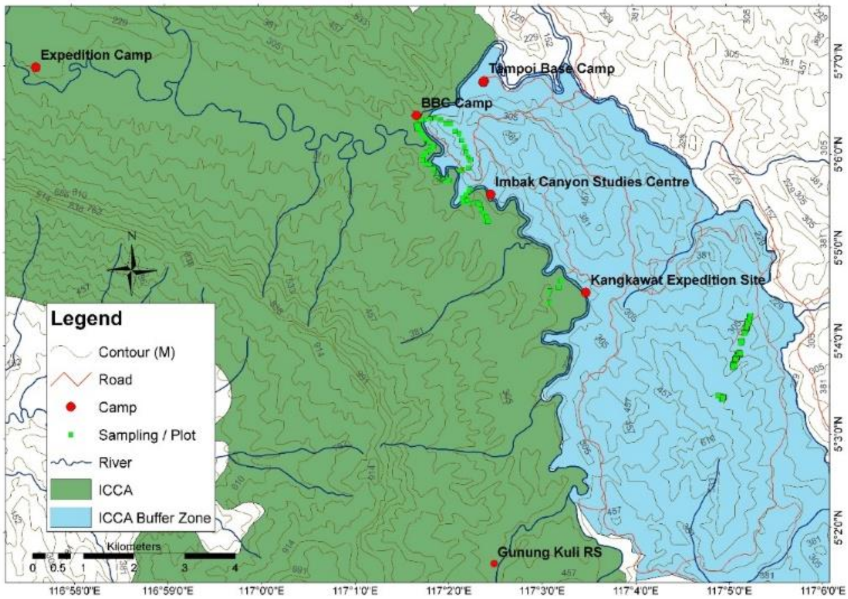

Figure 1. Map of Imbak Canyon Conservation Area indicating the Sungai Kangkawat expedition site (Source: the map was provided by the expedition organizer during Borneo Geographic Expedition 2018).

Results and Discussion

This study recorded a total of 31 termite species at Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA). The species comprised 21 genera, seven subfamilies and two families (Table 1). The collected termite species in this study consists of 30% of recorded termite species of Sabah by Thapa (1981).

Table 1. Termite species collected from Sg.Kangkawat, Imbak Canyon Conservation Area using a standardised transect and casual collection: Feeding groups, l = litter feeders, e = micro-epiphyte feeders, s = soil feeders, s/w = soil/wood interface feeders, w = wood feeders, (f) = fungus growers. * = new record.

Scientific Name	Feeding Group
Family: Rhinotermitidae	
Sub-family: Heterotermitinae	
Heterotermes tenuior (Haviland)	w
Sub-family: Coptotermitinae	
**Coptotermes borneensis* Krishna	w
Sub-family: Rhinotermitinae	
Schedorhinotermes sarawakensis (Holmgren)	w
**Schedorhinotermes tarakanensis* (Oshima)	w
Family: Termitidae	
Sub-family: Amitermitinae	
**Prohamitermes mirabilis* (Haviland)	s/w
Sub-family: Termitinae	
Dicuspiditermes nemorosus (Haviland)	s
Homallotermes eleanorae Emerson	s/w
**Kemneritermes* sp.1	s
**Malaysiocapritermes prosetiger*	s
Microcerotermes dubius (Haviland)	w
Pericapritermes latignathus (Holmgren)	s
Pericapritermes nitobei (Shiraki)	s
**Pericapritermes paraspeciosus* Thapa	s
Pseudocapritermes sp.1	s
Pseudocapritermes sp.2	s
Syncapritermes sp.1	s
Termes propinquus (Holmgren)	s/w
Sub-family: Macrotermitinae	
**Macrotermes gilvus* (Hagen)	w/l(f)
Macrotermes malaccensis (Haviland)	w/l(f)
Odontotermes grandiceps Holmgren	w(f)
**Odontotermes oblongatus* Holmgren	w(f)

Sub-family: Nasutitermitinae	
Bulbitermes constrictiformis (Holmgren)	w
Bulbitermes constrictus (Haviland)	w
Bulbitermes flavicans (Holmgren)	w
**Hirtitermes spinocephalus* (Oshima)	w
Hospitalitermes umbrinus (Holmgren)	e
**Leucopitermes leucops* (Holmgren)	s
Longipeditermes longipes (Haviland)	w
**Nasutitermes havilandi* (Desneux)	w
Nasutitermes longinasus (Holmgren)	w
**Nasutitermes neoparvus* Thapa	w
Number of Species	**31**

The common termite families in Malaysia, Rhinotermitidae (lower termite) and Termitidae (higher termite) were collected in this study. Family Termitidae dominated the termite assemblage with 87.1% (27 species). Subfamily Termitinae and Nasutitermitinae from family Termitidae dominated the termite assemblage of Sungai Kangkawat with 12 species and ten species respectively. These subfamilies also dominated the assemblage in the previous study at ICCA (Homathevi & Johar, 2011).

Family Rhinotermitidae only recorded four species from three genera. The recorded genera are similar as in the previous study at ICCA namely, *Heterotermes*, *Coptotermes* and *Schedorhinotermes* (Homathevi & Johar, 2011). These genera are ecologically important genera where they are categorised as wood feeders. The genus *Coptotermes* are identified as pest species that can attack living trees (Kuswanto et al., 2015).

Termites have different feeding habits. Five types of feeding groups were identified in this study. However, wood feeders dominated the assemblage with 48.4%, followed by soil feeders (32.2%), soil-wood interface feeders (9.7%), wood-litter feeders (6.5%) and epiphyte feeder (3.2%). Most of the primary forest of Sabah is dominated by soil feeders. However, wood feeders dominated the termite assemblage at Sungai Kangkawat compared to other feeders. A similar situation has also been observed in the Maliau Basin Conservation Area and Belum-Temenggor Forest Complex (Jones et al., 1998; Aiman Hanis et al. 2014).

A previous study conducted at ICCA recorded 29 termite species (Homathevi & Johar, 2011) while the present study recorded 31 termite species. Both studies have 43.9% species similarity. A total of 12 species were identified as new records for ICCA through this study (Table 1). This includes five new genera that were never recorded in ICCA. The genera are *Prohamitermes*, *Kemneritermes*, *Malaysiocapritermes*, *Hirtitermes* and *Leucopitermes*.

Conclusion

The present study has provided a checklist of termites at Sungai Kangkawat, ICCA and includes an update on the total number of termite species in ICCA (41 termite species). Twelve termite species and five genera are identified as a new record for ICCA through this study.

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Research Article

Harmonious Co-Existence between Nature and Mankind: An Investigation of a *Satoyama* Development – Like Mechanism at Imbak Canyon Conservation Area (ICCA), Sabah

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Abstract
This research is a preliminary survey of *Satoyama* development-like mechanism in Kg. Imbak, Tongod, Sabah. The objectives of this research are to determine the utilization of forest source among the local community in Kg. Imbak and their community-based conservation efforts. Face to face interviews were conducted to access primary data besides observation surveys. The data gathered are from published materials such as reports and articles. Kg. Imbak consists of *Dusun Sungai* People with a total population of 796 people. Collected data were analyzed using Descriptive Analysis and SWOT analysis. Kg Imbak is approximately 19.12 km drive from Tongod District and the local community still consumes forest source for their medicinal needs, bush meat, handicraft and construction materials such as using Ironwood tree to make coffins. Based on data collected, the Internal Factor Estimate Matrix (IFEM) is 2.59 while the External Factor Estimate Matrix (EFEM) shows a total of 2.58 indicating that Kg. Imbak, Tongod has a great potential and opportunities in terms of practicing the *Satoyama* model. There are 52 strategies determined in this research by using pair wise matching SO, WO, ST and WT.

Keywords: *Satoyama*, forest utilization, *Dusun Sungai* People, SWOT analysis, traditional knowledge, a community-based conservation effort

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Introduction

In early 1990, the concept of "mankind and nature are to live together" initially originated from Japanese words. It was improvised and translated to English to mean "harmonious co-existence between nature and mankind" (Iwatsuki, 2008). The concept described as "mankind and nature living together" is also known in biological terms as "symbiosis". It includes three types of phenomenon such as mutualism, commensalism and parasitism (Iwatsuki, 2008). The term "mankind" in this symbiosis concept refers to instances of humans parasitizing on nature. Therefore, if the words "symbiosis" is applied to the idea of "mankind and nature living together," it includes the concept that "mankind parasitizes nature" which describes a negative definition.

The concept of *Satoyama* is applied in societies in Japan. The first written reference to *Satoyama* is dates back to 1759. Forester Hyoemon Terauchi used the term *Satoyama* to describe the human-managed landscapes surrounding those communities. In Japan, the concept of *"mankind and nature are to live together"* can also be applied most at *Satoyama* zones of the Archipelago. The term *Satoyama* refers to a rural landscape adjacent to the *Hitozato* (villages in developed areas where people lived as local communities with agricultural fields), from which people got additional resources partly by a lifestyle based on collecting and hunting. With this understanding, the term *Satoyama* is also similar to the buffer zone of the Biosphere Reserved Area designated by UNESCO in the 1960s, which referred to a peripheral area for joining protected areas such as wildlife sanctuary with the residential area for the local community (Iwatsuki, 2008).

The *Satoyama*-like resource use such as "harmonious co-existence between nature and mankind," or secondary natural ecosystem, which is sustainable with interaction with the humans, is not unique to the Japanese society. *Satoyama* concepts are found in many places at many points of history globally, including *tagal* in Sabah, traditional *pekarangan* and *kebun-talun* in Java, etc.

Objectives of the research

1. To investigate similarities in the approach to *Satayoma* development in Imbak Canyon Conservation Area (ICCA), Sabah.
2. To determine *Satoyama* characteristics in the development of ICCA.
3. To explore the role of local community and stakeholders in the conservation and of the nature for sustainability.

Methodology

Research Site

There are many areas in Sabah involved in conservation and we selected Kg. Imbak, Tongod which is also well known as Sabah's heartland area, located approximately 260 km southeast from the capital city of Sabah, Kota Kinabalu. It takes a four hours' drive on a sealed road and continues with two hours of four-wheel drive on an unsealed road. There are 700 people of Dusun Sungai People and Murut community living at Kg. Imbak and with nature's riches and attractions.

Besides that, Kg. Imbak is a gateway to ICCA, which is also well known as one of the last frontiers of contiguous lowland forest with scenic views, high abundance of medicinal plants, and presence of nearby local communities. Kg. Imbak is only accessible by an unsealed road that cuts through it with stretches of modern ship wooden shops lined on each side.

Data Collection

The researchers conducted face-to-face interviews and field observation surveys from 28/09 – 04/10/2018. This method was chosen as it is more likely to elicit higher response rates than mail surveys (Lee & Han, 2002). Respondents aged 18 years and above are from the local community residing in Kg. Imbak, Tongod, Sabah. For this research, a qualitative data approach was used, therefore, sample sizes were ascertained in qualitative studies like in quantitative studies but not by the same means. The prevailing concept for sample size in qualitative studies is “saturation.” Saturation is closely tied to a specific methodology, and the term is inconsistently applied. The researchers proposed the concept of “information power” to guide adequate sample size for this research. Information power indicates that the more information the sample holds, relevant for the actual research, the lower amount of participants is needed. Thus, the researchers suggested that the size of a sample with sufficient information power depends on (a) the aim of the research, (b) sample specificity, (c) use of established theory, (d) quality of dialogue, and (e) analysis strategy. For this research, only 15 respondents were identified and interviewed (Malterud et al., 2016).

Data Analysis

Data was collected using Descriptive Analysis and SWOT analysis. SWOT analysis, an acronym for Strengths, Weaknesses, Opportunities, and Threats, is used in many fields, especially in the business planning department (Helms *et. al,* 2010).

It evaluates four (4) different elements of any project that involve specifying the research's objective and able to identify both internal and external factors to achieve the goals. Internal factors will identify both strengths and weaknesses of the plan. In contrast, external factors will provide an insight on opportunities and threats presented by the environment external to the local community. Collected data were analyzed using SWOT analysis and tabulated in IFEM and EFEM tables. Knowledge and insight needed could be identified for managers to make strategic decisions and guide their organization (Grant, 2008).

Results and Discussion

Demographic Profile

The preliminary data survey collected was based on an interview with the *Jawatankuasa Kemajuan Kampung* (JKK) Kg. Imbak, Tongod that showed the total population of their community was 796 persons. The majority of the community are Dusun Sungai People, and their primary religions are Christianity and Islam. However, this survey only interviewed a few villagers due to the far distance between the base camp to Kg. Tongod and challenging road accessibility due to the rainy season in ICCA.

Table 1. Profile of respondents – Demographic

Variables	Categories	Frequency	Percentage (%)
Gender	**Male**	**9**	**60%**
	Female	6	40%
Age	**21 > 30 years old**	**8**	**53%**
	31 > 40 years old	6	40%
	41 years old & above	1	7%
Level of education	Primary	2	13%
	Secondary	**9**	**60%**
	Tertiary	4	27%
Employment status	Self-employed	2	13%
	Government sector	**11**	**74%**
	None	2	13%

N = 15 respondents = 100 percent

Table 1 shows respondents' demographic profile based on five variables stated: gender, age, level of education, employment status, and monthly income (MYR). The result shows that male respondents (60%) were higher than female respondents (40%) in terms of gender—the distributions of male and female respondents equitably distributed in this survey. Eighty per cent of the survey was conducted at the base camp and information gathering was from the local community working as ICCA staff. The remaining 20% was completed at Kg. Imbak, Tongod.

About 93% of the respondents are aged between 21 and 40 years and 7% were above 50 years old, with the oldest respondent aged 80 years. A total of 796 persons were residing at Kg. Imbak, Tongod. Some 73% of the villagers completed their primary and secondary education, while 27% pursued their tertiary education. However, there were about three male respondents who did not complete secondary school due to the financial cost.

Female respondents (three persons) reached tertiary education level compared to male respondents (one person). Overall, most of the male and female respondents finished their primary school as Kg. Imbak, Tongod has a primary school, SK Imbak. They need to continue their secondary education at SMK Tongod, which is about 23 km from Kg. Imbak. In terms of employment, 74% of respondents work in t he government sector and 13% are self-employed. One-third of the respondents are working as wildlife rangers at ICCA , while most self-employed respondents are small retailers. Overall, most of the respondents are working, and only two of the respondents are housewives.

Monthly income (individual) and household expenditure

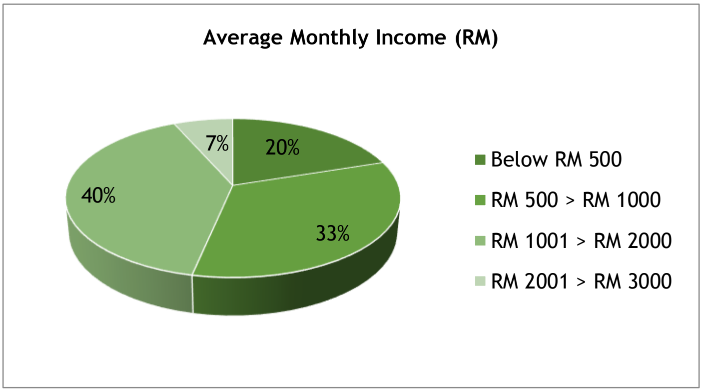

Figure 1. Percentage (%) Distribution of Respondent's Average Monthly Income (Individual)

Figure 1 above shows the percentage (%) distribution of the individual average monthly income of respondents. According to the pie chart above, each respondent has four segments of income: from below RM500 up to RM3,000 per month. The majority of respondents (46.7%) gained average monthly income between RM500 to RM1,000, while the lowest average monthly income gained by respondents consists of two categories, which are below RM500 (6.7%) and RM2,500 (6.7%) per month. There is no big difference between respondents that earned RM500 up to RM1,000 and RM1,001 up to RM2,000. As for small retailers, their average monthly incomes are between RM500 and up to RM2,000 and above. Based on an observation survey at Kg. Imbak, Tongod, there were about roughly 29 household members involved in small scale retail. Most of them sell vegetables and fish, petrol and fuel, and some own barbershops, cloth shops, bakeries, and even handicraft shops. One of the respondents was able to generate income of up to RM2,000 per month from her salted duck eggs and duck meat business.

Respondents who worked under ICCA have no financial issues when managing their household expenditure because they have permanent jobs. Overall, small scale retailers are the main economic source for the local community in Kg. Imbak, Tongod, due to the strategic location where tourists can stop to buy groceries before proceeding to the ICCA research centre.

Respondent's Source of Incomes

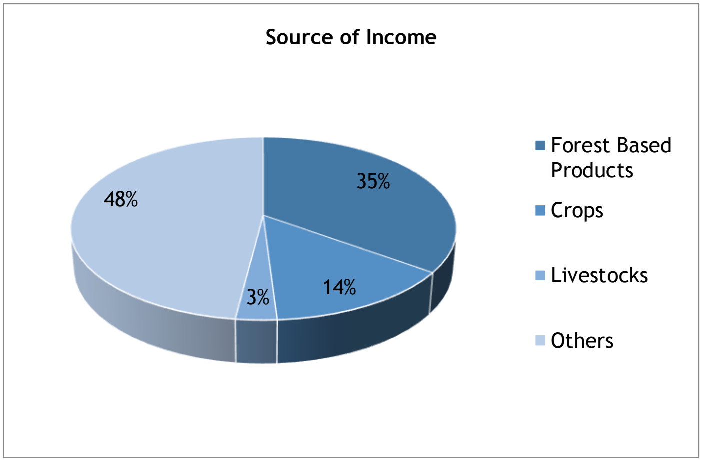

Figure 2. Percentage distribution (%) of respondent's source of income.

Figure 2 shows the percentage distribution (%) of the respondent's income sources. Four income sources were identified: from livestock, forest-based products, crops and others. Majority of the respondents have stable monthly income since almost all of them work with agencies such as government sectors. Beside working with governmet sectors, the data also shows that most respondents earned income from other sectors (48%), such as from homestay operations, small retailers (culinary and bakery) and part-time tourist guides during the weekend. The second highest source of income of respondents is from forest-based products (35%) followed by cash crops (14%) and livestock (3%). Forest sources such as ferns, bamboo shoots, and rattan or wild meats (deer, wild boar, and squirrel) were harvested for food and sometimes for commercial proposes (handicraft and fresh meats). Most of them said that their monthly payment (average below RM2,000) is sufficient enough to accommodate their daily needs.

Respondent's Average Monthly Expenditure

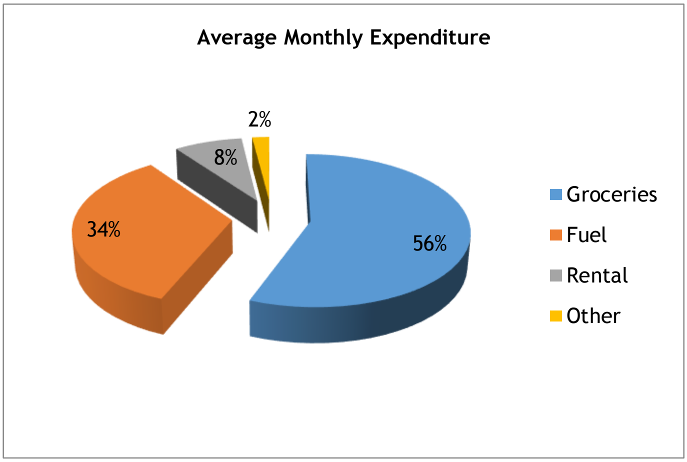

Figure 3. Average Monthly Expenditure (RM) of Respondent

Figure 3 shows the monthly expenditure (RM) breakdown of respondents. According to the pie chart above, there are four groups of expenditure made by respondent's monthly. The highest expenditure is for groceries (56%), followed by fuel (34%), room rental (8%) and other (2%) such as pocket money for school children. Groceries are essential as food stock among respondents since Kg. Imbak is located approximately 22 km from Pekan Tongod. Thus, local people tend to buy sufficient grocery stock to last them for a month. Recent research by those concerned with consumer practises and, in particular, with shopping practises (e.g., Miller, 1998; Gregson et al., 2002; Jackson et al., 2006) argue that shopping is more than an individual act, and rather a method of making meanings and values. For instance, Miller (1998) argued that ordinary acts of shopping, such as the purchase of household food, represent and enhance long-held social values such as thrift. For Miller, the importance of thrift can only be exercised by the repetitive actions of shopping, although the final items purchased can be different for different individuals based on how they assess quality. Thus, based on Miller's belief, this also happened amongst the local community of Kg. Imbak. Local people also spend their money on fuel and petrol because some of them still use generators for electricity while fishermen have engine boats. Based from the interview, it was discovered that a majority of the respondents can still afford their expenditure as most of them have few commitments, such as house rental, electricity and water bills, compared with urban people.

SWOT Analysis

Primary data and secondary data were collected and analyzed with SWOT analysis to access the harmonious co-existence between nature and people at ICCA and Kg. Imbak, Tongod. To determine the assigned weight, weight is assigned to each factor and the value of each weight should be between 0 and 1 (or alternatively between 10 and 100 if the 10 to 100 scale is used). Zero means the factor is not important, while one or hundred means the factor is the most influential and critical. However, the total value of all weights put together should equal 1 or 100. As for rate factors, rating is assigned to each factor, and is between 1 and 4. Rating indicates how effective the village's current strategies respond to the factor. Rating captures whether the factor represents a major threat (rating = 1), a minor threat (rating = 2), a minor opportunity (rating = 3), or a major opportunity (rating = 4). If rating scale 1 to 4 is used, then strengths must receive a 4 or 3 rating and weaknesses must receive a 1 or 2 rating. By multiplying each factor weight with its rating, a weighted score is attained (Ahmad Reza, 2011).

Table 2. Internal Factor Estimate Matrix (IFEM)

Strengths	Weight	Effectiveness Score	Final Score
Location Kg. Imbak is located on the gateway route to Imbak Falls (approximately 24 km using four wheel drive).	0.03	4	0.12
Facilities There are many retail stores (28) that sell various items, such as vegetables, gasoline, cakes, fabrics, kitchen utensils and also AGRO bank facility.	0.03	3	0.09
There is also a Ulu Kinabatangan information center where tourists can get information regarding ICCA and office for "Persatuan Porter dan Malim Kanyon Imbak", Tongod District, and a souvenir shop for local community crafts.	0.03	3	0.09
There is also a jetty on the banks of the Milian River as a facility for the Kg. Imbak using water transport such as fishermen.	0.02	3	0.06
Primary school, SK Imbak complete with water and electricity supply for the children of Kg. Imbak.	0.02	3	0.06
Natural resources As Kg. Imbak is located near forest reserve areas such as Gunung Tinkar Forest Reserve and Imbak Canyon Conservation Area, the natural resources are still abundant, such as wild boar, Belian tree, and rattan.	0.04	4	0.16
Socio-economic Small retailing, farming and agriculture such as oil palm plantation, banana farm and duck farm, are the main economic sources for the local community.	0.05	4	0.20
Culture The local community is actively involved in handicraft such as traditional rattan basket named "*wakid*", bamboo mat and basket with high values traditional motives, *bubu* and so on.	0.04	4	0.16
Kg. Imbak is dominated by Dusun Sungai people. The community has a unique culture. As for the funeral, they use *Belian* tree for the coffin engraved with buffalo heads motive. The coffin is covered with *kain songket* and kept in a cave so that their relatives can visit the deceased.	0.06	4	0.24
School committee of SK Imbak and community also collaborated by getting involving in cultural performances.	0.06	2	0.12
Community & Organization(s) JKK is responsible for managing the village development, and they send two community members for bakery training.	0.04	4	0.16
Kg. Imbak's community organization has an on-going *homestay* project for tourists, sponsored by Petronas in collaboration with Yayasan Sabah.	0.06	4	0.16
School committee of SK Imbak is also involved in environmental education sponsored by Petronas and			

ICCA, by organizing a programme that allows students to visit ICCA as a part of their research programme.	0.04	4	0.16
Weaknesses	**Weight**	**Effectiveness Score**	**Final Score**
Location The route was gravel and only can be accessed by four-wheel drive and no public transport.	0.03	2	0.06
Facilities Too many similar product among the retail shop especially vegetables type cause competition among the community.	0.01	2	0.02
No updated information, especially community activities and the basic facility such as toilet and electricity, is fair but sometimes no supply.	0.04	2	0.08
The jetty is just of basic design and safety is still a factor.	0.03	2	0.06
No environmental education and the school needs more environmental awareness.	0.05	1	0.05
Natural Source(s) Limited usage of natural sources by local community because some of the area is under protected area.	0.04	1	0.04
Socio-economic Large scale of land use required for agricultural activity.	0.04	1	0.04
Culture Their traditional handicraft is too common in Sabah and almost every town have *wakid, bubu* and *mat*.	0.04	2	0.08
A coffin requires a mature *Belian* tree and the quality of the coffin is determined based on the cutting process to reduce cracks in the coffin.	0.05	1	0.05
There might be commitment issues in cultural society due to time constraints since the school reputation are evaluated through academic exam achievement.	0.02	2	0.04
Community & Organization(s) Limited quota for skills and training programme and only selected community members can participate in capacity building .	0.04	2	0.08
Lack of promotion since there was weak communication link between Kg. Imbak and the main town due to poor network coverage to attract tourists.	0.04	2	0.08
Presently, environmental education is not listed as core subject by the Ministry of Education and only selected students can visit and explore ICCA centre. Hence, environmental knowledge was not distributed equally among the students.	0.05	1	0.05
Total	**1**	**-**	**2.59**

In this research, about 13 strength factors were identified and categorized into location, facilities, natural source, socioeconomic, culture, and community organization. The weight allocated to these factors was mounted between 0.01 and 0.06 and the effectiveness score ranged between 1 and 4.

Based on Table 2, "culture" has the highest factor at 0.24. Kg. Imbak is dominated by Dusun Sungai people community and their unique culture is still preserved such as funeral culture that uses *Belian* tree (Ironwood) as the coffin engraved with bufallo head motive and covered with *kain songket* for their deceased ancestor and the coffin is kept in a place such as a cave so that their relatives can visit their deceased ancestor. The lowest weight was 0.02 while the effectiveness score ranged between 1 and 2. Thus, the final score for IFEM table was 2.59. The results are shown in Table 2.

Table 3. External Factor Estimate Matrix (EFEM)

Opportunities	Weight	Effectiveness Score	Final Score
Location			
Kg. Imbak as one of the transit points/pit stops for tourists en route to Imbak's Fall and Gunung Tinkar.	0.04	4	0.16
Facilities			
Small retailing generates direct income for local community.	0.03	4	0.12
Increase in job opportunity for the local community to operate the centre.	0.06	4	0.24
The jetty allowed community to do river cruise activity with tourist.	0.02	3	0.06
School also can be attractive when it decorated with ecofriendly landscape to increase environmental awareness.	0.04	3	0.12
Natural Source(s)			
Local community still can access and use forest sources sustainably by applying permit.	0.04	4	0.16
Socio-economic			
Increase of income generating activity by local community through agricultural industry.	0.02	4	0.08
Culture			
Product enhancement on traditional handicraft meets market demand and fashion industry to make it more classy, branded and valuable.	0.04	3	0.12
Belian tree is of high value and strong material for the construction and furniture building industry.	0.08	4	0.32
A great collaboration by the school committee and Kg. Imbak community so that they can preserve the "Dusun Sungai People's" traditional music and dances.	0.03	4	0.12
Community & Organization(s)			
A skillful and well-trained community is ready to venture in a new industry that affords present industry demand.	0.02	4	0.08
Local community is able to generate side income through homestay programmes and more basic facilities will be improved due to tourist demand.	0.02	3	0.06
There is increasing environmental awareness and knowledge among the young generation.	0.02	4	0.08

Threats	Weight	Effectiveness Score	Final Score
Location Too many vehicles on the road might cause road accidents with wildlife.	0.01	2	0.02
Facilities There might be an unbalanced income source among the seller depending on product types and consumer demand.	0.05	2	0.10
Increasing the number of tourists can cause traffic, and the local community is not pleased with tourists' presence.	0.01	2	0.02
When water transportation is available, wildlife's natural habitat might be disturbed with human presence and illegal hunting and poachers easily access and escape from the reserve area.	0.07	2	0.14
Operation cost and financial issue will rise to decorate and maintain the schools.	0.02	2	0.04
Natural resource(s) Manipulation of forest sources could happen if there is no frequent monitoring activity by the enforcement team.	0.06	1	0.06
Socio-economic Increasing land usage for plantations also might cause habitat loss, environmental pollution and human animal conflict.	0.05	1	0.05
Culture The handicraft might lose traditional identity since the design are mixed with contemporary design and increased usage of natural source such as rattan might cause extinction.	0.05	2	0.10
Unsustainable used of *Belian* tree might cause extinction since the growth rates of *Bellian's* crop to mature tree are slow. Illegal lodging of *Belian* tree also increases due to high market demand in timber industry.	0.07	1	0.07
Student activities increases and they might face overload capacity in their daily routine instead of researching.	0.05	2	0.10
Community & Organisation Unfair knowledge, skills and training distribution among the community members that might affect their relationship, unity and trust.	0.05	2	0.10
Increase in social problems that might affect traditional culture of local community.	0.01	2	0.02
Too many subjects in education system might cause student overload to receive input. Hence, the information and knowledge are not distributed very well.	0.04	1	0.04
Total	**1**	**-**	**2.58**

According to Table 3, there were about 13 factors pertaining to opportunities as well and have been categorized into location, facilities, natural resource, socioeconomic, culture and community organization. The weight allocated to these factors is between 0.01 and 0.08. Meanwhile the effectiveness scores ranged between 3 and 4. The highest weighted score for EFEM is 0.32 stating that the *Belian* tree is of high value and strong material for construction and furniture building industry. However, the lowest weighted score is 0.02 consisting three threat factors -- too many vehicles on the road that may cause road accidents with wildlife, increase in number of tourists that can cause traffic and local community are not pleased with the presence of tourists, and increase in social problems that might affect traditional culture of the local community. Ultimately, the final score was 2.58. The result of this stage is shown in Table 3. The value of internal factor equalled 2.59 in Table 2, implying that strengths were more than weaknesses. At the same time, the value for external factor in Table 3 equalled 2.58, indicating that the opportunities are also more than threats. With that, it can be said that Kg. Imbak, Tongod has great potential and opportunities in terms of practicing the *Satoyama* model.

There were about 52 strategies determined in this research by using pair wise matching SO, WO, ST and WT. The general strategies are to improve the situation analysed through SWOT and are summarized below:

- S - O strategies proposed opportunities that fit well with the village strengths.
- W - O strategies to overcome weaknesses to suggest opportunities.
- S – T strategies to identify the ways that can be used to reduce vulnerability to the external threats.
- W – T strategies to establish a defensive plan to prevent the park's weaknesses from making it highly susceptible to the external threats.

Table 4: *Satoyama* Development Mechanism Strategies

***Satoyama* Development Mechanism Strategies**
SO strategies
1. Night safari activity could be added as an ecotourism activity along the road.
2. Grouping the retailers based on products they sell to reduce competition among themselves.
3. Appointed local community to get involved in operation of the information centre.
4. Creating a Fishermen's Association Kg. Imbak to carry out river activities including carrying out jetty upgrading work.
5. Using recycled materials to create ecolandscapes around the school complete with 3R bin.
6. Increase awareness among the local community to differentiate protected species and

common species.
7. Focus on current products and invent various products (eg. *Kerepek pisang*, banana wine, banana jam) from single type of agricultural plantation such as banana trees.
8. Skill and training for local community to create contemporary product that enable consumers use it every day, such as "*barait*" and rattan sling bag.
9. The uniqueness of old *Belian* coffin and funeral site could be one of tourism destination to attract tourist and learn "*Dusun Sungai* People's" culture.
10. Encourage school participation in dance art and cultural performances at international level so that student can promote their village as well.
11. Trained community member share their skill and training with other community member to make sure the skill and training are equally distributed.
12. Any homestay programme should be recognized and certified.
13. ICCA and Petronas organized more environmental activities such as camping programme inside ICCA and students are taught how to identify tree species and other basic conservationist tasks.

WO Strategies
1. Collaborate with tour and travel agency to improve transportation issues.
2. Reducing the price of products to avoid competitions.
3. JKK and community association organize weekly activity such as sports day to unite all the villagers and their activities are well documented at the information centre.
4. Enhance the jetty with additional huts and barriers for safety purposes.
5. More posters or mural paint about environmental awareness to encourage students to conserve and preserve nature.
6. Strictly enforce permit usage to access and harvest forest resources to avoid over exploitation.
7. Apply systematic agriculture and minimize land use by using terrace farming method or rotary crops type in single plot of agricultural land.
8. Collaborate with the Malaysian Handicraft Development Cooperation to guide local community enhance their handicraft products and also product marketing.
9. Control the usage of *Belian* coffin limited to elderly deceased only.
10. Establish a village culture society that comprises various age groups instead depending too much on SK Imbak.
11. JKK plays an important role to select potential community members that have high commitment and deserve training.
12. Collaborate with Sabah Tourism Boarrd, travel and tour agencies to promote the homestay.
13. Sabah's Ministry of Education and MOSTI (Ministry of Science, Technology and Innovation) should create School Environmental Club similar at Sarawak to encourage schools to establish *Kelab Pencinta Alam Sekitar* (PALS) to develop and pursue students interest in environmental conservation and protection.

ST Strategies
1. Create buffer zone for wildlife pedestrian along the road.
2. Revise and rebrand the current products to make it different and high market value from other village's product.
3. Tourism product and packages needs to be evaluated so that capacity for the community to accept tourist can be estimated.
4. Monitoring of river water quality every month and setting laws to penalize anyone suspected

of polluting the river.
5. Propose volunteer programme from agencies to give a talk about environmental education.
6. All stakeholders collaborate with the local community to monitor any suspicious activity such as the presenceof outsiders to reduce illegal hunting and poachers.
7. Introduce organic plantation to enhance crop yield by using compost soil , organic pesticides, biological control to reduce land use and pollution.
8. Control the usage of forest use such as rattan and focus more on abundance forest source such as bamboo.
9. Creating a joint venture with Sabah Forestry Department to grow more *Belian* trees for future use.
10. Organize regular schedules for dance training and encourage participation from primary one until primary four students.
11. JKK are more active and alert with district government on community programme enhancement.
12. Establish volunteer association such as *Persatuan Rela dan Rukun Tetangga* to reduce social problems and crime.
13. ICCA and PETRONAS organize environmental and young apprentice programme during school holidays and open this to any available young generation from Kg. Imbak.

WT Strategies

1. Place more speed limit signboards along the road to prevent fatal accidents between vehicle and wildlife.
2. All community focus on one type of product and scientific studies are needed for innovation.
3. Create collaboration with tour and travel agencies to deal with tourists regarding booking and reservation.
4. Increase awareness programmes regarding river conservation, proper sanitary and waste system to reduce river pollution by humans.
5. Create budget and proposal to seek funding and monitoring report for ecoschool environment.
6. Create collaboration with local villagers in order to monitor any suspicious foreigner at every border area to reduce illegal hunting and poachers.
7. Introduce millennial farming system such as aquaponic and vertical farming to minimize land usage.
8. Develop high quality traditional handicraft made from rattan that have premium value and sell it at a high price.
9. Replace the usage of *Belian* tree with other types of wood species but maintain the design and engraved motive of the coffin.
10. Other than traditional dances performed by students, elderly local community also can perform musical performance.
11. Selection of the participant is based on member's interest and types of available programme/training.
12. Create custom local communities law such as *sogit* to reduce social problems at village level.
13. Reduce unrelated subjects and focus on environmental education at SK Imbak as this is a platform for the future generation of the local community to get involved in ecosystem conservation.

Forest usage

Kg. Imbak has both road and river access that enables goods and supplies to be easily transported in. Typically, the types of forest resources collected and used can be divided into four categories:

1. Construction material
2. Handicraft
3. Bush meat
4. Medicinal plants

a. Construction materials

Timber logs used as *Lanteng*, which means floating jetty that functions as a floating beam and acts as a float. *Lanteng* is a multipurpose hut used as a jetty, boat engine and fuel storeroom, fishing hut and as the lavatory. When operated as a lavatory, a square hole is made on the *lanteng* floor. It is tied to a tree or strong pole to avoid being washed away by the river's current or flood. *Lanteng* is no longer made of timber logs as the Petronas fund was used to build a new jetty for the local community. Meanwhile, based on the field survey and observations, most of the house structures of the local community at Kg. Imbak is made of wood-based materials, and some of the houses were semi brick and wood-based.

The Dusun Sungai people have a funeral tradition where they use *Belian* tree as a coffin for their deceased elderly people. One matured *Belian* tree (Ironwood tree) with approximate 1 m diameter can make a full coffin. Usually, to construct or rebuild houses or *Belian* coffin making, larger logs are collected from outside the village, along the periphery of the forest reserves where the mature trees occur. However, at times conflict with the Sabah Foresty Department and Yayasan Sabah can occur when villagers are deemed to have slipped into the forest reserves and logs harvested were confiscated, much to the dissatisfaction of local villagers.

b. Bush meats

Very little hunting occurs today in Kg. Imbak, as their awareness about forest conservation and protected areas has increased. However, a wild animal such as wild boar, squirrel and deer may be sought as food source when the opportunity arises.

c. Handicraft

Bamboo and rattan are collected and commonly used in the making of traps such as *bubu*, basket such as *wakid*, handicrafts and traditional tools. Presently, the women community of Kg. Imbak engage in handicraft making and sale for tourism. They have one shop at Ulu Kinabatangan Information Centre to exhibit their handicraft and sell these as souvenirs.

d. Medicinal Plants

Medicinal herbs are from the forests, and among the more popular herbs are *Langot, Ambiau, Sangkarang* and *Topok*. Eventhough, more households today rely on access to clinics and hospitals in nearby small towns in Tongod District, medicinal herbs are still crucial for Dusun Sungai people in Kg. Imbak, especially when there is an emergency.

Community-Based Conservation Efforts

Existing Conservation Efforts

Imbak Canyon was designated a Class I (Protection) Forest Reserve in 2003 by Yayasan Sabah Group, making it a conservation area for research, education, training and recreation. It is one of four conservation areas in Sabah in addition to Tumenung Hullu and neighbouring Danum Valley and Maliau Basin. There are various grounds for the protection of ICCA including biodiversity, particularly botanical, geological including the scenic amenity associated with the site, and the neighbouring indigenous community and unique range of forest knowledge they possess which as yet remains not fully documented.

To accelerate efforts to preserve the pristine ecology of the canyon for the benefit of present and future generations, Yayasan Sabah entered into a sponsorship agreement on ICCA with Petronas, which allocated a total of RM83 million in two phases towards the preservation of the 30,000 ha ICCA (New Straits Times, 2015). The scope of funding (first phase: RM6 million) covers environmental education, community outreach and public awareness, including construction of the Ulu Kinabatangan Jetty in Kg. Imbak. Meanwhile, the second phase of the funding (RM77 million) was for the construction of the Imbak Canyon Research centre in 2013. The aim is to link the community in Kg. Imbak and researchers who were also covering Ethno-Forestry research and documentation (Daily Express, 2015). The ICCA provides facilities such as a research centre for the indigenous community in biodiversity and sustainable use of natural resources. Overall, based on the collection of secondary data, there were about four types of community-based conservation efforts (under sponsorship of Yayasan Sabah and Petronas) that have been implemented at Kg. Imbak between 2013 and 2017. These are:

1. Preservation of the traditional knowledge through traditional medicine practitioners
2. Forest knowledge through porters and guides for visitors at ICCA
3. Engagement of women involved in handicraft making
4. Environmental education for young generations under *Program Sentuhan Ilmu PETRONAS*
5. "*Homestay Po'pomponan*" through Planting Tomorrow Programme

a. Preservation of traditional knowledge through traditional medicine practitioners.

The local community has a strong bond with forest and nature. Before modernization, the local community used herb and forest plants in their traditional healing practices. The traditional healing practice of the local community was very useful in improving the harmaceutical field through local plant identification and their usage. Thus, community outreach programme has successful recruited at least two members of the local community (Mr. Tomas Sayang and Mr. Lokman Jawa) from Kg. Imbak to preserve their traditional healing practices.Both of them have used plants locally named *Langot, Ambiau, Sangkarang* and *Topok* for over 50 years to cure illness such as headache, cough, fever and also can be used as poison or decoration purposes (The Borneo Post, 2015). However, the interest to become traditional plant healing practitioners among the young generation is low due to easy access to nearby hospital and clinic at Tongod district. Thus, they said it was important for the younger generation to master in plant identification and conservation for future benefits especially in the medical and pharmaceutical field. This traditional knowledge has been documented and catalogued by the local community under PETRONAS and Yayasan Sabah sponsorship programme for future record.

b. Forest knowledge through porters and guides for visitor at ICCA.

Persatuan Porter dan Malim Kanyon Imbak have been established and registered under the Registrar of Societies (Jabatan Pendaftaran Pertubuhan Malaysia) since March 2017 (Yayasan Sabah, 2019) and most of the members are appointed from the Kg. Imbak's community. All porters and localized tourist guides had their licenses funded by Yayasan Sabah. Thus, the local community may be able to expand their source of income by carrying out tour and guiding activities. Most of the local tourist guides were appointed to assist tourists hiking into ICCA.

c. Engagement of women through handicraft.

Women play an important role in the local community development especially in Kg. Imbak. Recognizing the importance of women's contribution in the development of the tourism industry in Kg. Imbak, JKK Kg. Imbak lead by Mdm. Nur Linda, has sent several women representatives from among residents of Kg. Imbak to participate in culinary skills and handicrafts in conjunction with the sponsorship programme with PETRONAS and Yayasan Sabah. According to JKK Kg. Imbak, so far two residents have managed to open their own cake shop as a result of previous culinary and bakery skills training. At the same time, the villagers are also well-versed in bamboo and rattan handicraft making such as mats, *wakid* and these handicraft products have the potential to be commercially marketed internationally as tourism products for Imbak's community.

e. Environmental education for young generations under Program Sentuhan Ilmu PETRONAS

After the ICCA was created as a premium forest reserve, Yayasan Sabah and Petronas realized that the involvement of local residents in conservation activities was crucial to ensure sustainability of the forest reserve. Dusun Sungai people also play an important role in conservation activities surrounding it. The villagers' cooperation facilitates the monitoring of forest reserves from encroachment by illegal loggers as well as poachers. Therefore, Yayasan Sabah and Petronas have organized an environmental awareness and education activity with students of SK Imbak, Tongod, known as the "*Program Sentuhan Ilmu* PETRONAS." Selected students from Primary 4 have the opportunity to carry out activities at ICCA such as the identification and classification of plants and wildlife.

f. "Homestay Po'pomponan" through Planting Tomorrow Programme

In addition, Kg. Imbak has the potential to be developed as a tourism spot due to its strategic location on the way to Imbak Canyon and Kinabatangan River. Kg. Imbak is also easily accessible to the tracking trail to Gunung Tinkar Forest Reserve which houses unique attractions (peak is exactly at the centre of Sabah) and also represents strong tourism attractions for Kg. Imbak. The starting trail for hiking atGunung Tinkar is about 30 minutes' drive from Kg. Imbak and a hike to and fro an approximately 582.4 m peak takes about six to eight hours (New Straits Times, 2017). Thus, Kg. Imbak always act as a pit stop for tourists before they continue hiking Gunung Tinkar or visiting Imbak Canyon Conservation Area. Currrently, there are about 22 registered homestay operators known as *"Homestay Po'pomponan" and* have been operating since 2016 (BERNAMA, 2017). PETRONAS has funded and sponsored building materials for the homestays, and built a handicraft kiosk and gravity-fed water supply system for the local community through the Planting Tomorrow Programme with an aim to improve the standard of living through the provision of alternative water supply solutions and livelihood enhancement activities.

Conclusion

This research examines the strengths, weaknesses, opportunities and threats of harmonious co-existence between mankind and nature between a conservation area (ICCA) and a local community (Kg. Imbak). The livelihood of the community in Kg. Imbak is fully affected by the nearby conservation area especially the Dusun Sungai people in Kg. Imbak community in terms of culture, socioeconomy and education. Overall, the local community of the Dusun Sungai people still depend on forest resources such as *Belian* tree for funeral purposes. Scientifically, *Belian* tree or *Eusideroxylon zwageri* (Ironwood) is of very high quality and is used for the construction and furniture industries (FRIM, 2014). However, this tree species is a slow growth plant and the unsustainable usage of *Belian* tree could make this species extinct. Dusun Sungai people's cultures are very unique and it gained advantage from the gazetting of the nearby forest reserves making Kg. Imbak a potential tourism site. Although forest resources extraction and utilization still occurs in the village, the potential harmonious co-existence in the research site following the *Satoyama* model was identified through SWOT analysis. The Internal Factor Estimate Matrix (IFEM) is 2.59 while the External Factor Estimate Matrix (EFEM) shows a total of 2.58 indicating that Kg. Imbak, Tongod has great potential and opportunities in terms of practicing the *Satoyama* model. There are 52 strategies determined in this research by using pair wise matching SO, WO, ST and WT that can be reviewed and implemented to ensure minimal human impact on natural resources adjacent to the conservation area.

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Short Notes

Preliminary Checklist of Orchids in the Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA), Sabah, Malaysia

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Abstract
A study on orchids diversity was carried out in the Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA), Sabah, Malaysia. The study aimed to record species composition and distribution of orchids in the furtherance of orchid conservation objective in the gazetted conservation area. A total of 95 species and 30 genera were collected from South Rim, Kawang, and Nepenthes trails. The collection consists of 91 epiphytes, two terrestrials, and two mycoheterotrophs. More orchids were found in the riverine than inland areas. Our study on the species composition based on the vegetation types shows that the presence of inconspicuous and achlorophyllous, either mycoheterotrophic or leafless epiphytic orchids, are indicators of the undisturbed vegetation types. Though the finding was preliminary and brief, our encounter of endemic and rare species underlines the importance of Sungai Kangkawat forest area as an orchid biodiversity hotspot.

Keywords: Borneo, endangered, ICCA, lowland forest, Orchidaceae, riverine forest.

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Introduction

Imbak Canyon Conservation Area (ICCA) comprises 30,000 hectares of undisturbed rainforest located deep in the heart of Sabah, approximately 300 km from Kota Kinabalu. The conservation area consists of a 25 km long valley surrounded on three sides by steep sandstone cliffs up to 1,000 m. Its stunning wilderness area essentially forms a self-contained ecosystem. This forest area is also an important wildlife corridor linking two protected areas in Sabah -- Danum Valley and Maliau Basin, and is enriched with plant biodiversity and acclaimed as a genetic seed bank. Recognising the significance of this heritage site for conservation, the Sabah State Government gazetted Imbak Canyon as a Class I (Protection) Forest Reserve in 2009, providing legal status as a protected area (Latif & Sinun, 2012). The ICCA comprises primary lowland mixed dipterocarp and upper montane forests, including at around 800 m of the dipterocarp forest that starts with patches of montane heath or *kerangas* forest (Pesiu et al., 2019). Upper elevations of the canyon home to a high diversity of carnivorous pitcher plants and orchids.

Thus far, a number of botanical studies carried out by local institutions within the ICCA have provided insights on species composition and ecology of the vascular plants. The most recent study aimed to document the diversity of the interesting, endemic, rare, and threatened plant species in Batu Timbang by Pesiu et al. (2019). A total of 413 species from 82 families were recorded from the study area of which 93 species were endemic to Borneo, including 10 endemic species to Sabah (Pesiu et al., 2019). Meanwhile, previous expeditions in Mount Kuli by Suratman et al. (2011) recorded 153 tree species from 46 families, and Sugau et al. (2011) on the study of Dipterocarpaceae recorded a total 42 species. A few studies on other vascular plants, such as by Chong et al. (2011) on the study of *Begonia* recorded eight species, and Shim et al. (2011) on the study of ferns recorded a total of 104 species from 21 families. Noteworthy is a study on Orchidaceae by Go et al. (2011) that reported a total of 109 species in ICCA. With approximately 25,000 species, orchids are the most speciose and widespread flowering plants (Swarts & Dixon, 2009). It is estimated that as abundant as 3,000 species of wild orchids occur in Borneo (Lamb, 1991; Beaman et al., 2001).

Sadly, the abundance and distribution ranges of plant species in and around the ICCA have largely declined due to selective logging, development of human settlements, and large-scale agriculture (Bernard et al., 2013). Therefore, as part of a conservation effort, a scientific expedition was conducted with an objective to record the diversity, composition, and distribution of orchids in selected sites in the Sungai Kangkawat area of ICCA. There is still a lack of knowledge concerning the orchid flora of different vegetation types in ICCA. The expedition was also intended to collect principal information to support the development of a biodiversity conservation management plan in the ICCA. Here in this paper, we report our preliminary findings.

Materials and Methods

Study site

A botanical sampling through a geographic expedition was held from 28th September 2018 to 4th October 2018 in a lowland mixed dipterocarp forest, which includes a riverine forest, in the Sungai Kangkawat Research Station, ICCA (Figure 1). Three selected trails were studied; South Rim, Kawang and Nepenthes trails.

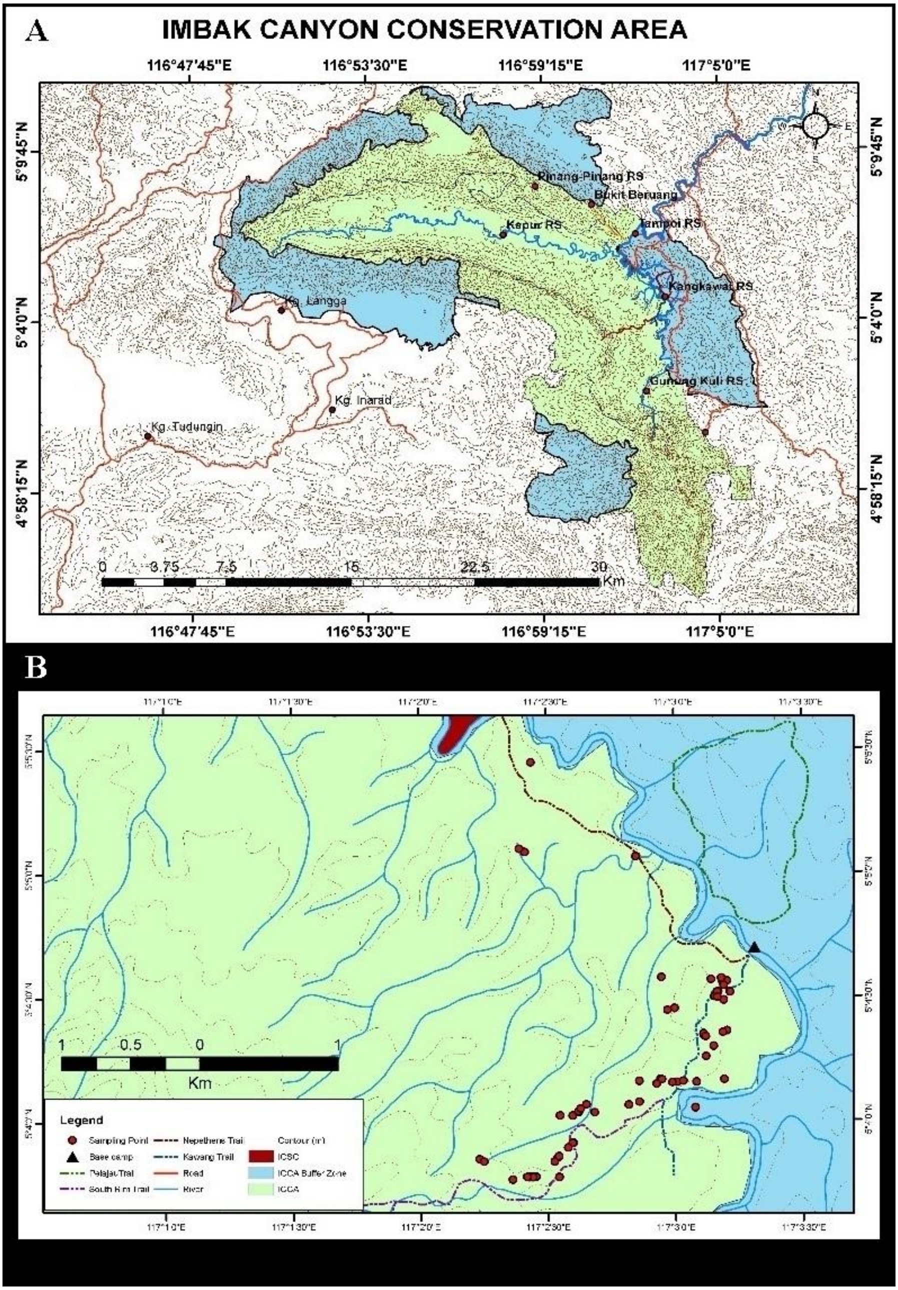

Figure 1. Imbak Canyon Conservation Area (ICCA) in Sabah (A) and locations of the sampling plots (B).

Sample collection and processing

The field exploration was done using opportunistic sampling method. The samples, with or without floral structures, were preserved using standard herbarium technique after Bridson & Forman (2000), and the ones without floral structures were transplanted into an ex-situ conservatory in the Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah (UMS), as living collections, where the plants were further nourished for flowering.

Sample identification

The orchid taxa were identified according to the monographs of Seidenfaden & Wood (1992), Wood (1997), Beaman et al. (2001), Comber (2001), and Wood (2003). The legitimate nomenclatures were checked through the KEW World Checklist of Selected Plant Families (WCSP) (Govaerts et al., 2020). A total of 65 species of these were identified only at genus level due to the lack of floral structures or flowers alcohol collections. Some of the fertile specimens had damaged flowers, making photography and dissection difficult. Moreover, upon making this checklist, only a few of the living plants cultivated in the ex-situ conservatory were blooming. Hence, the identifications of the incomplete specimens were made based on the diagnostic morphology of the vegetative structures alone. The distribution status was validated by referring to the monographs and checklists of Wood et al. (1993), Wood & Cribb (1994), and Beaman et al. (2001); and digitalised herbarium collection deposited in the international databases, such as Swiss Orchid Foundation (SOF) (https://orchid.unibas.ch/index.php/en/), National Herbarium of the Netherlands (NHN) accessed through Browse Dutch Natural History Collections: BioPortal (Naturalis) (http://bioportal.naturalis.nl/), and also WCSP (Govaerts et al., 2020).

Results and Discussions

A total of 147 orchid specimens were collected from South Rim (40 specimens), Kawang (47 specimens), and Nepenthes (60 specimens) trails. The total specimens are confined to 95 species and 30 genera, and consisting of 91 epiphytes, two terrestrials, and two mycoheterotrophs. Of these, only 31 specimens were completely identified to their respective taxa. The findings are listed in Table 1. The checklist includes brief information on each species growth habits, trails, and elevations. Some of the collected orchid species are shown in the Colour Plate (Figure 2, 3, 4 & 5). Of these identifiable specimens, two species are recorded as endemic to Borneo; *Phalaenopsis modesta* (Blume) Blume and *Trichoglottis borneensis* (J.J.Wood) Kocyan & Schuit. (Figure 2).

However, *Trichoglottis borneensis* was only identified based on the narrowly elliptic with acuminate apex, well-spaced, and dark green leaves that describe the homotypic genus, *Ventricularia,* a recircumcribed genus belonged to the subtribe Aeridinae (Kocyan & Schuiteman, 2014), and the very short inflorescence and scale-like floral bracts (Seidenfaden & Wood, 1992). It is comparable to the closely related *Trichoglottis ventricularis* Kocyan & Schuit by having a distinctly larger plant.

Figure 2. Orchids endemic to Borneo found in ICCA, *Phalaenopsis modesta*; A: flower (of a plant cultivated in the ex-situ conservatory), B: plant; *Trichoglottis borneensis*; C: plant.

In addition, we had an interesting finding of *Agrostophyllum trifidum* Schltr. and *Appendicula merrillii* Ames (Figure 3), two rare species with a small range of distribution (Govaerts et al., 2020) or small area of occupancy in Malaysia. Also, we encountered terrestrial species that are often overlooked to the inconspicuous appearance yet diminishing in the wild due to forest disturbance. Some species with striking appearance are also threatened by illegal collection, and now mostly confined to undisturbed or primary habitats (Besi et al., 2020). This includes jewel orchids *Cystorchis javanica* Blume, one species of genus

Zeuxine Lindl., a ghost orchid *Taeniophyllum* Blume (Figure 3), and two mycoheterotrophs, a small plant of *Aphyllorchis pallida* Blume and *Lecanorchis multiflora* J.J.Sm. (Figure 4).

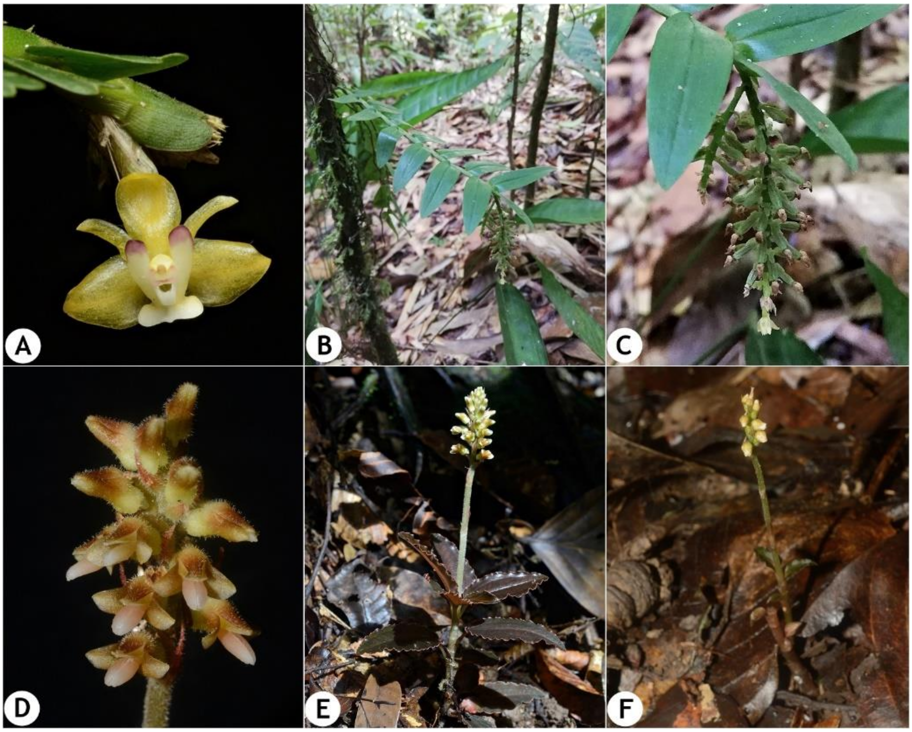

Figure 3. Rare orchids found in ICCA, *Agrostophyllum trifidum*; A: flower, *Appendicula merrilii*; B: plant, C: inflorescence, *Cystorchis javanica* (jewel orchid); D: inflorescence, E: plant, *Zeuxine* sp. 1; F: plant.

Moisture-demanding orchid species depend primarily on vegetation types and the ground condition (Besi et al., 2019, 2020). Nepenthes trail harboured the most abundant orchid species, where the mycoheterotrophic orchid species were discovered growing on the moist riverine forest floor (Figure 4). Its location close by the river, a water source, provides more moisture and nutrients to the area, hence, the most favourable condition for mycoheterotrophy. The extent of their leaf reduction is an adaptation to the heterotrophic mode of nutrition of these peculiar orchid species. They normally produce green leaves abd occasionally achlorophyllous (Salmia, 1989). Adaptation to heterotrophy was limited in this species since leaves are still well developed in the achlorophyllous form. Progressive reduction in the length and numbers of leaves which parallel reduction in green pigmentation and change of habitat from open sites to shaded woodland habitats (Cribb, 1978).

Figure 4. Mycoheterotrophic and ghost orchids found in ICCA, *Aphyllorchis pallida* (mycoheterotroph); A: flowers, B: plant, *Lecanorchis multiflora* (mycoheterotroph); C: flower, *Taeniophyllum* sp. 1 (ghost orchid); D: plant.

Comparable to the ghost orchid, *Taeniophyllum*, is another type of achlorophyllous orchid living uniquely by being leafless and only has photosynthetic roots for survival. Their narrowness to the shaded pristine forest area has made them the best biological indicator for climatic changes and soil health. This also simply means that the Nepenthes trail was very much undisturbed compared to the other trails explored during the short expedition. Consequently, the results indicate conservation priorities, and can be used for conservation planning, as well as for the management of habitats in which orchids grow.

Conclusions and Recommendations

The collection of 95 orchid species only represents a very small percentage of the orchid diversity of ICCA. Most of the specimens lacked floral structures upon identification. Nevertheless, the species richness could be higher if the specimens were fertile. It can be concluded that the cool, moist, and shaded conditions in the riverine forest are pleasant for orchids. Our results particularly show that the indicator species have a significant presence in the riverine area, the undisturbed area and area near to a water source. However, a deeper study is required to assess the impact of other factors on the distribution and abundance of orchids, including the effects of mycorrhizal fungi and different types of management. It is very important to keep this pristine environment protected to ensure the survival of precious orchids and other organisms. In response to foreseen threats, the integrated conservation approaches sponsored by Malaysia's national oil company, Petronas, and managed by the Yayasan Sabah, are highly recommended to be continued.

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Table 1. Preliminary List of Orchid Taxa found in three Selected Trail in Sungai Kangkawat, ICCA, Sabah

Genera		Taxa	Trails	Growth Habits	Elevation, Δ (m)
(1) *Acriopsis* Reinw. ex Blume	(1)	*Acriopsis indica* C.Wright	Kawang	Epiphytic	207
	(2)	*Acriopsis liliifolia* (J.Koenig) Ormerod var. *liliifolia*	South Rim	Epiphytic	285
(2) *Agrostophyllum* Blume	(3)	*Agrostophyllum glumaceum* Hook.f.	Kawang	Epiphytic	238
	(4)	*Agrostophyllum trifidum* Schltr.	Kawang	Epiphytic	207
(3) *Aphyllorchis* Blume	(5)	*Aphyllorchis pallida* Blume	Nepenthes	Mycoheterotroph	203
(4) *Appendicula* Blume	(6)	*Appendicula merrillii* Ames	South Rim	Epiphytic	220
	(7)	*Appendicula reflexa* Blume var. *reflexa*	Kawang	Epiphytic	203
	(8)	*Appendicula* sp. 1	Kawang	Epiphytic	227
(5) *Bryobium* Lindl.	(9)	*Bryobium pudicum* (Ridl.) Y.P.Ng & P.J.Cribb	Kawang	Epiphytic	197
	(10)	*Bryobium* sp. 1	Nepenthes	Epiphytic	213
	(11)	*Bryobium* sp. 2	Nepenthes	Epiphytic	213
(6) *Bulbophyllum* Thouars	(12)	*Bulbophyllum apodum* Hook.f.	South Rim	Epiphytic	285
	(13)	*Bulbophyllum caudatisepalum* Ames & C.Schweinf.	South Rim	Epiphytic	264
	(14)	*Bulbophyllum flavescens* (Blume) Lindl.	Nepenthes	Epiphytic	227
	(15)	*Bulbophyllum longerepens* Ridl.	Nepenthes	Epiphytic	213
	(16)	*Bulbophyllum macranthum* Lindl.	Nepenthes	Epiphytic	227
	(17)	*Bulbophyllum macrochilum* Rolfe	South Rim	Epiphytic	221
	(18)	*Bulbophyllum* sp. 1	South Rim	Epiphytic	235
	(19)	*Bulbophyllum* sp. 2	Nepenthes	Epiphytic	230
	(20)	*Bulbophyllum* sp. 3	South Rim	Epiphytic	218
	(21)	*Bulbophyllum* sp. 4	South Rim	Epiphytic	321
	(22)	*Bulbophyllum* sp. 5	Nepenthes	Epiphytic	182
	(23)	*Bulbophyllum* sp. 6	Nepenthes	Epiphytic	204
	(24)	*Bulbophyllum* sp. 7	Nepenthes	Epiphytic	203
	(25)	*Bulbophyllum* sp. 8	Kawang	Epiphytic	207
	(26)	*Bulbophyllum* sp. 9	Kawang	Epiphytic	201
	(27)	*Bulbophyllum* sp. 10	Kawang	Epiphytic	224
	(28)	*Bulbophyllum* sp. 11	Kawang	Epiphytic	219
	(29)	*Bulbophyllum* sp. 12	Kawang	Epiphytic	234
(7) *Callostylis* Blume	(30)	*Callostylis pulchella* (Lindl.) S.C.Chen & Z.H.Tsi	Nepenthes	Epiphytic	230
	(31)	*Callostylis* sp. 1	Nepenthes	Epiphytic	213
(8) *Coelogyne* Lindl.	(32)	*Coelogyne foerstermannii* Rchb.f.	South Rim	Epiphytic	273
	(33)	*Coelogyne septemcostata* J.J.Sm.	Kawang	Epiphytic	201
	(34)	*Coelogyne* sp. 1	Nepenthes	Epiphytic	219
	(35)	*Coelogyne* sp. 2	Nepenthes	Epiphytic	203
	(36)	*Coelogyne trinervis* Lindl.	Kawang	Epiphytic	239
(9) *Cylindrolobus* Blume	(37)	*Cylindrolobus neglectus* (Ridl.) J.J.Wood	Nepenthes	Epiphytic	230
	(38)	*Cylindrolobus* sp. 1	Nepenthes	Epiphytic	230
	(39)	*Cylindrolobus* sp. 2	Nepenthes	Epiphytic	230
	(40)	*Cylindrolobus* sp. 3	Kawang	Epiphytic	245

(10) *Cystorchis* Blume	(41)	*Cystorchis javanica* (Blume) Blume	Nepenthes	Terrestrial	230
(11) *Dendrobium* Sw.	(42)	*Dendrobium angustifolium* (Blume) Lindl.	Nepenthes	Epiphytic	207
	(43)	*Dendrobium brevicolle* J.J.Sm.	Nepenthes	Epiphytic	230
	(44)	*Dendrobium* cf. *speculum*	South Rim	Epiphytic	281
	(45)	*Dendrobium pachyphyllum* (Kuntze) Bakh.f.	Nepenthes	Epiphytic	203
	(46)	*Dendrobium prostratum* Ridl.	South Rim	Epiphytic	283
	(47)	*Dendrobium setifolium* Ridl.	Kawang	Epiphytic	238
	(48)	*Dendrobium* sp. 1	Nepenthes	Epiphytic	230
	(49)	*Dendrobium* sp. 2	Nepenthes	Epiphytic	230
	(50)	*Dendrobium* sp. 3	South Rim	Epiphytic	208
	(51)	*Dendrobium* sp. 4	South Rim	Epiphytic	221
	(52)	*Dendrobium* sp. 5	Kawang	Epiphytic	200
	(53)	*Dendrobium* sp. 7	Kawang	Epiphytic	236
	(54)	*Dendrobium* sp. 8	Nepenthes	Epiphytic	213
	(55)	*Dendrochilum* sp. 1	South Rim	Epiphytic	285
	(56)	*Dendrochilum* sp. 2	Kawang	Epiphytic	197
	(57)	*Dendrochilum* sp. 3	Kawang	Epiphytic	197
(12) *Eria* Lindl.	(58)	*Eria* sp. 1	South Rim	Epiphytic	281
	(59)	*Eria* sp. 2	Nepenthes	Epiphytic	213
(13) *Grosourdya* Rchb.f.	(60)	*Grosourdya* sp. 1	South Rim	Epiphytic	295
(14) *Lecanorchis* Blume	(61)	*Lecanorchis multiflora* J.J.Sm.	Kawang	Mycoheterotroph	201
(15) *Liparis* Rich.	(62)	*Liparis* sp. 1	Nepenthes	Epiphytic	230
	(63)	*Liparis* sp. 2	South Rim	Epiphytic	247
	(64)	*Liparis* sp. 3	Nepenthes	Epiphytic	203
	(65)	*Liparis* sp. 4	Kawang	Epiphytic	201
(16) *Mycaranthes* Blume	(66)	*Mycaranthes pannea* (Lindl.) S.C.Chen & J.J.Wood	Kawang	Epiphytic	235
	(67)	*Mycaranthes* sp. 1	Kawang	Epiphytic	244
(17) *Oberonia* Lindl.	(68)	*Oberonia* sp. 1	Nepenthes	Epiphytic	NA
	(69)	*Oberonia* sp. 2	Kawang	Epiphytic	201
(18) *Oxystophyllum* Blume	(70)	*Oxystophyllum sinuatum* (Lindl.) M.A.Clem.	Nepenthes	Epiphytic	213
	(71)	*Oxystophyllum* sp. 1	Kawang	Epiphytic	238
(19) *Pennilabium* J.J.Sm.	(72)	*Pennilabium* sp. 1	South Rim	Epiphytic	221
(20) *Phalaenopsis* Blume	(73)	*Phalaenopsis modesta* J.J.Sm.	Kawang	Epiphytic	235
	(74)	*Phalaenopsis* sp. 1	Kawang	Epiphytic	235
(21) *Pinalia* Lindl.	(75)	*Pinalia* sp. 1	Nepenthes	Epiphytic	213
	(76)	*Pinalia* sp. 2	South Rim	Epiphytic	285
	(77)	*Pinalia* sp. 3	Nepenthes	Epiphytic	204
	(78)	*Pinalia* sp. 4	Nepenthes	Epiphytic	227
	(79)	*Pinalia* sp. 5	Kawang	Epiphytic	238
	(80)	*Pinalia* sp. 6	Kawang	Epiphytic	201
(22) *Pomatocalpa* Breda	(81)	*Pomatocalpa* sp. 1	South Rim	Epiphytic	210
(23) *Pteroceras* Hasselt ex Hassk.	(82)	*Pteroceras* sp. 1	Kawang	Epiphytic	212
(24) *Robiquetia* Gaudich.	(83)	*Robiquetia* sp. 1	Nepenthes	Epiphytic	93
	(84)	*Robiquetia* sp. 2	Kawang	Epiphytic	208
	(85)	*Robiquetia* sp. 3	Kawang	Epiphytic	198

(25) *Strongyleria* (Pfitzer) Schuit.	(86)	*Strongyleria* sp. 1	Nepenthes	Epiphytic	204
(26) *Taeniophyllum* Blume	(87)	*Taeniophyllum* sp. 1	South Rim	Epiphytic	295
(27) *Thrixspermum* Lour.	(88)	*Thrixspermum* sp. 1	Nepenthes	Epiphytic	214
	(89)	*Thrixspermum* sp. 2	Kawang	Epiphytic	201
(28) *Trichoglottis* Blume	(90)	*Trichoglottis borneensis* (J.J.Wood) Kocyan & Schuit.	South Rim	Epiphytic	248
	(91)	*Trichoglottis* sp. 1	Kawang	Epiphytic	219
(29) *Trichotosia* Blume	(92)	*Trichotosia* sp. 1	Nepenthes	Epiphytic	202
	(93)	*Trichotosia* sp. 2	Nepenthes	Epiphytic	213
	(94)	*Trichotosia* sp. 3	Nepenthes	Epiphytic	215
(30) *Zeuxine* Lindl.	(95)	*Zeuxine* sp. 1	Nepenthes	Terrestrial	214
30		**95**			

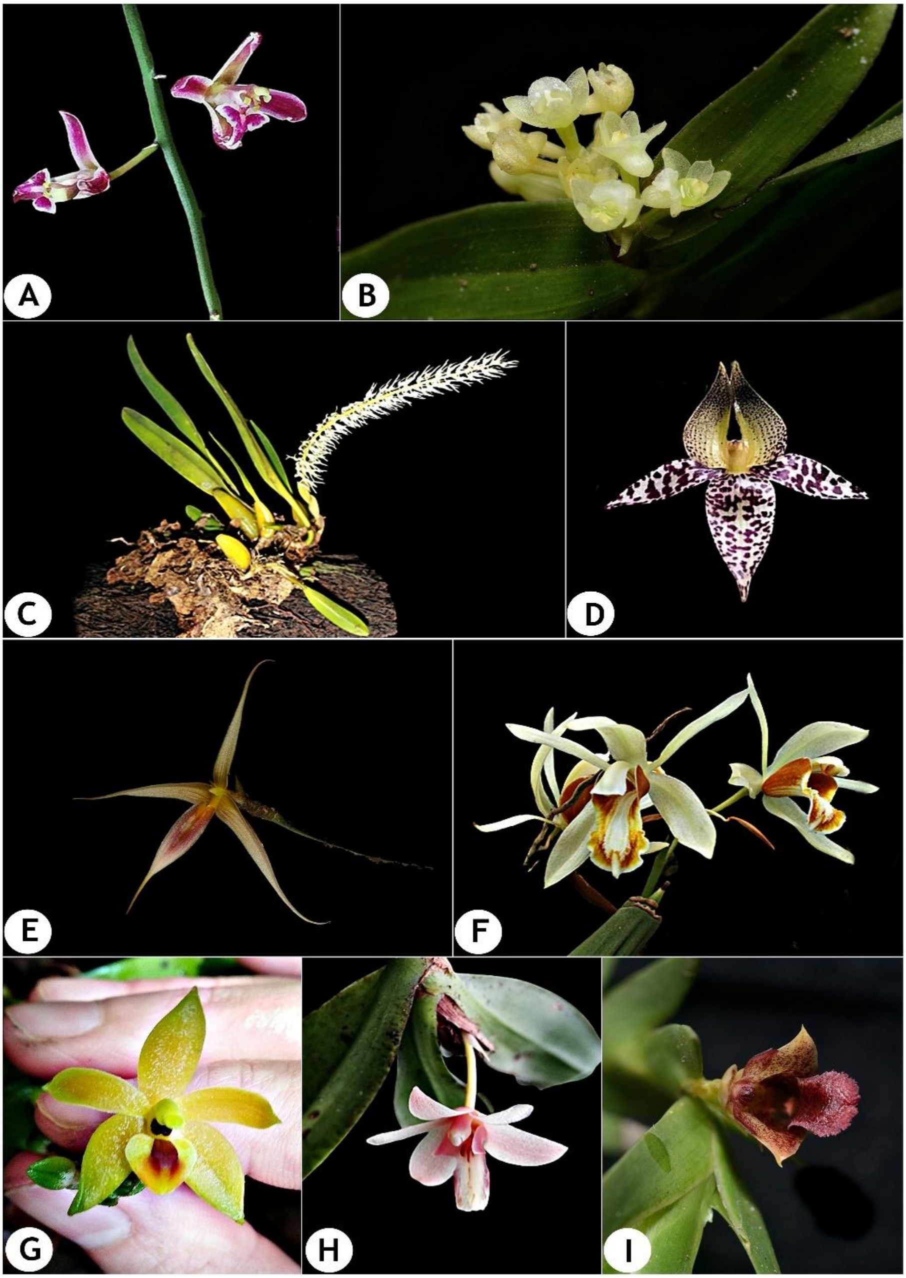

Figure 5. Orchids of Imbak Canyon Conservation Area; A: *Acriopsis liliifolia* var. *liliifolia*, B: *Appendicula reflexa* var. *reflexa*, C: *Bulbophyllum apodum*, D: *Bulbophyllum macranthum*, E: *Bulbophyllum macrochilum*, F: *Coelogyne trinervis*, G: *Callostylis pulchella*, H: *Cylindrolobus neglectus*, I: *Oxystophyllum sinuatum*

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Research Article

The mosses of Kangkawat Research Station, Imbak Canyon Conservation Area, Sabah, Malaysia

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Abstract

A total of 65 species, two subspecies and one variety of mosses in 32 genera and 17 families from 102 individuals were collected during the Borneo Geographic Expedition at Kangkawat Research Station from 29th September to 3rd October 2018. This number represents ca. 10% of the taxa of mosses reported for Sabah and ca. 9% of the taxa reported for Borneo. The largest moss family recorded in this area was Calymperaceae with 18 species and one subspecies which is ca. 28% of the total taxa collected, followed by Sematophyllaceae with eight species (ca. 12%). Out of the 68 taxa of mosses from the study area, ten are new to Imbak Canyon Conservation Area including one new to Sabah, which is *Chaetomitrium weberi* Broth. By and large, the moss species richness of Kangkawat Research Station is typical of the conservation area.

Keywords: Borneo Geographic Expedition, ICCA, new records.

Introduction

Imbak Canyon Conservation Area (ICCA) is a Class 1 (Protection) Forest Reserve with a total area of 30,000 ha. It is one of the five conservation areas that are managed by Yayasan Sabah Group, in addition to Danum Valley, Maliau Basin, Silam Coast and Taliwas River. This area comprises of habitat ranging from lowland dipterocarp forests to lower montane heath forests.

The mosses of ICCA have been explored since 2000 when the area was still largely inaccessible (Suleiman & Gisil, 2015). A milestone in bryological exploration in ICCA was in 2010 during a scientific expedition to Mount Kuli Research Station organized by the Academy Sciences of Malaysia. During the expedition, Suleiman et al. (2011a) reported 119 taxa of mosses with one new record to Borneo and two to Sabah.

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The richness of mosses of ICCA led to a floristic study of this conservation area by Chua & Suleiman (2015) from 2011 to 2012. They added 62 new records to ICCA with three new records to Sabah and five to Borneo. Thus, the total number of mosses in ICCA is 191 taxa in 68 genera and 19 families.

A scientific expedition organized by the Institute of Tropical Biology and Conservation, Universiti Malaysia Sabah was held from 28th September to 9th October 2018 in Kangkawat Research Station, ICCA. The expedition site covered both primary and secondary forests ranging from elevation 250 m to 500 m a.s.l. This area was only recently accessible, and it was not covered by Chua & Suleiman (2015). Thus, the objective of this study is to carry out an inventory of mosses from Kangkawat Research Station and adjacent areas to fill in the gaps of knowledge of the moss richness in ICCA.

Methodology

Mosses were collected along the Kawang, South Rim, Nepenthes and Palajau trails (Table 1). Common substrates of mosses were surveyed extensively, such as on rotten logs, tree roots, tree trunks, lianas, branches, soils, termite mounts, rocks and boulders. Special attention was given to substrates near rivers and streams, as this habitat is very condusive for the growth of mosses. The collected specimens were curated, identified and deposited at the BORNEENSIS Herbarium (BORH) of Universiti Malaysia Sabah with duplicates in Sandakan Herbarium (SAN) of Sabah Forestry Department.

Table 1. Collection details of mosses collected from Kangkawat Research Station

Collection No.	Collection detail
MS 6458–6510	Kawang Trail; primary forest, N 5°04’41.3”, E117°03’17.2”, 29 September 2018.
MS 6511–6544	South Rim Trail; primary forest, N 5°04’41.3”, E117°03’17.2” to N 5°03’41.8”, E117°01’53.2”, 30 September 2018.
MS 6545–6558	Nepenthes Trail; primary forest, N 5°04’39.4”, E117°07’57”, 1 October 2018.
MS 6559–6560	Palajau Trail; secondary forest, N 05°04’48”, E117°03’18” to N 05°05’60.5”, E117°03’41.7”, 2 October 2018.

Note: MS - M. Suleiman

Results and Discussion

A total of 102 specimens of mosses were collected during the Borneo Geographic Expedition at Kangkawat Research Station, ICCA (Appendix 1). It comprises of 65 species, two subspecies and one variety of mosses in 32 genera and 17 families (Table 2). This number represents ca. 10% of the total 651 taxa of mosses reported for Sabah and ca. 9% of the 771 taxa reported for Borneo (Akiyama, 2012; Akiyama & Suleiman, 2015; Andi & Suleiman, 2005; Andi et al., 2015; Chua & Suleiman, 2015; Ellis, 2016; Ellis et al., 2010, 2016a, 2016b, 2018, 2019; Higuchi et al., 2008; Ho et al., 2010; Mohamed et al. 2010; Suleiman & Akiyama, 2007; Suleiman & Andi, 2019; Suleiman & Jotan, 2015; Suleiman et al., 2006, 2009, 2011a, 2011b,2017a, 2017b). Calymperaceae is the dominant family from this area with 19 taxa, followed by Sematophyllaceae with eight taxa. These families are common in the lowland areas of Borneo.

Table 2. Summary of the mosses collected from Kangkawat Research Station.

No.	Families	Genera	Species
1	Calymperaceae	6	18 + 1 subsp.
2	Fissidentaceae	1	5
3	Garovagliaceae	1	2
4	Hypnaceae	3	5
5	Hypnodendraceae	1	1 + 1 subsp.
6	Hypopterygiaceae	1	1
7	Leucobryaceae	2	4 + 1 var.
8	Meteoriaceae	1	1
9	Neckearaceae	2	2
10	Orthotrichaceae	1	2
11	Pilotrichaceae	1	1
12	Polytrichaceae	1	2
13	Pylaisiadelphaceae	3	4
14	Rhizogoniaceae	1	1
15	Sematophyllaceae	4	8
16	Symphyodontaceae	2	7
17	Thuidiaceae	1	1
	Total	**32**	**65 + 1 var. + 2 subsp.**

Among the 102 specimens of mosses collected during the expedition, one species, *Chaetomitrium weberi*, has contributed to the richness of mosses of Sabah. This species was previously known as a Philippine endemic but later reported for Borneo by Tan et al. (1997) based on a specimen from Kalimantan Tengah Province of Indonesia. In addition, ten species are reported for the first time from this conservation area (Table 3). Thus, the current number of mosses for ICCA is 201 taxa in 68 genera and 27 families (Chua & Suleiman, 2015). This represent ca. 26% of the taxa reported for Borneo and ca.31% of the taxa reported for Sabah.

Several other mosses found from Kangkawat Research Station are rarely reported from Borneo. For example, *Macromitrium falcatulum*, which was found on fallen branch, is the third record for Borneo after it was reported by Brotherus (1912) and Dixon (1916) more than a century ago. Similarly, *Fissidens autocious* was only reported twice in Borneo, based on its type specimen from Sandakan (Dixon, 1916) and a recent collection from Pulau Gaya (Suleiman & Rimi, 2016). While, *Chaetomitrium lancifolium* which was previously reported as new to Borneo from Crocker Range Park (Suleiman et al., 2017b), was also found from this area. This species has a finely acuminate leaf apices and twisted tip, with filamentous gemmae found at its leaf axil. It can be confused with small *Acroporium* in the field, such as *Acroporium diminutum,* from its lax leaves.

Table 3. List of mosses reported as new to Imbak Canyon Conservation Area.

No.	Families	Species
1.	Calymperaceae	*Calymperes strictifolium* (Mitt.) G. Roth
2.	Calymperaceae	*Mitthyridium flavum* (Müll. Hal.) H. Rob.
3.	Calymperaceae	*Mitthyridium jungquilianum* (Mitt.) H. Rob.
4.	Calymperaceae	*Syrrhopodon albidus* Thwaites & Mitt.
5.	Fissidentaceae	*Fissidens autocious* Thér. & Dixon
6.	Hypnaceae	*Ectropothecium zollingeri* (Müll. Hal.) A. Jaeger
7.	Hypnodendraceae	*Hypnodendron subspininervium* subsp. *subspininervium* (Müll. Hal.) A. Jaeger
8.	Orthotrichaceae	*Macromitrium falcatulum* Müll. Hal.
9.	Symphyodontaceae	*Chaetomitrium lancifolium* Mitt.
10.	Symphyodontaceae	*Chaetomitrium weberi* Broth.

The endemic mosses of Borneo are relatively low. However, two Bornean endemics were found from the study area. The first one is *Chaetomitrium maryatii* which was described from Maliau Basin Conservation Area in 2001 (Akiyama & Suleiman, 2001). The second endemic species is *Pogonatum iwatsukii* which was found growing on rocks near the river along the Nepenthes Trail. The latter is fairly common throughout the lowland forests in Sabah.

It is worth to note that, *Fissidens laxitextus* which was previously reported as new to Borneo (Chua & Suleiman, 2015), was collected in the study area. This shows the diminutive moss is common in ICCA. Previously, this species was only found growing on termite mounds (Chua & Suleiman, 2015; Suleiman & Rimi, 2016). However, it was also found growing on thin layer of soil on tree trunks in Kangkawat Research Station.

Conclusion

Overall, ICCA has a relatively rich moss flora in terms of number of taxa, compared to other large conservation areas in Sabah such as Maliau Basin Conservation Area. More explorations, especially to less accessible areas, will definitely increase the number of mosses from this conservation area.

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Appendix 1. Checklist of mosses of Kangkawat Research Station
Species marked with an asterisk (*) are new to Imbak Canyon Conservation Area and double asterisk (**) are new to Sabah. The arrangement of families follows that of Buck & Goffinet (2010). MS denotes for M. Suleiman.

CALYMPERACEAE
Arthrocormus schimperi (Dozy & Molk.) Dozy & Molk.
On tree trunk, 300 m, MS 6471.

Calymperes fasciculatum Dozy & Molk.
On tree trunk by river, 250 m, MS 6556.

Calymperes porrectum Mitt.
On tree trunk by stream, 500 m, MS 6535.

**Calymperes strictifolium* (Mitt.) G. Roth
On tree trunk by river, 300 m, MS 6459.

Calymperes taitense (Sull.) Mitt.
On treelet and tree trunk, 300 m, MS 6463, 6468.

Exostratum blumei (Nees ex Hampe) L.T. Ellis.
On tree root and bases by river and waterfall, 300–450 m, MS 6461, 6527.

Leucophanes angustifolium Renauld & Cardot
On tree buttress by river, 300 m, MS 6460.

Leucophanes octoblepharioides Brid.
On tree trunk, 300 m, MS 6470.

Mitthyridium fasciculatum (Hook. & Grev.) H. Rob. subsp. *fasciculatum*
On rotten root, 400 m, MS 6537.

Mitthyridium fasciculatum subsp. *cardotii* (M.Fleisch.) B.C. Tan & L.T. Ellis
On fallen branch, 250 m, MS 6555.

**Mitthyridium flavum* (Müll. Hal.) H. Rob.
On fallen branch, 300 m, MS 6475.

**Mitthyridium jungquilianum* (Mitt.) H. Rob.
On rotten log, 300 m, MS 6544.

Mitthyridium undulatum (Dozy & Molk.) H. Rob.
On treelet trunk and shrub branches, 300 m, MS 6469, 6485, 6486, 6501.

Mitthyridium wallisii (Müll.Hal.) H. Rob.
On fallen bark and branches 250—300 m, MS 6512, 6547, 6557.

**Syrrhopodon albidus* Thwaites & Mitt.
On soil in open area, 450 m, MS 6523.

Syrrhopodon albo-vaginatus Schwägr.
Growing on soil and rotten logs in open and partial shade by river, 300—450 m, MS 6490, 6493, 6525.

Syrrhopodon confertus Sande Lac.
On rotten log and tree buttress, 300—500 m, MS 6491, 6536.

Syrrhopodon loreus (Sande Lac.) W. D. Reese
On tree trunk, 300 m, MS 6481.

Syrrhopodon muelleri (Dozy & Molk.) Sande Lac.
On tree trunk, 300 m, MS 6476.

FISSIDENTACEAE
**Fissidens autocious* Thér. & Dixon
On rock by streambed, 300 m, MS6497.

Fissidens crispulus Brid.
On rocks and tree trunk by streambed and waterfall, 300—450 m, MS 6480, 6498, 6515, 6522.

Fissidens hollianus Dozy & Molk.
On shrub trunk and and tree buttress, 250—300 m, MS 6472, 6554.

Fissidens laxitextus Broth. *ex* Gangulee
On termite mounts and tree trunk, 300—450 m, MS 6502, 6506, 6533.

Fissidens pellucidus Hornsch.
Growing on wet rock by waterfall, 450 m, MS 6519.

GAROVAGLIACEAE
Garovaglia compressa Mitt.
On treelet trunk and liana by stream, 300 m, MS 6489, 6499.

Garovaglia elegans (Dozy & Molk.) Hampe *ex* Bosch & Sande Lac.
On treelet branch, 300 m, MS 6551.

HYPNACEAE
Ectropotheciella distichophylla (Hampe ex Dozy & Molk.) M. Fleisch.
On tree trunk, 300 m, MS 6464.

Ectropothecium eleganti-pinnatum (Müll.Hal.) A. Jaeger
On twigs, 300 m, MS 6508.

Ectropothecium striatulum Dixon *ex* E.B. Bartram
Growing in open area, on wet rotten log by waterfall, 450 m, MS 6517.
Recorded as new to Borneo from ICCA (Ellis et al., 2015).

**Ectropothecium zollingeri* (Müll.Hal.) A. Jaeger
Growing in open area, on wet rock by waterfall, 450 m, MS 6516.

Vesicularia miquelii (Sande Lac.) M. Fleisch.
On rotten logs, 300 m, MS 6474, 6494.

HYPNODENDRACEAE
Hypnodendron subspininervium subsp. *arborescens* (Mitt.) A.Touw
On tree trunk, 300 m, MS 6507.

**Hypnodendron subspininervium* subsp. *subspininervium* (Müll. Hal.) A. Jaeger
On tree trunk by waterfall, 450 m, MS 6529.

HYPOPTERYGIACEAE
Hypopterygium vriesei Bosch & Sande Lac.
On liana, 300 m, MS 6462.

LEUCOBRYACEAE
Cladopodanthus heterophyllus (M. Fleisch.) E.B. Bartram
On fallen branches, 250—400 m, MS 6539, 6553.

Leucobryum aduncum var. *aduncum* Dozy & Molk.
On rotten log and termite mount on the ridge, 300—500 m, MS 6492, 6513, 6526b, 6560.

Leucobryum aduncum var. *scalare* (Müll. Hal. *ex* M. Fleisch.) A. Eddy
On rotten log, 500 m, MS 6514.

Leucobryum chlorophyllosum Müll. Hal.
Growing in open area on tree root by waterfall, 450 m, MS 6526a.

Leucobryum sanctum (Nees *ex* Schwägr.) Hampe
Growing on wet rotten log and rock in open area by waterfall, 3000—450 m, MS 6482, 6520.

METEORIACEAE
Aerobryopsis wallichii (Brid.) M. Fleisch.
On shrub branches and tree trunk by waterfall, 300—450 m, MS 6500, 6530, 6540.

NECKERACEAE
Himantocladium cyclophyllum Enroth
On tree buttress by river, 300 m, MS 6458.

Pinnatella mucronata (Bosch & Sande Lac.) M. Fleisch.
On tree trunk and boulder by waterfall, 300—450 m, MS 6465, 6521.

ORTHOTRICHACEAE
**Macromitrium falcatulum* Müll. Hal.
On fallen bark on ridge, 450 m, MS 6538a.

Macromitrium fuscescens Schwägr.
On fallen bark on ridge, 450 m, MS 6538b.

PILOTRICHACEAE
Callicostella papillata (Mont.) Mitt. var. *papillata*
On liana, 300 m, MS 6473.

POLYTRICHACEAE
Pogonatum iwatsukii A. Touw
On rock by river, 250 m, MS 6552.

Pogonatum piliferum (Dozy & Molk.) A. Touw
On rock by waterfall, 450 m, MS 6528.

PYLAISIADELPHACEAE
Mastopoma pulchellum (Herzog) H. Akiy.
On tree trunk, 300 m, MS 6509.

Taxithelium instratum (Brid.) Broth.
On rotten logs by stream, 300 m, MS 6477, 6545.

Taxithelium kerianum (Broth.) Broth.
On treelet branch, 300 m, MS 6548.

Trismegistia lancifolia var. *lancifolia* (Harv.) Broth.
On boulder, rotten log and root by waterfall, 300—450 m, MS 6483, 6524, 6532.

RHIZOGONIACEAE
Pyrrhobryum latifolium (Bosch & Sande Lac.) Mitt.
On rotten log and tree trunk, 300—450 m, MS 6484, 6534.

SEMATOPHYLLACEAE
Acanthorrhynchium papillatum (Harv.) M. Fleisch.
On liana and rotten log, 300 m, MS 6505, 6549.

Acroporium adspersum (Hampe) Broth.
On treelet branch, 300 m, MS 6487.

Acroporium convolutum var. *convolutum* (Sande Lac.) M.Fleisch.
On rotten logs, 300 m, MS 6495, 6496.

Papillidiopsis aquatica (Dixon) B.C. Ho & B.C. Tan
Growing on rock in open area by waterfall, 450 m, MS 6518.
Papillidiopsis bruchii (Dozy & Molk.) W.R. Buck & B.C. Tan
On shrub branch, 300 m, MS 6546.

Papillidiopsis complanata (Dixon) W.R. Buck & B.C. Tan
On liana, 300 m, MS 6504.
This species was reported as new to Borneo from ICCA (Chua & Suleiman, 2015).

Trichosteleum boschii (Dozy & Molk.) A. Jaeger
On tree trunk, 300 m, MS 6510.

Trichosteleum saproxylophilum (Müll.Hal.) B.C. Tan, W.B. Schofield & H.P. Ramsay
On rattan node, 300 m, MS 6541.

SYMPHYODONTACEAE
**Chaetomitrium lancifolium* Mitt.
On fallen branch, 300 m, MS 6478

Chaetomitrium maryatii H. Akiy. & Suleiman
On treelet trunk, 300 m, MS 6550.

Chaetomitrium orthorrhynchum (Dozy & Molk.) Bosch & Sande Lac.
On treelet branch, 300 m, MS 6479.

Chaetomitrium cf. *orthorrhynchum* (Dozy & Molk.) Bosch & Sande Lac.
On treelet branch, 300 m, MS 6488.

Chaetomitrium setosum Broth. ex Dixon
On shrub branches, 300 m, MS 6503, 6542.
**Chaetomitrium weberi* Broth.
On treelet trunk, 450 m, MS 6531.

Dimorphocladon bornense Dixon
On liana, 300 m, MS 6543.

THUIDIACEAE
Pelekium velatum Mitt.
On rotten log and liana, 300 m, MS 6466, 6467.

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Research Article

Tourists' Perceptions of Insects as the Determinants of Insect Conservation through Entomological Ecotourism

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Abstract

Insects are commonly featured in recreation and tourism around the world, despite the generally negative public perception surrounding them. Many people enjoy watching butterflies in insectarium gardens, observing and collecting dragonflies, and admiring the light displays of fireflies. In many cases, activities like these are becoming increasingly popular and these positive interactions with insects encourage public appreciation of insects, but vary acuities in their forms and approaches. Thus, understanding the pattern of insect appearances in recreation and tourism activities in a variety of discernments can provide important insights into effective ways of promoting insect conservation through ecotourism, which is often overlooked in biodiversity conservation strategies. However, these types of interdisciplinary studies are relatively new and remain limited in both entomology and tourism sciences. A field survey was carried out at Kangkawat Research Station, Imbak Canyon Conservation Area, where a 1 kilometre entomological ecotourism trail was designed and developed to incorporate insects in enhancing ecotourism at the reserve. Insects that can be found along the 1 kilometre trail were recorded and the collection was conducted using baited traps and sweep netting. Based on the insects survey, the Shannon Diversity Index (H') of Kangkawat is 4.60 while Simpson Index is 176.72 with Fisher Alpha Index at 313.3 that concludes Kangkawat Research Station insect richness to be the second highest after the Crocker Range.

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In adressing the knowledge gaps between insect conservation and ecotourism, a survey on attitudes towards insects was designed and then completed by 384 tourists around Kota Kinabalu City. The standardized questionnaire known as the Personal Meaning of Insects Map (PMIM) was administered to tourists and their responses were elicited prior to and after observing insect photos. The results shows that “spider” had the 100% connectivity in response to the most detested insect based on their previous encounters with insects. This result shows that there is an existing entomology knowledge gap among the respondents, indicating the need for further interventions in terms of nature interpretation. Therefore a quality guided nature interpretation as an educational tool should take into account how the general public understands (or misunderstands) insects further and where interpretive information could be better applied if we are to develop management and educational tools that address human-insect encounters.

Keywords: entomological ecotourism, insect-human interaction, Personal Meaning of Insects Map, conservation, knowledge gaps.

Introduction

Nature-based tourism that incorporates insects, herewith termed by the authors as ‘entomological ecotourism’ or ‘entotourism’ promotes the values of ecotourism in new ways through several discrete models developed on whether an entomological eco-tour focuses on a single phenomenon, is paired with another eco-tour focus, or is primarily research-based, entomological ecotourism (Lemelin & Williams, 2012). In short, the presence of ‘entotourism’ is evident in the ecotourism industry. However, in order for insects to be accepted into general ecotourism, interpretation and guide training should focus on the most charismatic insects in the world to capture the interest of more than just dedicated entomological eco-tourists. Hence, for entotourism to be successful, it needs to appeal to a broader audience (Cardoso et al., 2011; Whelan, 2012).

There is no universally accepted definition for entotourism. There is currently little-to-no reference in scientific or historical literature to entomological ecotourism. This is simply because the word was never really recorded before as a separate entity. A lack of precedent for the use of the word does not imply, however, that the definition is new. In fact, just as the pioneers of ecotourism would scour the planet in search of adventure and exploration, entomogical ecotourists also explore the globe for its rich and spectacular insect fauna. The same founders of ecotourism were also, serendipitously, the founders of entotourism (Lemelin & Williams, 2012). Suggesting that entotourism has grown from an ancestral notion to a modern-day concept as ecotourism. Entotourism has become a multidimensional philosophy from the beginning of collecting insects for museums. Today, it is defined as nature-based tourism that combines insect education as a means of enhancing environmental and community welfare (Maryati et al., 2000; Whelan, 2012; Lemelin & Williams, 2012).

Insects are presently considered as an emerging industry in the field of ecotourism, such as the monarch butterfly (*Danaus plexippus*) watching tourism in Mexico (Whelan, 2012), fireflies (*Pteroptyx spp.*) watching in Sabah, Malaysia (Syazlina et al., 2016) and glow-worm tourism in Australia (*Arachnocampa spp.*) (Hall, 2012). Invertebrates appear, aside from a few exceptions, to be overwhelmingly hated, according to studies conducted by Bart (1972), Kellert (1993) and Woods (2000). The fact that favoured animals appear to be aesthetically appealing or human-like, considered intelligent, and largely 'beneficial to humans,' explains this almost universal aversion. In essence, these assumptions impact our comprehension, relationships and management of these creatures to a large degree. However, recent studies have shown that human interactions with insects can also be both optimistic and indifferent (Evans & Bellamy, 2000; Hogue, 1987; Lorimer, 2007; Lemelin, 2009; Franklin, 2005; Lorimer, 2007).

Whether negative, optimistic or ambivalent, studies show that a variety of factors determine human experiences with insects. Corporeal signals (visual, auditory, olfactory) (Estren, 2012), early childhood interactions (Bixler, 2002; Chawla, 1999; Ewert et al., 2005; Kals et al., 1999; Tunnicliffe & Reiss, 1999), insect depiction in popular culture, schooling, and scientific literature are some of these factors (Barua et al., 2012; Lemelin, 2009; Rule & Zhbanova, 2012; Zold et al., 2012; Zoldosova & Prokop, 2006), and the entanglement of these multispecies interactions in various activities and locales (Lemelin, 2013; Moore & Kosut, 2014). What these studies show is that we should be wary of animal studies that are largely dependent on a list created by a researcher that often promotes simplistic dichotomies based on love or hate, while discounting in these interactions ambiguities or inconsistencies. Instead, through approaches that consider the complexities and contradictions that constitute human values of nature in general (Norton, 2000), and insects in particular, we can strive to understand human-insect interactions (Lemelin & Williams, 2012).

In explaining the different inconsistencies and nuances surrounding human experiences with insects, an deductive visual analysis approach, such as the one used in this study, was especially useful. Although the aim of this study was to gain a greater understanding of these entanglements, the objective of this paper is also to disentangle these morasses by identifying the various dialectics and ambivalent aspects of these encounters while also increasing our understanding of these encounters, probably leading to more constructive or at least accommodating experiences in entotourism and insect conservation.

Study Site and Methodology

Entotrail in Kangkawat

The 1 kilometre entomological ecotourism or entotourism trail was developed at the Kawang Trail and Nepenthes Trail in Kangkawat. Insects were collected using a standardized quadrat of 25m X 25m in the middle of the 200m each along the 1km line transect (see Figure 1 and Figure 2). Bait traps were also hung every 200m along the 1km line transect. Forty-three species of butterflies from 38 genera and six families are reported accounting for 4.6% of the 944 species reported in Borneo and evenly distributed with a Shannon Diversity Index (H') value of 3.64 and Species Evenness Index (E') value of 0.8819. Seven subfamilies of ants have been recorded consisting of 24 genera and 74 species with most of the species collected from subfamilies Myrmicinae, Ponerinae, Formicinae and Dorylinae. The most recorded genus was *Polyrhachis* with 19 species followed by *Dolichoderus*, *Crematogaster* and *Componatus* with eight, seven and five species respectively. A nocturnal survey was conducted by Razy et al. (2019) and based on their survey more than 100 insect species were recorded. The mean Shannon Diversity Index (H') is 4.60 while Simpson Index is 176.72 with Fisher Alpha Index at 313.3 that concludes Kangkawat Research Station insect richness to be the second highest after the Crocker Range.

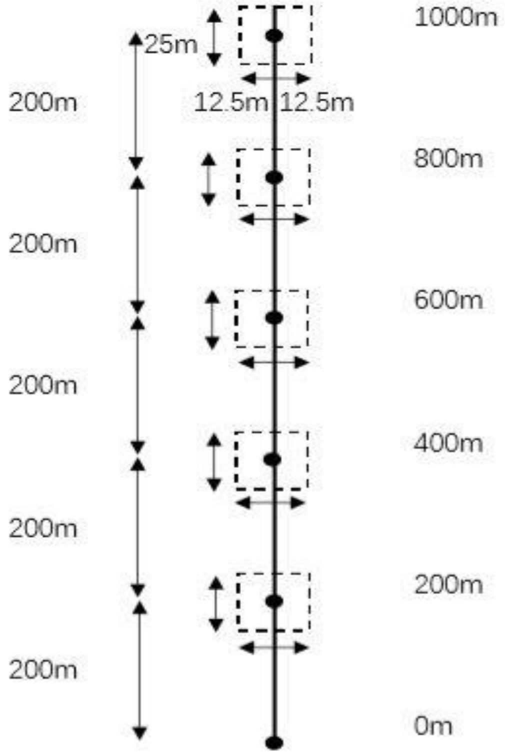

Figure 1. Diagram showing the entotrail design.

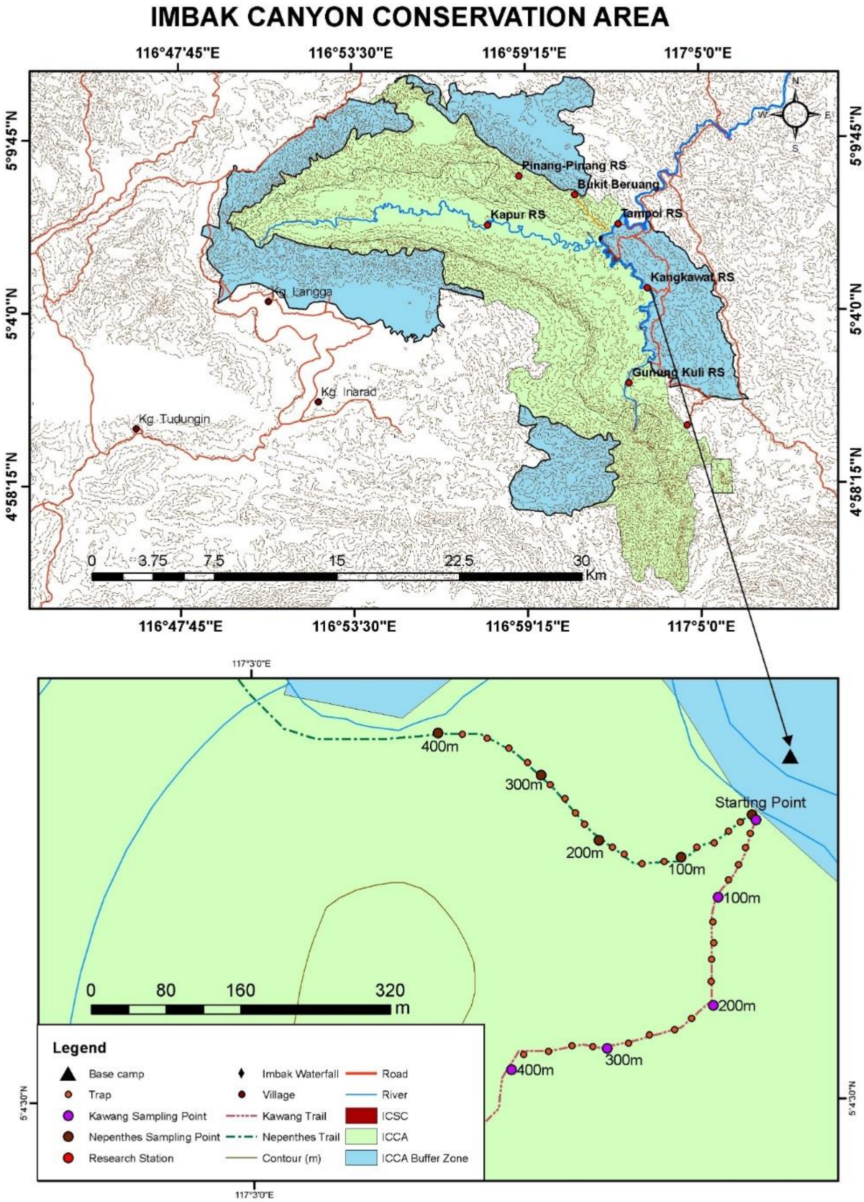

Figure 2. Map showing the location of the two selected trails for entotourism trail.

Personal Meaning of Insects Map (PMIM)

As for tourists perceptions, the study team used a deductive analysis approach consisting of visual charts, recognising some of the problems identified in previous insect studies (i.e., where the negative aspects of insects are frequently searched out) (Fiffy et al, 2015; Lemelin & Williams, 2012; Whelan, 2012). Visual mapping activities such as mind maps, idea maps, and personal meaning of insect maps (PMIM) are commonly used in education (Eppler, 2006; Kalof et al., 2011; Wheeldon & Faubert, 2009), offering an opportunity for participants to have different viewpoints without fear of judgement or correction on a subject such as animals and planets. These views are also used to test methods for communication and education offered by organisations such as museums, zoos and planetariums.

Because this study was conducted in locations without butterfly pavilions, insectariums and museums, the visit to one of these establishments was replaced with photos depicting several types of insects. Not only did this approach allow us to standardize the methodology, but it also provided an opportunity to survey individuals in areas that would have traditionally been overlooked by researchers while also highlighting how human encounters with insects are determined by corporeal cues or physical indications, social mores, and recreational activities. The outcome of this study will also assist in the development of outreach programming that will demystify and educate the public about insects.

The PMIM consisted of three phases including a pre-viewing phase, where respondents were asked to provide their impressions of insects based on their past experiences, a phase where respondents are asked to view insect images, and a post-viewing phase, where respondents were asked to provide any additional information regarding insects that may have come up from the viewing phase.

Using Leximancer software (Loosemore & Galea, 2008), the data sets were analysed using thematic content analysis. It provides the context for addressing the themes, concepts and trends found that are the basis for all qualitative analysis of study (Berg, 2001). The software is a proprietary text mining and text analytical method based on mathematics that can be used to determine the correct meaning of text and visually display the extracted information. Leximancer helps to construct a thesaurus of words around a collection of initial seed words in addition to quantifying and coding text fragments, and shows the data in a 'concept diagram' (Loosemore & Galea, 2008) by integrating the proximity of the words in the transcripts. The qualitative data analysis shifts from the general concepts and themes to text transcripts and codes (Creswell, 2005). Before analysis of data, the transcripts are formatted and transfered to Microsoft Word document. Result derived from the analysis are in the form of conceptual map.

Results and Discussion

Demographic Background of the Respondents for Pre-Viewing Phase of the PMIM

A total of 384 tourists were interviewed for 20 to 30 minutes each during the data collection period between the end of September 2018 to January 2019. Most of the interviews were carried out at the departure hall of Kota Kinabalu International Airport and around a 20km radius of Kota Kinabalu City including tourists at islands. The respondents were approached while they were waiting for flights, mostly during one hour and half prior to their departure time and during their resting time such as after lunch and while sun bathing in the field. Respondents' demographics were summarized in Figure 3 below.

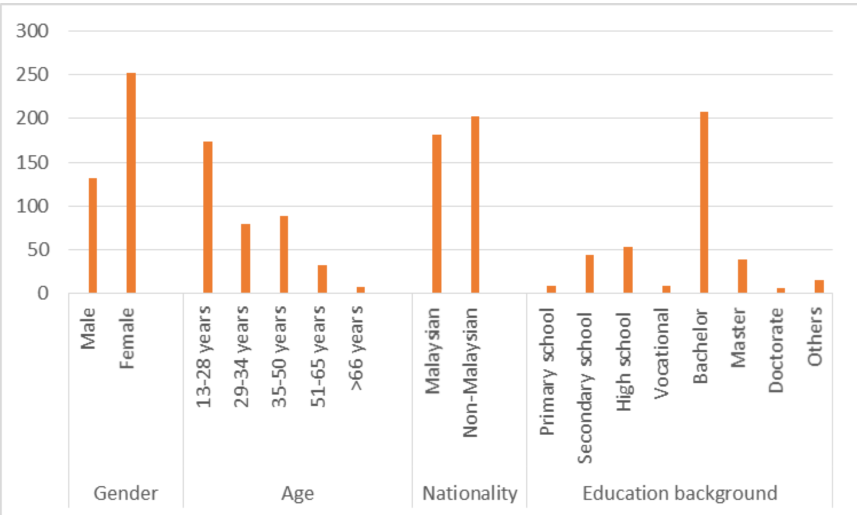

Figure 3. Demographic background of respondents for pre-viewing phase of the PMIM.

Past Experiences with Insects

In order to elicit the respondents' past experience with insects, the question posted was, "Recall a time when you felt exceptionally good about your experience with insects?". There were a few responses obtained from the respondents from “There’s no good experience, to a “happy feeling”, “beautiful view”, or their “best moment”. However, the most prevalent responses were, “… no good experience, except for that …” and the respondent would go on to describe their experience. Good dimensions are defined in this study as the dimensions that lead to participants’ happy experiential conditions with insects contributing to a positive experience. In obtaining the respondents’ bad experience, they were prompted with the question, “Recall a time when you felt exceptionally bad about your experience with insects”. Responses were wide ranging. Apart from that, bad experience could be defined as the dimension leading to “worse moment”, “bad feeling”, “angry feeling”, “disgusting feeling”, “sad feeling” or “fear feeling” with insects contributing to their negative experience. In analysing the respondents experience regarding their psychological dimensions, all accounts about their good and bad experiences, or even ‘not so bad’ experience were analysed (see Table 1).

Table 1. Emotional aspects related to psychological dimensions of respondents on experience with insects.

Psychological Dimensions on Experience	Emotional Aspects
Disgusting	“disgusting”, “make me sick”, “stop eating”
Fear	“scream out load”, “scared”, “insecure”, “painful effect”, “frightening”, “creepy sound”, “poisonous”
Happy	“happy”, “excited”, “beautiful”, “enjoy”, “colorful”, “attractive”, “interesting”, “unique”, “delicious”, “best”, “mesmerized”
Anger	“stressed”, “bothered”, “noisy”
Sad	“sad”, “guilty”

Some of the indicative comments made by the respondents that signify their good and bad experiences with insects include:

- “… cockroaches (ah, so disgusting!) crawled under my skirt and I was so shocked. Eww!”
- “.. during that time my younger sister and I went to the museum. Out of nowhere, I felt something crawling on my hand. I was shocked realizing that was a weird spider. We both screamed and ran away to get our parents .. ”
- “.. cicadas, oh my God! I just can’t describe the moment. They fly into my room and make weird sound. Like so creepy and it was big in size. So noisy!”
- “..when I visited butterfly farm somewhere in Peninsular Malaysia. .. they are beautifully created by God. It’s a good thing to be an attraction towards tourist”

- “Good thing is insects can be a bait for fishing. My father used grasshopper or bugs to be the bait”
- “.. you might see this as silly behaviour. But every time I kill an insect I feel really sad and guilty. Their lifespan is not long like us, and they will die soon even if we don’t kill them”

Viewing Images of Insects

As part of the interviews, respondents were asked to view images of insects. Figure 4 shows the results of a content analysis of the respondents’ perceptions of insects after viewing the images. Based on the analysis, all respondents stated that their most unpleasant experiences were with spiders, followed by mosquitoes, with agreement that it was because of these insects are the most annoying and they are afraid of these invertebrates. The content anaysis was conducted with Leximancer and the results show that, while there is an overall unpleasantness in relation to the insects, the primary motivation for respondents who “like” insects was found to be related to characteristics of the insects’ that are charismatic, unique and beautiful such that even during a creepy situation may produce magical moments, awe and happiness. In a comparison of results from Table 1 and Figure 4, it was revealed that respondents’ personal connection with insects is very important. This finding indicates that it would be beneficial to understand how encounters with insects through entotourism are shaped by experiences, memories, and feelings and suggests ways in which the entotourism trails can be designed to better engage and inform visitors.

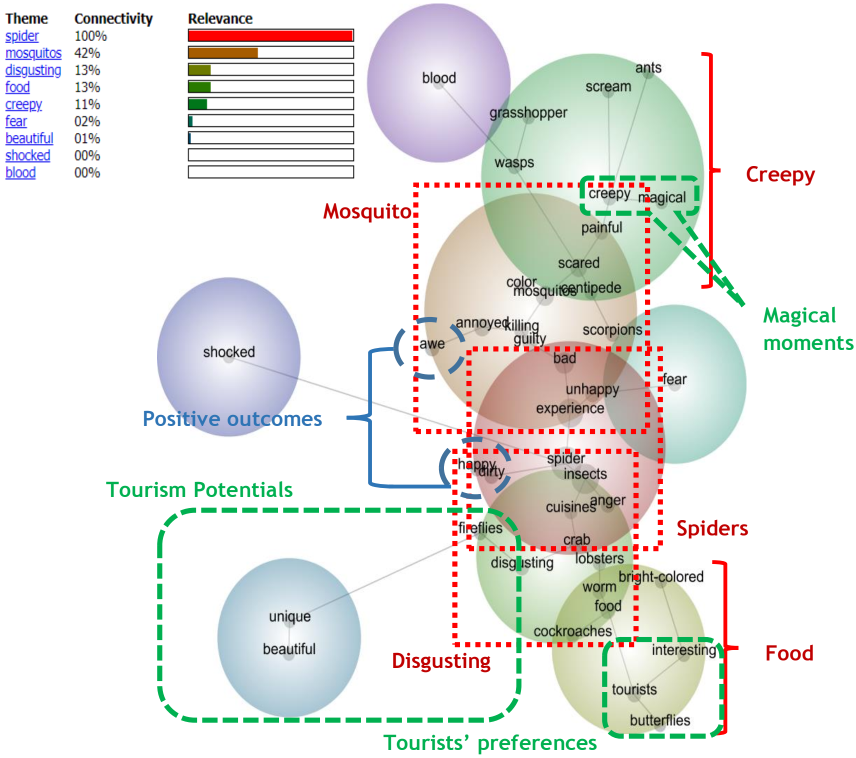

Figure 4. Respondents' view of Insects.

Post-Viewing of Insects Images

A post-viewing phase was undertaken where respondents were asked to provide any additional information regarding insects that they may have thought of following the viewing phase. Figure 5 presents the Leximancer results and shows that insects can be the subject of viable ecotourism experiences. However as shown in Figure 5, respondents demonstrate specific preferences of insects characteristics that they would like to see when if by chance participating in any entotourism activities. These explicit preferences include, beautiful, unique, rare and interesting. When these preferences were matched with specific insects, the analysis shows that the most frequently occuring insects mentioned are fireflies, beetles, butterflies, dragonflies and stick insects.

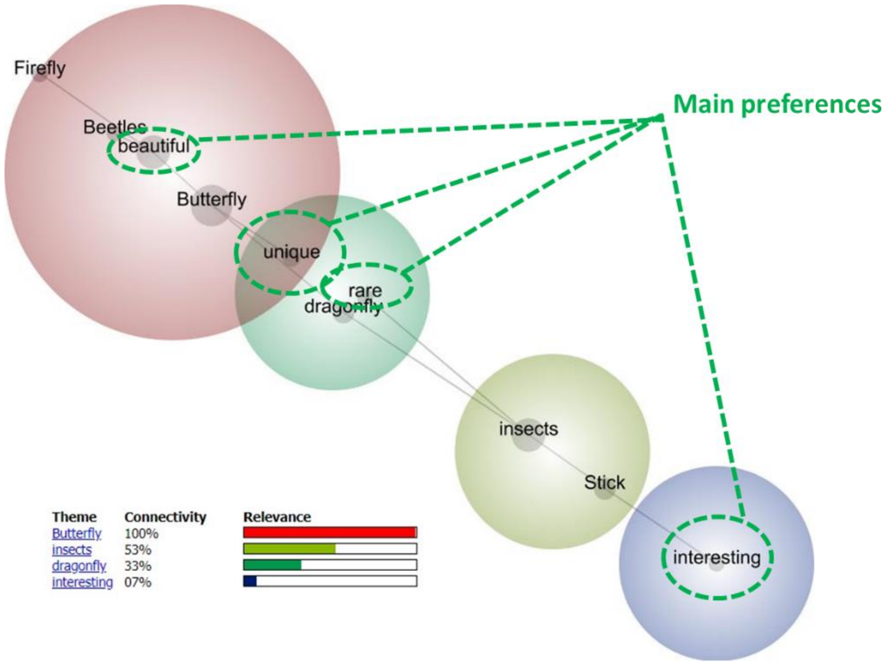

Figure 5. Respondents' main preferences of insects in terms of entotourism.

In the perceptual diagram outlined in Figure 6, it is apparent that the majority of the "insect enthusiasts" cluster was attracted to the concepts of learning about insects through entotourism. However, as indicated in Figure 6, entotourism needs to occur through a guided tour because nature interpretation adds information and awareness about insects. Together with quality interpretation within a natural settings, the primary motivation for respondents to learn and eventually to appreciate insects more widely can be attained.

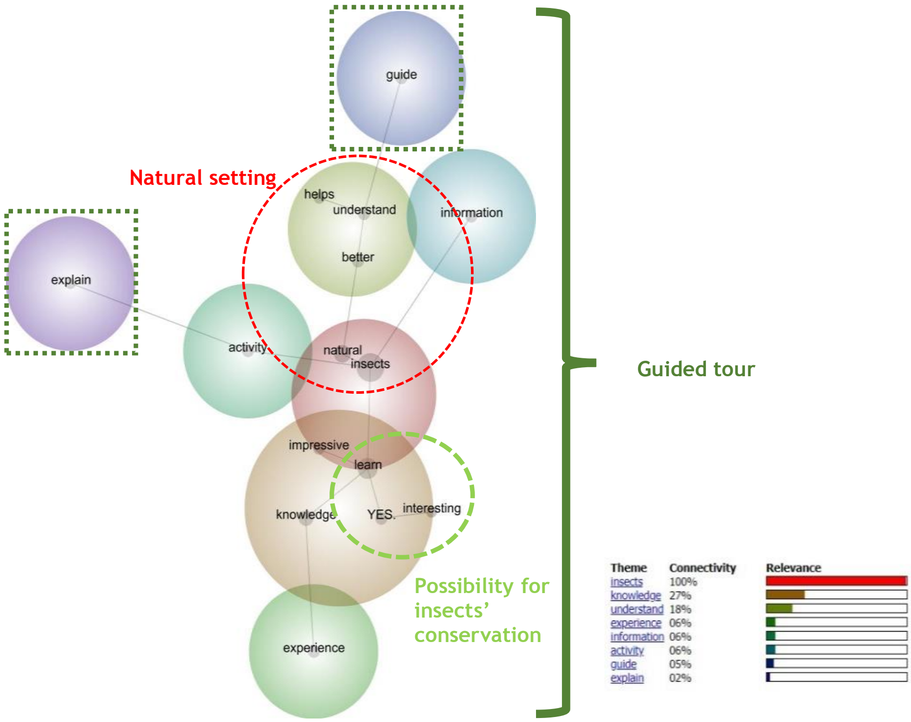

Figure 6. Respondents' concepts of entotourism activities.

Conclusion

The results of this deductive research largely support the findings of other studies that have acknowledged the contradictory aspects of human interactions with insects (Kellert, 1993), ambivalent (Lorimer, 2007) and optimistic (Lemelin, 2009; Moore & Kosut, 2014; Raffles, 2010). Similar to the conclusions drawn by Lemelin (2009, 2013) and Moore & Kosut (2013), participants appeared to note beautiful, unusual, uncommon and fascinating butterflies, beetles, fireflies, stick insects and dragonflies that then discriminate against other species / order such as ants, termites, bees, wasps and grasshoppers that could possibly be associated with adverse emotions. Thus, human interactions with insects can be accepted and even endured and not embraced in certain circumstances (i.e. during certain outdoor activities), but this will depend on how they are remembered to elicit emotional responses based on past experiences and today's perception of the world of insects.

As our study illustrates, the images engaged respondents and helped to remind them of the popularity of certain species like bees and butterflies, and the aesthetic appeal of dragonflies, praying mantises, and ladybugs. In some cases, the images were enough to remind certain respondents that they did indeed like certain types of insects. The aim of this study was to investigate the relationship between entotourism and respondents' views of insects. The overall results of the study indicate that the success of entotourism activities are very dependent on the charismatic appeal of insects. Results also show that respondents are convinced of what they want to experience and see during insects-based tourism activities. These findings suggest that the image of insects needs to be further investigated using strategies aimed at increasing tourists' acceptance of the insect realm. Importantly, the elements of psychology (emotions), philosophy (aesthetics), tourism and insects – and how these components interact to create a touristic experience must be fulfilled and achieved so as to ensure sustainable entomological ecotourism.

Whatever model of tourist motivation to experience entotourism one adopts, the importance of interpretation is vital. Knudson et al. (2003) assert that interpretation "translates or brings meaning to people about natural and cultural environments" (p. 3). While others have proposed that interpretation, "forges emotional and intellectual connections between the interests of the audience and the inherent meanings in the resources" (Brochu & Merriman, 2002, p. 20). In this light, it seems that it is possible to forge meaningful and connections with contrasting entomological phenomena.

The study does make a positive advance in the understanding of what constitutes tourist entomological knowledge, experiences and preferences. In conclusion, a relationship was identified that showed valuing insects through interpretation, could be a predictor of insects conservation awareness. Elements that can mediate this relationship include tourists' past experiences, knowledge of insects. and preferences for particular insects. The findings enhances understanding of human-insects relationship and how entotourism activities can be developed and designed. From a wider perspective, the findings of this study indicate that insects have a significant pull factor and present destinations with a unique marketing opportunity. According to Fiffy et al.'s (2015) study on tourists perspective - inclusion of entotourism concept in ecotourism activity, shows that the Structural Equation Modeling (SEM) of the study is 65% variance of all the independent variables that are "activity", "information", "interest" and "willingness" of insects watching tourism have described "ecotourism" well.

This shows that ecotourism is driven by independent variables, thus the conservation of insects through ecotourism may be increased.

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Short Notes

Wild Gingers (Zingiberaceae) at Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA), Sabah

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Abstract

This study was carried out during the Geographic Borneo Expedition in 2018 (28 September – 3 October 2018) with the objective to assess the diversity of gingers (Zingerberaceae) at Sungai Kangkawat, Imbak Canyon Conservation Area (ICCA). Four tracks were surveyed, namely, Sungai Kawang, Nepenthes, South Rim and Pelanjau. Any ginger clump along these tracks were visually searched and sampled. The plants (stems, leaves and rhizomes) together with their flowers and fruits, if present, were collected, labelled and kept in a ziplock bag for herbaria preparation and identification. Information on ecology, habitat and location coordinates of each species were also recorded. Species identification was carried out using published taxonomic keys and pictures of the plants. There were 11 genera found along Sungai Kawang track, seven along Nepenthes track, three along South Rim track, and five along Pelajau track. Previous unpublished expedition report stated that there were 48 ginger species in ICCA. However, in the present study, only 28 known species from 11 genera were found. The low number of species was associated with difficulty to identify the ginger samples, as many were lacking flowers, probably due to the lapse of the flowering season.

Keywords: Zingiberaceae, Sabah, flower

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Introduction

Imbak Canyon Conservation Area (ICCA) is situated in the central area of Sabah, about 300 km from Kota Kinabalu. It is located at the west of Danum Valley Center and north of Maliau Conservation Centre, the two biodiversity important forests in Sabah. ICCA covers a total area of about 30,000 hectares, encompassing two ridge-top virgin jungle virgin jungle reserves, which are rich in biodiversity and unique in geology and geomorphologic attributes. ICCA is still under exploration with respect to physical environment and biodiversity. There were three (2004, 2009 and 2011) previous explorations and expeditions to ICCA, which were organized to study the flora, fauna communities and physical environments of the area.

In Sabah, there are 152 known species from 13 genera of gingers (Gobilik & Yusof, 2005). There could still be many new reports or new species to be found, but the specimens are not yet well described and identified or collected. Zingiberaceae consists of more than 1500 species and 53 genera, which mostly can be found in the tropics. Borneo has nearly 19 genera with new genus is still reported.

In an expedition to ICCA in 2004, Gobilik et al. (2005) reported that there were 48 species of gingers in that area, but the report was not published by the expedition committee as expedition proceedings. Hence, the list of gingers in ICCA is yet to be available to the public. During the ICCA's Sungai Kangkawat Borneo Geographic Expedition in 2018, gingers were again surveyed, and published in the present paper, with the hope that the information will be made available for the general knowledge of conservationists about ginger composition in ICCA specifically at Sungai Kangkawat.

Methodology

The gingers were surveyed at the study area along four tracks, namely, Sungai Kawang, Nepenthes, South Rim and Pelanjau trails (Figure 1) during the expedition (Sungai Kangkawat, ICCA Geographic Borneo Expedition, 28 September – 3 October 2018). Various sterile species, flowering and fruiting wild ginger species were sampled randomly along these trails. The collected plants with their flowers if present, fruits, leaves and rhizomes were photographed and pressed for herbaria preparation (Appalasamy et al., 2019) and identification. The habitat and location coordinates were recorded for each of the species. The fertile and sterile Zingiberaceae plants were identified using keys and pictures.

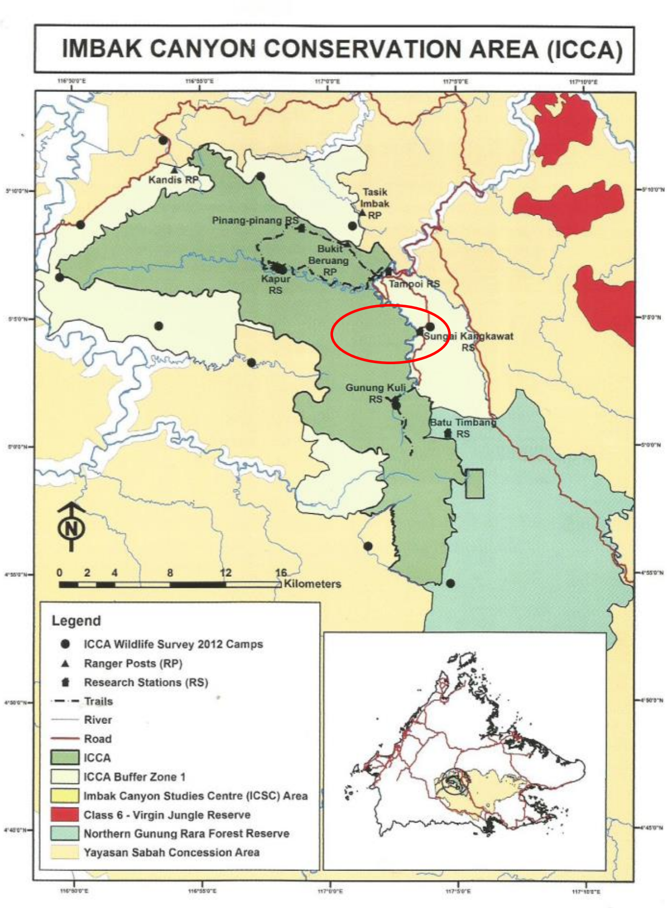

Figure 1. The map and location of Imbak Canyon Conservation Area (ICCA) in Sabah. The red circle indicates area covered during the survey.

Results and Discussion

There were 11 genera of gingers found along Sungai Kawang track, seven along Nepenthes track, three along South Rim track, and five along Pelajau track. In total, there were 28 species and 11 genera of gingers found at the study area (Table 1 and Figure 2). There were nine species of *Boesenbergia* found, but all specimens were sterile and thus, identification to species was difficult. *Plagiostachys* was also found to have more species (four species), but were also already at fruiting stage. It was followed by *Amomum* with three species (Figure 2).

Table 1. The genera and species of gingers at the study area.

Genus	Species	Trail	Collection number
Zingiber Mill.	*Z. flammeum* Theilade & Mood	Kawang	SA16
	Z. pseudopungens R. M. Sm.	Kawang	L & A 01
Etlingera Giseke	*E. fimbriobracteata* (K. Schum.) R. M. Sm.	Pelajau	SA30
	E. brevilabrum (Valeton) R. M. Sm.	Kawang	SA17
Alpinia Roxb.	*A. ligulata* K. Schum.	Kawang	SA08
	A. aquatica (Retz.) Roscoe	Kawang	L & A 02
Amomum Roxb.	*Amomum coriaceum* R.M. Sm.	Kawang	SA14
	Amomum laxisquamosum K. Schum.	Kawang	SA20
	Amomum oliganthum K. Schum.	Pelajau	SA33
Elletaria Maton	*Elletaria* sp. 1	Kawang	L & A 03
	Elletaria sp. 2	Kawang	L & A 04
Plagiostachys Ridl.	*P. longicaudata* Julius & A. Takano	Kawang	SA09
	Plagiostachys breviramosa	Kawang	SA10
	Plagiostachys sp. 1	Kawang	SA12
	Plagiostachys sp. 2	Kawang	SA37
Boesenbergia O. Kuntze	*Boesenbergia* sp. 1	Kawang	L & A 05
	Boesenbergia sp. 2	Kawang	L & A 06
	Boesenbergia sp. 3	Kawang	L & A 07
	Boesenbergia sp. 4	Kawang	L & A 08
	Boesenbergia sp. 5	Kawang	L & A 09
	Boesenbergia sp. 6	Nepenthes	L & A 10
	Boesenbergia sp. 7	Nepenthes	L & A 11
	Boesenbergia sp. 8	South Rim	L & A 12
	Booesenbergia pulchella (Ridl.) Merr.	South Rim	L & A 13
Hedychium Konig.	*Hedychium muluense* R.M. Sm.	South Rim	L & A 14
Burbedgia Hook f.	*B. pauciflora* Valeton	Kawang	SA22
Globba L.	*G. pendula* Roxb.	Kawang	SA15
Hornstedtia Retz.	*Hornstedtia* sp. 1	Kawang	SA21

Note: Initial denote collector. L & A = Lam Ye Fan & Nur Azizun Rusdi; SA = Suganthi Appalasamy

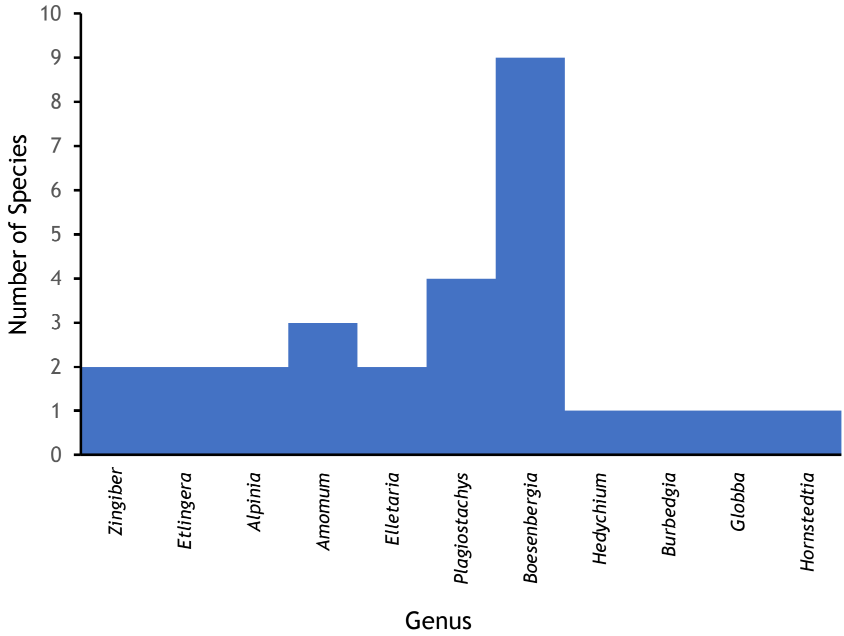

Figure 2. The number of species in every genus found in the study area.

The presence of flowers and fruit capsules enabled the identification of the *Amomum* species. All specimens of the genera *Elletaria* and *Hornstedtia* were not successfully identified to species level due to lack of flowers or fruits. A few of the species were described in Figure 3. The list of gingers in Table 1 will be the first formal publication of such information for ICCA.

In Sabah, there were 13 genera of Zingiberaceae reported (Gobilik & Yusof, 2005) and this study successfully found 11 genera in ICCA which indicates the importance of this area as a biodiversity important forest. However, in contrast with the previous study in ICCA which reported 48 species of Zingiberaceae, this current study only list 28 species. This could be due to the collection of samples which were restricted to fertile plants during this expedition. In addition, the expedition was focused in Kawang, Pelajau, Nepenthes and South Rim trails which were unexplored before this.

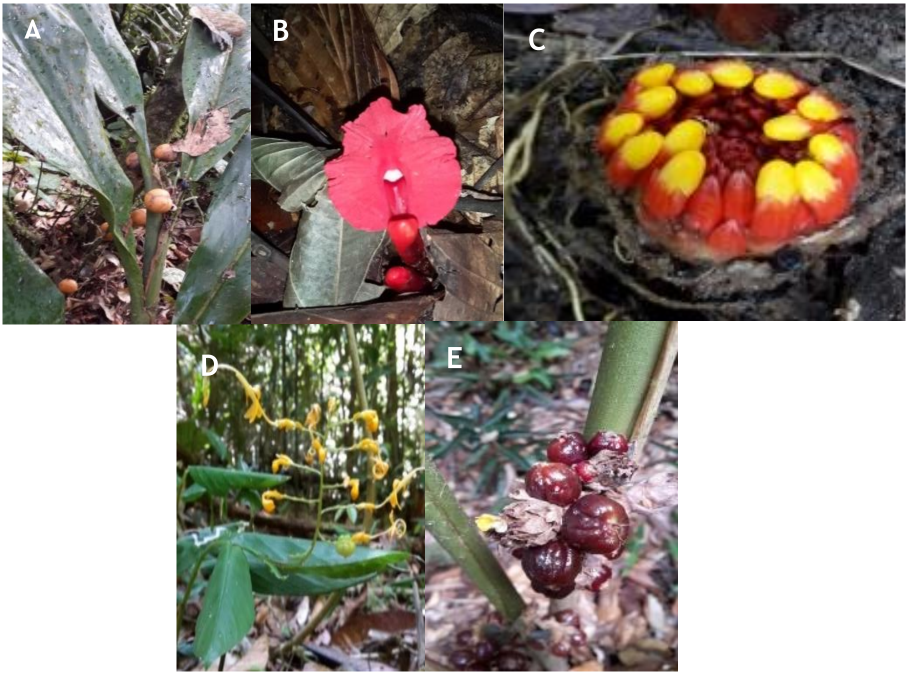

Figure 3. Pictures of a few species found at the study area. A. *Alpinia ligulata*; commonly found in lowland to hill forest (1000m). The capsules are brown and soft in texture. B. *Etlingera brevilabrum*; commonly found in wet lowland area. Flowers are always far (1 m) away from the mother plants connected by long rhizomes; fruits forms underground. C. *Etlingera fimbriobracteata*; this species is a profound 'coloniser' along the ridges of forest with leafy shoots reaching to 3-4 m. The inflorescences are bright yellow, emerging around or near the leaf bases, usually covered or buried under leaf litters. D. *Globba pendula*; commonly found in wet lowland area. A common sighting around waterfall area. Some species with aromatic odor. E. *Plagiostachys* sp. 1; this species found to be growing in clusters of a few leafy shoots with bright reddish fruits. The flowers are minute, yellowish white inflorescence. The red fruits usually about 1.5cm long with oblong to pear shaped.

Acknowledgements

We would like to extend our gratitude to Institute for Tropical Biology & Conservation, Universiti Malaysia Sabah and Yayasan Sabah Group for the facilities, logistics and support during the Borneo Geographic Expedition: Kangkawat Research Station, Imbak Canyon Conservation Area, Tongod, Sabah 2018 (Grant No. SDK0043-2018), Sabah Biodiversity Council for the access license (Ref. JKM/MBS.1000-2/1JLD.3 (246)), Imbak Canyon Management Committee for research permission and Yayasan Sabah's staffs for assistance and support in the field; last but not least to Universiti Malaysia Kelantan for their support during the expedition.

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Research Article

Insect Diversity of Sg. Kangkawat Research Station in Imbak Canyon Conservation Area (ICCA), Sabah

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Abstract

The nocturnal insect diversity was very high, with more than 100 insect species in a square metre in all light-trapping sites. The mean Shannon Index was 4.60 while Simpson Index was 176.72. It is interesting to note that Sg. Kangkawat insect richness appears to be the second highest after Crocker Range, when compared with 25 other forest reserves in Sabah. There were more than 13 endemic species and a subspecies recorded during the survey, including an undescribed species of moth (Geometridae, *Plutodes* sp.). In view of the high diversity and intriguing insect fauna, Sg Kangkawat Research Station has potential in promoting nature tourism for special interest tourists. Encroachment is among the threats within this forest reserve. For the general public, the boundary of some parts of the forest reserve is still not clear. Hence, it is important to have more signages to denote the forest reserve boundary. Public awareness and environmental education have to be enhanced among the local communities so that they are aware of the significance of biodiversity conservation of forest resources. The threats and issues have indirectly affected the insect fauna. As such, the forest quality would have to be enhanced in order to maintain the interesting and endemic insect fauna for biodiversity conservation. On-going cooperation with the relevant authorities, such as Sabah Forestry Department and Sabah Wildlife Department, will enhance conservation efforts and curb future encroachment. Further biodiversity research with relevant agencies should be encouraged.

Keywords: Insect, nocturnal insect, diversity, light-trap, Bornean endemic.

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Introduction

Sungai Kangkawat Research Station is located within the famous Imbak Canyon Conservation Area (ICCA). ICCA serves as a vital gene bank or seed source for forest rehabilitation, and an ideal site for research in its lowland dipterocarp forest. Besides research related activities, ICCA is ideal for wilderness recreation such as jungle-trekking, bird-watching, nature or outdoor photography, camping, and night-walks to observe wildlife.

Among the studies conducted were in the areas of biodiversity, entomology, botany, forestry, herpetology, ichthyology, eco-tourism and other related fields. The expedition was part of Yayasan Sabah Group's conservation efforts that includes providing a platform for scientists and academicians to conduct research.

Methodology

Light-trapping

Light trap was used to sample nocturnal insects. The trap consists of a vertical white sheet (2 X 2 m) illuminated by a 250W mercury-lithium bulb. It was powered by a portable Yamaha generator. The trap was set up in an open area facing the forest reserve, from 7:00 to 9:00 p.m. A GPS (Model: Garmin GPSMAP 60CSx) was used to determine the coordinates of each sampling site. Temperature and humidity were taken with a digital hygrometer from Extech Instruments (model no. 445702).

To evaluate diversity of the sampling area, insect species and individuals (≥ 5 mm) within the 1 X 1 m square of the white cloth were enumerated from 8:30 to 9:00 pm. This is a rapid biodiversity assessment method because by the end of the sampling time, species and individual numbers can be obtained, and the data can be used to calculate diversity indices. This method is simple, fast and can be carried out by non-insect specialist. To avoid compounding human error, the same staff was assigned to count the species and individual numbers throughout the sampling period, and also for other sampling sites. The sampling was carried out for three nights at three different sites.

Sweep net and manual collection

Sweep nets were used to collect flying insects while other insects were sampled using fine forceps. Butterflies were put in triangle papers while other specimens were put in vials with 75% ethanol solution. Sampling was conducted along the trails established for the expedition. The sampling was conducted from 9 a.m. until 1 p.m. for three days.

Insect specimens and identification

In this survey, focus was given to certain insect groups, i.e., butterflies, moths, beetles, dragonflies and damselflies. Only selected insects for further research work were sampled, as to minimize the workload at the laboratory in preparing the specimens for identification. Photographs were taken 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 genus 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) for butterflies; Holloway (1983, 1985, 1986, 1988, 1989, 1993, 1996, 1997, 1998a & b, 1999, 2001, 2003, 2005, 2008, 2009 & 2011) and Robinson et al. (1994) for moths; Fujita (2010), Makihara (1999) and Tung (1983) for beetles; Seow-Choen (2016) for stick insects; Orr (2003) and Tang et al. (2010) for dragonflies and damselflies. Some other insects were identified based on Hill & Abang (2005).

Diversity indices

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

Results and Discussion

Nocturnal insect diversity as assessed through light-trapping

The nocturnal insect diversity is shown in Table 2. Data were not available for Site C because of a heavy downpour before the enumeration could be conducted. A mean 118 species of nocturnal insects were recorded from one-square-metre of the light-trapping cloth, with an average of individuals. The mean Shannon Index was 4.60 while Simpson Index was 176.72.

During light-trapping, the temperature was 24^0C - 25^0C with humidity reaching 88% (Table 1). The distribution of insect species from the light-trapping sites is reflected in the species-rank abundance curves in Figure 1. Simpson's Index shows lower value in Site A because of a more dominant species with 18 individuals, which is *Apis dorsata* (Hymenoptera: Apidae), compared to Site B. This is also reflected in the higher staggered slope of the species-rank abundance curve of Site A.

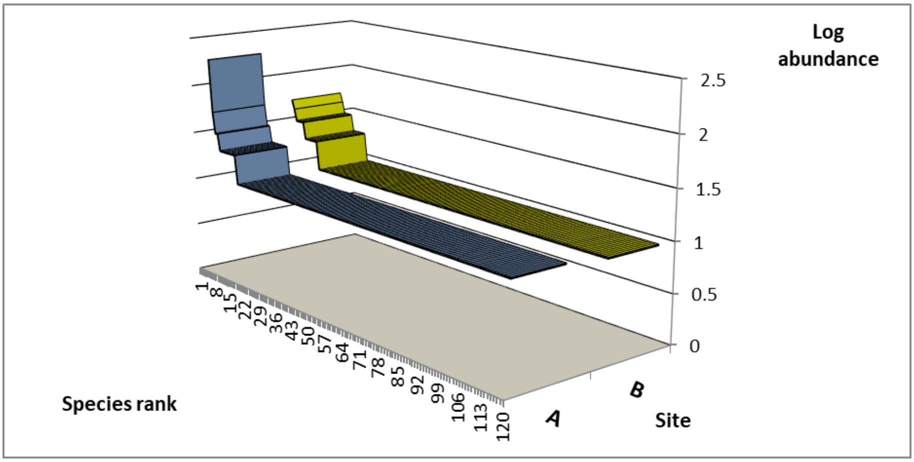

Figure 1: Species-rank abundance curves of the light-trapping in Sg. Kangkawat Research Station.

Table 1: Light-trapping sites in Sg. Kangkawat Research Station.

Sampling site	Coordinates	Elevation (m)	Temp. (°C)	Humidity (%)	Sampling date	Remarks
A	N 05°04'41.8" E 117°03'38.3"	244	25.3	84	29 Sept	No moon with clear sky.
B	N 05°04'39.8" E 117°03'30.2"	220	24.5	88%	30 Sept	No moon with clear sky.
C	N 05°04'39.5" E 117°03'30.5"	212	n.a	n.a	01 Oct	Heavy downpour at 7:30 pm. Hence, light-trapping was cancelled.

Table 2: Insect diversity within a one-square-metre, as sampled through light-trapping in Sg. Kangkawat Research Station.

No.	Sampling site	Species	Ind.	Shannon	Simpson
1.	A	117	150	4.49	64.14
2.	B	141	126	4.70	290.29
3.	C	-	-	-	-
	Mean	118.5±2.12	145.5±6.36	4.60±0.14	176.72±160.61

When the nocturnal insect richness is compared with 25 other forest reserves in Sabah, it is interesting to note that Sg. Kangkawat insect richness appears to be the third highest after Crocker Range and almost similar to Bukit Hampuan FR, as shown in Figure 2. In terms of nocturnal insect diversity as reflected by Shannon Index, it is the second highest after Crocker Range FR (Figure 3).

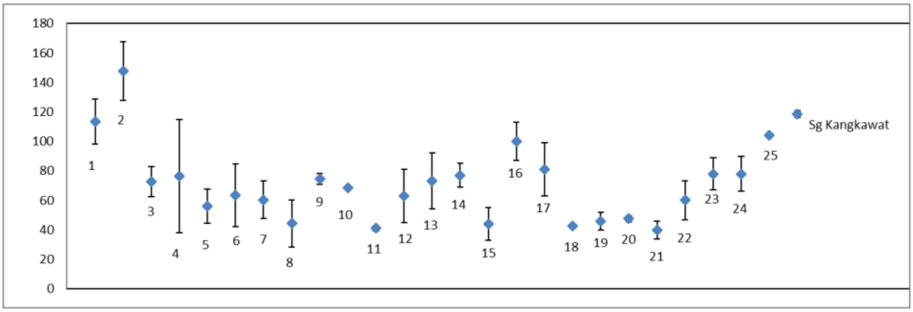

Figure 2: Species number (±standard deviation) within one square metre as assessed through light-trapping in various forest reserves in Sabah (1 = Bkt Hampuan, 2 = Crocker Range, 3 = Rafflesia, 4 = Gn. Lumaku, 5 = Gunong Lumaku, 6 = Milian Labau, 7 = Kawag, USM Office, 8 = Sg. Kapur, 9 = Sg. Siliawan, 10 = Nurod Urod, 11 = Punggol & Sansiang, 12 = Gg Tinkar, 13 = Sg Imbak 2a&2b, 14 = Tim-Bot, 15 = T. Bohangin, 16 = Sg Imbak 2c&2d, 17 = Kungkular, 18 = Pensiangan, 19 = Nuluhon Trusmadi, 20 = Batu Timbang, 21 = Tambulanan, 22 = Trusan Sugut, 23 = IJM SG, 24 = Ulu Kalang & 25= Sg. Rawog).

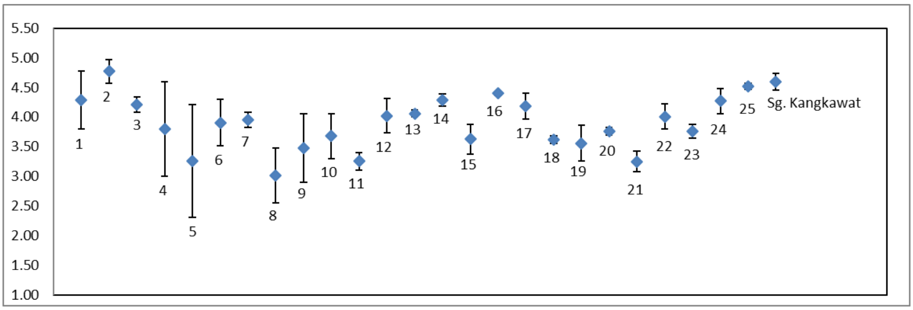

Figure 3: Shannon Index (±standard deviation) within one square metre as assessed through light-trapping in various forest reserves in Sabah (For sites1-25, refer to details in Figure 2).

Bornean endemic insect species from the survey

One undescribed moth species and at least 13 Bornean endemic species and a Bornean endemic subspecies were recorded during the survey, as listed in Table 3. This information provides input towards recommendations on high conservation values (HCV) of the area, based on HCV 1 as stipulated in HCVRN (2013).

Table 3. Bornean endemic insect species recorded from Sg. Kangkawat Research Station

No.	Species	Author	Order	Family
1	*Eulichas fasciolata*	Fairmaire	Coleoptera	Eulichadidae
2	*Dorcus thoracicus*	Moellenkamp	Coleoptera	Lucanidae
3	*Chalcosoma moellenkampi*	Kolbe	Coleoptera	Scarabaeidae
4	*Amata egenaria*	Walker	Lepidoptera	Erebidae
5	*Barsine lucibilis*	Swinhoe	Lepidoptera	Erebidae
6	*Amblychia cavimargo*	Prout	Lepidoptera	Geometridae
7	*Plutodes evaginata*	Holloway	Lepidoptera	Geometridae
8	*Plutodes* sp. (undescribed)		Lepidoptera	Geometridae
9	*Acytolepis ripte*	Druce	Lepidoptera	Lycaenidae
10	*Caleta elna elvira**	Fruhstorfer	Lepidoptera	Lycaenidae
11	*Ugia disjungens*	Walker	Lepidoptera	Noctuidae
12	*Haaniella echinata*	Redtenbacher	Phasmatodea	Phasmatidae
13	*Lonchodes* nr *abbreviatus*	Brunner	Phasmatodea	Phasmatidae
14	*Phobaeticus kirbyi*	Brunner	Phasmatodea	Phasmatidae

*subspecies endemic to Borneo

The undescribed moth species is from the genus *Plutodes* of the family Geometridae. It did not match any of the species featured in Holloway (1993), and Roger Kendrick (pers. comm.) suggested that it is a species that is close to *Plutodes cyclaria*. Unfortunately, the specimen was not collected and only photographs were taken.

At least five Bornean endemic moth species were recorded in this expedition, namely a wasp-like moth (*Amata egenaria*), and a *Barsine lucibilis* of family Erebidae, two Geometrid Moth (*Amblychia cavimargo* and *Plutodes evaginata*) and a Noctuid Moth (*Ugia disjungens*). Apart from these, there were a Bornean

Lycaenid Butterfly (*Acytolepis ripte*) and an endemic subspecies of Lycaenid Butterfly (*Caleta elna elvira)*. For beetles, three Bornean endemic species were recorded. *Eulichas fasciolata* is a Forest Stream Beetle which was attracted to the light trap. Although it is endemic, this species is locally common. The other beetles are black Stag Beetle (*Dorcus* nr *thoracicus*) and Three-horned Rhinocheros Beetle (*Chalcosoma moellenkampi*). Three Bornean endemic stick insect were recorded, namely a *Lonchodes* nr *abbreviatus*, a *Phobaeticus kirbyi* and a *Haaniella echinata*. The *Lonchodes* nr *abbreviates* was featured in Soew-Choen (2016). The *kirbyi* is the common species among the *Phobaeticus* and also was featured in Seow-Choen (2016). The *Haaniella echinata* is the common stick insect that can be spotted in most of the lowland forest reserves in Sabah.

The insect fauna (non-endemic) of Sg. Kangkawat Research Station

During the expedition, the main insect groups that were documented were butterflies, moths, beetles, dragonflies and the rest were grouped as other insects.

Butterflies

A total of 17 butterfly species were recorded. Interesting butterflies sighted during the expedition were the Rajah Brooke's Birdwing (*Trogonoptera brookiana*) and the Golden Birdwing (*Troides amphrysus flaviscolis*). The former is Malaysia's national butterfly while the latter is an iconic species which is often featured in Sabah's nature tourism promotion. Both are protected species under Schedule 2 of the Sabah Wildlife Conservation Enactment 1997. The male Rajah Brooke's Birdwing was spotted a number of times flying across the river near the base camp of Sg. Kangkawat. Another butterfly that was commonly sighted resting on the damp river bank was the Cruiser, *Vindula dejone dejone*.

Moths

At least 32 moth species were documented during this expedition. The most interesting moth sighted was the Cossidae Moth, *Xyleutes mineus* (Cossidae), because of its striking red wings with their unusual blue-black patches. Other interesting moth species included the Geometrid Moth (*Pingasa tapungkanana*) and the black and white Swallowtail Moth, *Lyssa menoetius* (Uraniidae). From the family Cossidae, *Xyleutes strix* was the largest goat moth recorded, with a body length (including wings) up to 6 cm and wing span of 12 cm.

Beetles

Twelve macro beetle species were recorded during the survey. *Chalcosoma moellenkampi* was the largest beetle recorded through light trap and it is known as one of the types of pests found in oil palm plantations. It is also one of the largest beetles in Borneo. Other large beetles recorded included the Three-horned Rhinoceros Beetle, *Chalcosoma atlas*. Another interesting beetlerecorded was the Click Beetle, *Alaus* sp., which can do an acrobatic jump when disturbed.

Dragonflies and damselflies

At least four Odonata common species were sighted in Sg. Kangkawat Research Station during the survey. The Odonata fauna is reported by Choong et al. (2019). It is also interesting to note that the Black Velvetwing Damselfy, *Dysphaea demidiata*, was found in abundance resting on the damp part of the riverine area.

Other insects

At least 11 species of other insects were recorded including termites, bugs, wasps, honeybees, ants, praying mantises, crickets, and stick insects. The most interesting insect was the Exploding Ant, *Camponotus (Colobopsis) saundersi*. It can rupture its abdomen and secrete yellowish fluid when attacked by intruders.

Threats and issues affecting insect diversity

Sungai Kangkawat Research Station is located within the Imbak Canyon Conservation Area. There are threats that may affect forest reserves such as forest fire, poaching, fragmentation, and encroachment as the study site is located near local villages and it is accessible by vehicles. These threats have been discussed and were similar to that of other forest reserves (Nilus et al. (2014); Chung & Lee (2009); Chung et al. (2018)).

In terms of insects, the forest harboured interesting fauna as well as Bornean endemic insects even though it was just a short expedition. Hence, the forest has to be protected and monitored to minimize encroachment and to enhance the forest quality.

Conclusion

The data procured from the expedition serves as baseline information as there was no insect diversity survey in this research station in the past. Research findings have revealed that the nocturnal insect diversity was very high, second after the Crocker Range FR, in comparison with 25 other sites in Sabah. Hence, from the insect diversity perspective, this area is of utmost importance. The Bornean endemic insect species recorded provide salient information to enhance the conservation of Sg. Kangkawat Research Station.

It is important to conduct continuous monitoring and enforcement at strategic locations within the reserve to minimize threats and adverse issues. This will ensure the forest quality is improved in order to maintain the interesting biodiversity, including insects. On-going cooperation with the relevant authorities, such as Sabah Forestry Department and Sabah Wildlife Department, may curb future incidences of encroachment into the conservation area. Further biodiversity research with Universiti Malaysia Sabah to enhance the conservation of that area is needed.

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Research Article

Butterfly (Lepidoptera: Papilionoidea) fauna of Kangkawat Research Station, Imbak Canyon Conservation Area, Sabah, Malaysia

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Abstract

Forty-three species of butterflies from 36 genera and six families are reported for Kangkawat Research Station, Imbak Canyon Conservation Area (ICCA). This accounts for 4.6 percent of the 944 species reported in Borneo. Compared to studies from other localities in ICCA, the butterfly fauna in Kangkawat Research Station is diverse and evenly distributed with a Shannon's index of Diversity (H') value of 3.636 and Simpson's index of Species Evenness ($E_{1/D}$) value of 0.776.The most dominant family is Nymphalidae with 27 species recorded followed by Lycaenidae with 11 species. Seven species are new records for ICCA: *Eurema blanda*, *Mycalesis dohertyi*, *Nacaduba berenice*, *Arhopala aedias agnis*, *Arhopala agesias*, *Drupadia cineas* and *Taractrocera ardonia*. Three species: *Mycalesis kina*, *Acytolepis ripte* and *Drupadia cineas*, which are endemic to Borneo are also recorded here. The presence of the butterfly species of high conservation value highlights Kangkawat Research Station as an important area for conservation of these species.

Keywords: butterfly, Kangkawat Research Station, endemic, new records

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Introduction

In 2009, Imbak Canyon was classified as a Class I (Protection) Forest Reserve by the Sabah State Government (Suleiman et al., 2011; Sabah, 2017). The conservation area consists of 30,000 hectares of virgin rainforest and is part of the Danum Valley-Maliau Basin-Imbak Canyon forest complex (Reynolds et al., 2011; Jaini et al., 2015), and known as Imbak Canyon Conservation Area (ICCA). In ICCA, the forest vegetation consists of lowland dipterocarp forest and lower montane heath forest.

Butterfly fauna has been surveyed throughout several scientific expeditions conducted since 2000 at different parts of ICCA. The first expedition in 2000 was conducted in Sungai Imbak Forest Reserve and recorded 174 butterfly species (Jalil et al., 2008). The second expedition in 2004 covered the central part of ICCA and had successfully listed 72 butterfly species and 133 individuals (Hasegawa & Chey, 2009). This was followed by a third expedition in 2010 in the southern region, Gunung Kuli and recorded 50 butterfly species and 79 individuals (Sulaiman et al., 2011). Subsequently, the Borneo Geographic Expedition 2018 was carried out in the south eastern part of ICCA, Kangkawat Research Station from 28 September till 9 October 2018. During the expedition, this study was conducted to determine the faunal composition of butterfly in Kangkawat Research Station and make notes of notable butterfly species (i.e. endemic, rare and protected species) occurring in the area.

Methodology

The survey was conducted daily from 29th September to 2nd October 2018 between 09:00h to 17:00h at the vicinity of Kangkawat Research Station (05° 04' North and 117° 03' East; Figure 1). Manual collection using aerial net was done at lowland dipterocarp forest (along the Kawang, South Rim and Nepenthes trail, secondary forest along the logging track (Pelajau trail) and along the riverbank of Sg. Kangkawat (as shown in Appendix 2). At the same time, ten traps were installed along the Kawang trail with rotten bananas used as bait.
Each captured specimen was sacrificed by gently pressing the thorax and stored in a glassine envelope. Specimens were then brought back to the laboratory for identification to species level using keys by Otsuka (1988), Corbet & Pendlebury (1992) and Otsuka (2001) and recent taxonomic hierarchy and classification by Kirton (2014).

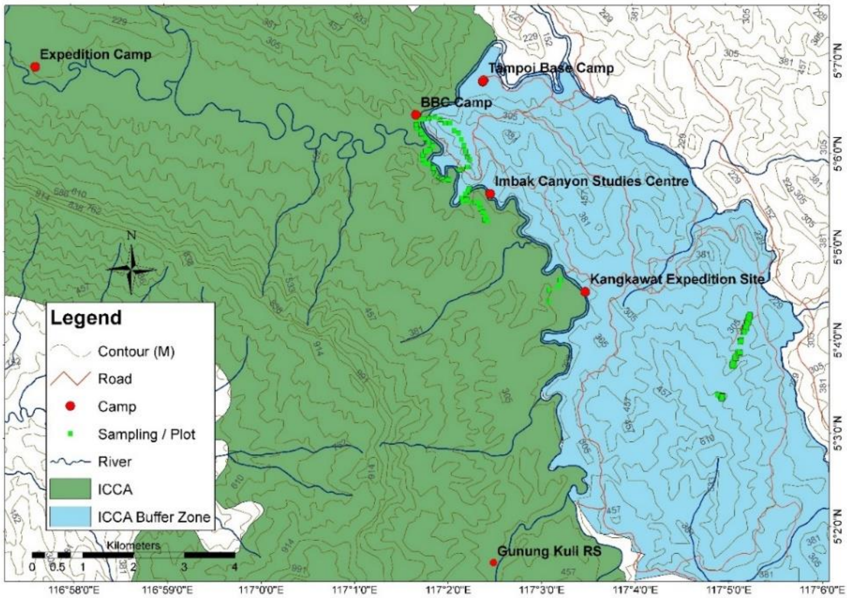

Figure 1. The sampling trail at the vicinity of Kangkawat Expedition site (Source: Conservation & Environmental Management Division, Yayasan Sabah)

Data Analysis

Following reccommendations by Magurran (2004), several indices were used such as Shannon's diversity index (H') to measure diversity of butterfly and Simpson's evenness index ($E_{1/D}$) to describe the pattern of species distribution and evenness in the assemblage. All data were analysed using statistical software; Paleontological Statistics version 1999-2013 (PAST).

Results and Discussion

Species composition

A total of 43 butterfly species comprising of 79 individuals from six families was recorded during the inventory (listed in Appendix 1). The six families were: Nymphalidae (27 spp.), Lycaenidae (11 spp.), Papilionidae (2 spp.), Pieridae (1 sp.), Riodinidae (1 sp.) and Hesperiidae (1 sp.). The collection was dominated by Nymphalidae, which contributed about 70% of the butterfly abundance. The least represented family were Pieridae (1%) and Hesperiidae (1%) (Figure 2). Nymphalid species were easily found as they are active fliers and polyphagous that feed on flower nectar, pollen, juices of rotten fruits, carrion and dung (Fiedler, 1998). This makes them forage in larger areas and inhabit different forest ecosystems (Majumder et al., 2013). The use of traps, baited with rotten fruits had successfully added to a higher number of nymphalid species such as species of subfamilies Satyrinae and Charaxinae to the collection, enhancing the sampling effort by 26%. On the other hand, hesperiids were least represented and difficult to spot when in flight since they are fast fliers and naturally well camouflaged due to their morphological resemblance to moths (Kirton, 2014). Typically, pierid species are often found congregated on puddles or riverbanks on a sunny day and locally abundant in lowland forest especially on secondary plant associates and are found in open areas (Corbet & Pendlebury, 1992; Abang, 2006). Therefore, Pieridae was only represented by a single species and individual during this study. This might be influenced by several environmental factors; diversity of vegetation (limited host plants and blooming of flowers), weather conditions (rainy and wet season) and canopy openness (more shaded area).

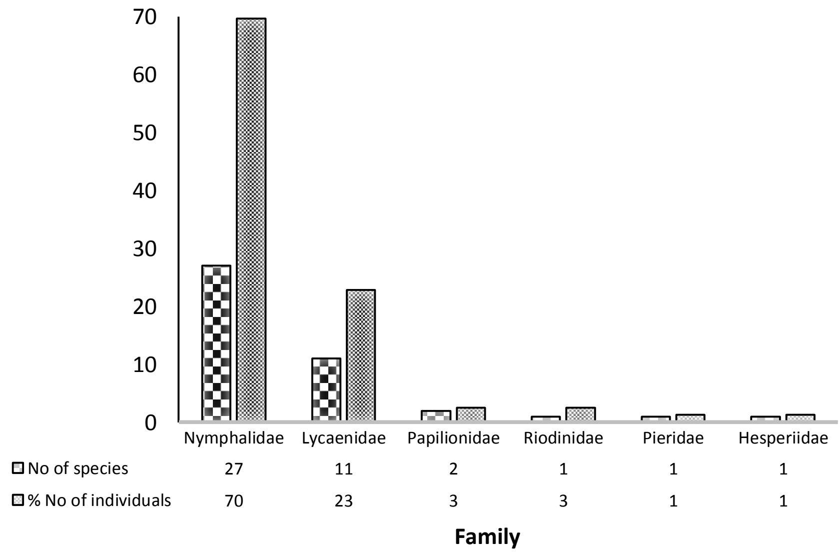

Figure 2. Faunal composition of butterfly species in Kangkawat Research Station, ICCA

Rank abundance curve as in Figure 3 shows two species were dominant; *Mycalesis kina* having the highest abundance (5 individuals), followed by *Drupadia theda* with 4 individuals recorded, while species ranked between 3rd to 23rd were classified as intermediate such as the fruit-feeding nymphalids (*Mycalesis dohertyi, Neorina lowii* and *Zeuxidia amethystus*) and the common species (*Ypthima baldus, Parthenos sylvia, Moduza procris* and *Prosotas nora* (species shown in Appendix 2). The common species could easily be found at the forest clearing, open area, secondary forest and moist spot especially at the logging track in Pelajau trail. Some species were singletons such as *Trogonoptera brookiana, Prothoe franckii, Charaxes bernadus, Acytolepis ripte* and *Arhopala agesias*. Some singleton species were considered uncommon as most of them are fast fliers and strictly confined to forested areas. Some of them are also cryptic as they are well camouflaged and rarely seen flying (Kirton, 2014). In addition, the thoroughness of the sampling effort and weather condition could contribute to low abundance of butterflies in the sampling area (Magurran & McGill, 2011).

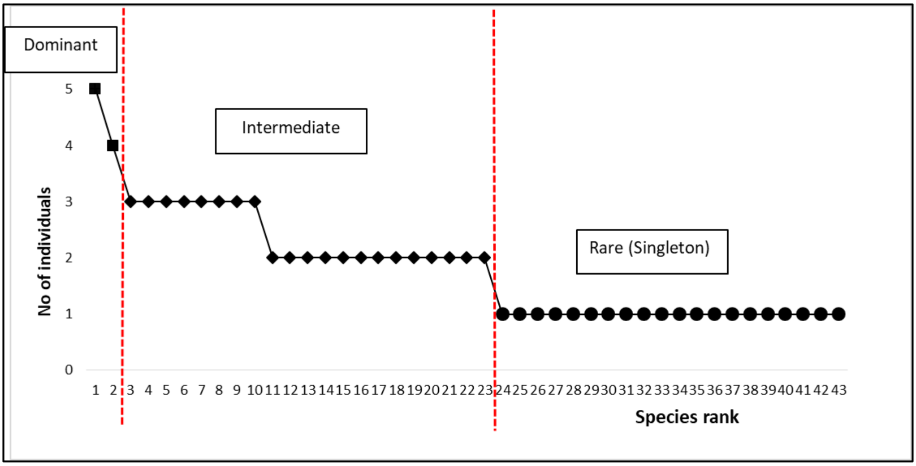

Figure 3. Rank abundance curve of butterfly in Kangkawat Research Station

In terms of species diversity and distribution, the values of Shannon Diversity Index (H’) is 3.636 and Simpson Evenness Index (E’) is 0.776. This indicated a high diversity of butterfly species that are evenly distributed in the area. This is comparable to the diversity of butterfly reported in the southern part of Imbak Canyon, Gunung Kuli with H’= 3.83 and E’= 0.97 respectively (Sulaiman et al., 2011).

Conservation status

There are some notable species among the collection from Kangkawat Research Station. Three butterfly species recorded are endemic to Borneo, namely *Mycalesis kina* Staudinger, 1892, *Acytolepis ripte* (Druce, 1895) and *Drupadia cineas* (Grose-Smith, 1889):

Mycalesis kina Staudinger, 1892

This species was originally found in Kinabalu, Lawas (Fruhstofer 1908; NHM, 2018). Despite being noted as endemic species to Borneo (Otsuka, 1988), this species was widely recorded in all forest habitats and easily found in the sun-lit sections of the forest (Otsuka, 2001). It was abundantly recorded in Danum Valley, Sabah (Hamer et al., 2003), Kubah National Park, Sarawak (Christhina & Abang, 2014) and Kuala Belalong, Brunei (Orr & Haeuser, 1996). In fact, this species was previously recorded in ICCA by Jalil *et al.* (2008) and Hasegawa & Chey (2009). In this study, this species is considered as the most dominant species recorded and found at several sampling transects (Kawang, Nephenthus and Pelajau trail). It was collected both manually using aerial net and baited trap.

Acytolepis ripte (Druce, 1895)

This species is also known as *Cyaniris ripte* H.H. Druce (NHM, 2018) and *Lycaenopsis ripte* (Druce) (Chapman, 1909) and firstly collected by Sir Hugh Low in Labuan (Druce, 1895). It could be found in lowland forest and previously reported in Kuala Belalong, Brunei (Orr & Hauser, 1996) and central part of ICCA during the Imbak Canyon Scientific Expedition 2004 (Hasegawa & Chey, 2009).

<u>*Drupadia cineas* (Grose-Smith, 1889)</u>

This species was previously known as *Sithon cineas* Grose-Smith, firstly recorded by J. Whitehead in Mount Kinabalu. It is also a synonym for *Biduanda hewitsonii* Druce, which was recorded in Sarawak (Cowan, 1974). Previously, it was recorded in Poring Hot Spring at the southeastern part of Mount Kinabalu (Hauser et al., 1997) and Lambir Hill, Sarawak (Itioka et al., 2009). This species was not recorded in ICCA from previous expeditions of 2000, 2004 and 2011. During this study, a single individual was collected manually at the logging track, Pelajau trail and thus added a new record for ICCA.

In term of conservation status, there are five species listed in Wildlife Protected Species Act 2010 [Act 716] which are *Trogonoptera brookiana* (Wallace, 1855), *Troides amphrysus* (Cramer, [1779]), *Idea stolli* (Moore, 1883), *Charaxes bernadus* (Fabricius, 1775) and *Prothoe franckii* (Godart, [1824]). The last two species are shown in Appendix 2. Due to their aesthetic appeal and striking colouration, both *T. brookiana* and *T. amphrysus* are vulnerable to specimen trade for souvenir purpose. In turn, they are also listed in Appendix II of Convention on International Trade in Endangered Species of Wild Flora and Fauna (UNEP-WCMC, 2012; CITES, 2016).

Addition to the butterfly fauna in ICCA

The documentation of butterfly fauna in ICCA was periodically reported in 2008, 2009 and 2011 following several scientific expeditions. When compared to the previous reports, this study has added 7 new records for ICCA. They are *Eurema blanda* (Boisduval, 1836), *Mycalesis dohertyi* Elwes, 1891, *Nacaduba berenice* (Herrich-Schaffer, 1869), *Arhopala aedias agnis* C. & R. Felder, [1865], *Arhopala agesias* (Hewitson, 1892), *Drupadia cineas* (Grose-Smith, 1889) and *Taractrocera ardonia* (Hewitson, 1868) (Appendix 1). Overall, the current number of species recorded in ICCA is 222, representing 24% of the total butterfly fauna in Borneo (944 sp.; Otsuka, 2001).

Conclusion

In spite of limited time, manpower and survey area, also unpredictable weather conditions, this study has provided a significant contribution in recording the diversity of butterflies in ICCA. Based on results of this study, Kangkawat Research Station holds a comparable diversity of butterflies making the conservation of the area even more important than ever. The presence of seven new records for ICCA from such a short expedition proves that there is still more to be discovered here. The endemic and protected species found in the area will hopefully encourage deeper studies on their assemblage in future.

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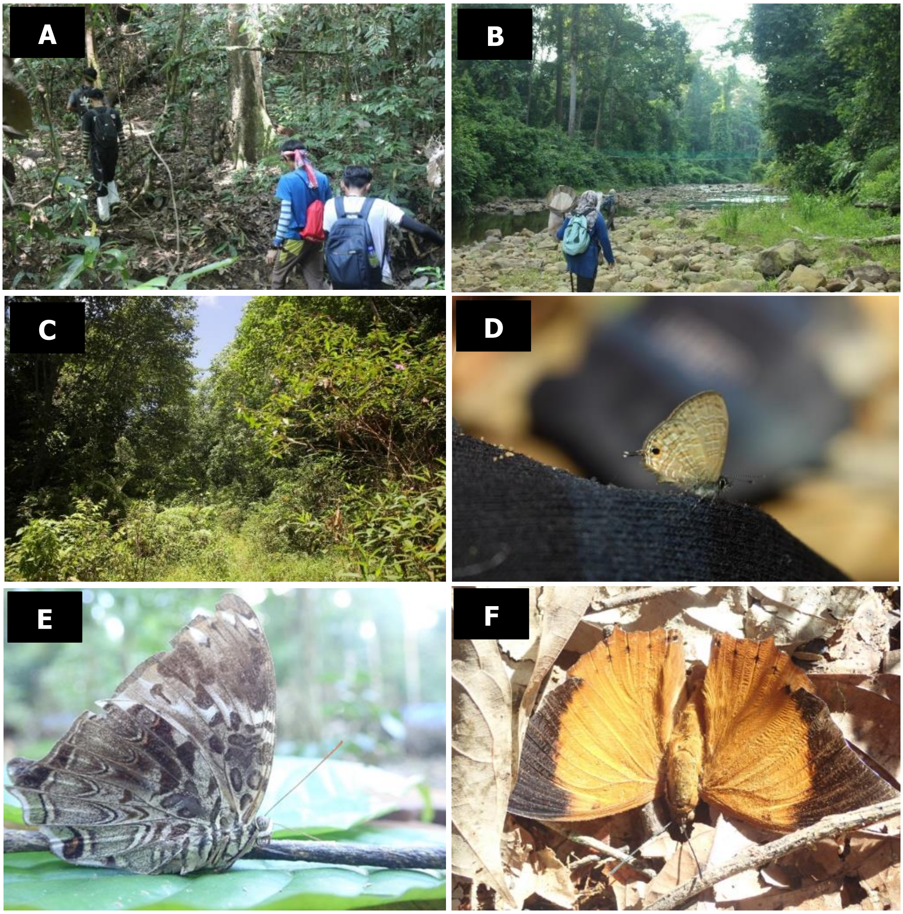
Appendix 1. The checklist of butterfly recorded from the Borneo Geographic Expedition 2018 Sungai Kangkawat, Imbak Canyon is arranged systematically according to the current taxonomic classification by Kirton (2014). The sampling trails, where butterflies were recorded are abbreviated by KW (Kawang), SR (South Rim), NP (Nepenthes), PJ (Pelajau) and Sg. Kangkawat (SK). Notable species are preceded with '*****' to indicate endemic species to Borneo, '**x**' to represent protected species under Wildlife Conservation Act 2010) and '**+**' to mark a new record for Imbak Canyon Conservation Area.

Family/ Subfamily	Species Name	Sampling Trail				
		KW	**SR**	**NP**	**PJ**	**SK**
PAPILIONIDAE						
Papilioninae	X *Trogonoptera brookiana (Wallace, 1855)* -observation					
	X *Troides amphrysus* (Cramer, [1779])				/	
PIERIDAE						
Coliadinae	+*Eurema blanda* (Boisduval, 1836)					
NYMPHALIDAE						
Danainae	X *Idea stolli* (Moore, 1883)	/	/			/
Satyrinae	*Neorina lowii* (Doubleday, [1849])	/		/		
	Zeuxidia amethystus Butler, 1865	/				
	Coelites euptychiodes C.&R. Felder, [1867]	/			/	
	Ragadia makuta (Horsfield, [1829])	/	/			
	+*Mycalesis dohertyi* Elwes, 1891	/				
	Mycalesis fusca (C.&R.Felder,1860)	/			/	
	******Mycalesis kina* Staudinger, 1892	/		/	/	
	Mycalesis maianeas Hewitson, [1864]	/				
	Mycalesis mineus (Linnaeus, 1758)				/	
	Mycalesis oroatis Hewitson, [864]	/	/			
	Mycalesis orseis Hewitson, [1864]				/	
	Ypthima baldus (Fabricius, 1775)		/		/	
	Ypthima pandocus Moore, [1858]					/
Charaxinae	*Polyura athamas* (Dury, [1773])					/
	X *Charaxes bernadus* (Fabricius, 1793)	/				
	X *Prothoe franckii* (Godart, [1824])	/				
Heliconiinae	*Cethosia hypsea* Doubleday, [1847]				/	
	Vindula dejone (Erichson, 1834)					
	Cirrochroa tyche (C.&R.Felder,1861)				/	
	Terinos atlita (Fabricius, 1787)					

	Cupha erymanthis (Drury, [1773])					
Limenitidinae	*Parthenos sylvia* (Cramer,[1775])				/	
	Moduza procris (Cramer, [1777])				/	/
	Bassarona dunya (Doubleday, [1848])	/				
	Tanaecia clathrata (Vollenhoeven,1862)	/				
Nymphalinae	*Rhinopalpa polynice* (Cramer,[1779])		/			
RIODINIDAE						
Nemeobiinae	*Paralaxita orphna* (Boisduval, 1836)	/				
LYCAENIDAE						
Miletinae	*Logania malayica* Distant,1884	/				
Polyommatinae	*Caleta elna* (Hewitson, [1876])					
	***Acytolepis ripte* (Druce, 1895)					
	Celastrina lavenduralis (Moore,1877)	/	/		/	
	Jamides pura (Moore,1886)		/		/	
	+*Nacaduba berenice* (Herrich-Schaffer,1869)		/			
	Prosotas nora (C.Felder,1860)				/	/
Theclinae	+*Arhopala aedias agnis* C.&R.Felder, [1865]	/				
	+*Arhopala agesias* (Hewitson, 1892)	/				
	**+*Drupadia cineas* (Grose-Smith, 1889)				/	
	Drupadia theda (C.&R.Felder, 1862)	/	/			
HESPERIIDAE						
Hesperiinae	+*Taractrocera ardonia* (Hewitson, 1868)				/	
Total number of species	43					
Total number of individuals	79					
Number of families	6					
Endemic species	3					
New records for ICCA	7					

Appendix 2. (A) The forest vegetation at Kawang, South Rim, (B) Sg. Kangkawat, (C) Pelajau trails, (D) male of *Prosotas nora* was seen sipping minerals on the bank of forest stream, and the protected species under Wildlife Conservation Act 2010 [716]; (E) *Prothoe franckii,* (F) *Charaxes bernadus*.



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Research Article

Solitary Fireflies of Kangkawat Research Station, Imbak Canyon, Sabah

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Abstract

A survey on solitary fireflies was carried out at Kangkawat Research Station in October 2018. A total of 33 fireflies were collected; three adult males, 13 adult females and 17 larvae. Three fireflies species were identified from male specimens, namely *Pygoluciola wittmeri*, *Luciola* sp. and most larvae consists of *Pyrocoelia* sp. This is a new record, mapping the existence of the species in Imbak, hence expanding the geographical knowledge of *Pygoluciola*, *Luciola* and *Pyrocoelia*. There are five morphospecies of unidentified females and three morphospecies of larvae. Three videos of larvae showed an emission of a long glow while the adult female in captivity exhibited single-peaked pulsing light. Male flashes were observed to emit long glows with intermittent rest. Most adult fireflies were caught flying between trees while larvae were found among twigs, leaf litter and leaves.

Keywords: Solitary firefly, *Pygoluciola wittmeri*, *Luciola* sp., *Pyrocoelia* sp., Lampyridae.

Introduction

Firefly (Coleoptera: Lampyridae) is a subject of fascination for many because of its ability to emit light. It is also a tourism attraction in Borneo (Mahadimenakbar et al., 2014; Syazlina et al., 2016). Various research projects have been conducted focusing on the mangrove fireflies (Mahadimenakbar et al., 2018; Mahadimenakbar & Fiffy Hanisdah, 2016; Foo & Mahadimenakbar, 2015, 2016, 2017) because of their ability to flash en masse and function as a tourism magnet. However, much about fireflies remains a mystery, even information as basic as species distribution.

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There are more than 2,000 species of firefly described worldwide (Hu & Fu, 2018; Mu et al., 2016; Silveira & Mermudes, 2014) with several new species discovered in forested areas year after year. For example, in Malaysia, the genus *Emasia* (Lampyridae: Ototrinae) was erected from a firefly found in Gunung Emas, Tambunan, Sabah (Bocakova & Janisova, 2010). A new species of *Pygoluciola dunguna* was described by Nada & Ballantyne (2018) found at a lowland dipterocarp forest of Dungun, Peninsular Malaysia. New records were also documented, such as *Pteroptyx tener* (Swatdipong et al., 2015) and *Australoluciola* sp. that were newly found in Thailand (Sartsanga et al., 2017). These findings are due to explorations in new and unexplored territories.

As much as mangrove fireflies are revered, information regarding the solitary firefly is falling behind. In Borneo, especially Sabah, there are only a few places in which non-mangrove fireflies were discovered such as in Maliau Basin (*Luciola* sp. found; Muslim et al., 2010), Tabin Wildlife Reserve (*Pyrocoelia opaca*; written as *Lychnuris opaca* in Chung & Binti, 2008), Mahua (*Pygoluciola guigliae* and *wittmeri*; Ballantyne & Lambkin, 2006), Kionsom (*Pygoluciola wittmeri*; Chey, 2008), Ulu Kimanis (Chung et al., 2002) and Mesilau (*Pygoluciola kinabalua*; Ballantyne & Lambkin, 2001). This left a huge unchecked area in the interior part of Sabah for firefly species distribution especially the solitary fireflies. Hence, this study is conducted to survey firefly species in Imbak Canyon to expand our geographical knowledge pertaining to the solitary fireflies.

Methodology

Sampling

Sampling was carried out for two hours (8–10pm) along Kawang Trail (5th October 2018) and Nepenthes Trail (6th and 8th October 2018) during the Borneo Geographic Expedition Kangkawat, 2018, organised by UMS. Fireflies were collected opportunistically using sweep net (for flying adults) and forceps (for larvae) by three people equivalent to six man-hours sampling effort. Each location of sampled fireflies was recorded using a GPS receiver and temperature and humidity were measured using the Kestrel Weather Station. Sampling was more focused on catching the adult firefly as soon as possible to avoid escape and flash recordings were not prioritized but only taken when they were sedentary using Canon EOS 100D. Live fireflies and larvae were killed and stored in 70% ethanol.

Species Identification

In general, female fireflies are unidentified due to lack of identification key hence species identification is based on male samples. Intact samples and male genitalia were photographed using Zeiss Image Analyzer at the Institute for Tropical biology and Conservation, UMS. All samples were identified by Wan Faridah Wan Jusoh up to genus level and later by the authors using key provided by Nada & Ballantyne (2018) for *Pygoluciola*. Flash patterns were extracted using FFMPEG and ImageJ by measuring grayscale frame-by-frame (modified method from Konno et al., 2016).

Results

Firefly Species, Composition and Distribution

Thirty-three fireflies were caught made up of three adult males, 13 adult females and 17 larvae (Figure 1). Most individuals were caught within Nepenthes Trail (25 individuals), five from Kawang Trail and three by the river near the base camp (Figure 2). Male caught within the Nepenthes Trail was identified by WFWJ as *Pygoluciola* sp. (Figure 3-5) and the two remaining males were *Luciola* sp. (Figures 6 and 7). The *Pygoluciola* specimen is consistent with *Pygoluciola wittmeri* described in Nada and Ballantyne (2018) by having no tibiae curved, bifurcate median posterior projection of ventrite 7 (V7 henceforth) at apex and deeply emarginate apex visible from the ventral view. Its light organ (LO) on V7 is also consistent with *Pygoluciola wittmeri* described in Ballantyne & Lambkin (2006) by having shallow anteromedian emargination and not posteromedially emarginated (Figure 4; arrow). The V7 light organ was also described by Chey (2008) as a heart-shaped light organ.

Females are unidentified. However, based on pronotum, elytra and abdominal shape, female specimens were clustered into five morphospecies (Figures 8–17) and larvae were distinctively grouped into four morphospecies (Figures 18–29). Eleven out of 17 larvae are from the genus *Pyrocoelia* sp. which is marked as morphospecies 2 in Figures 21–23.

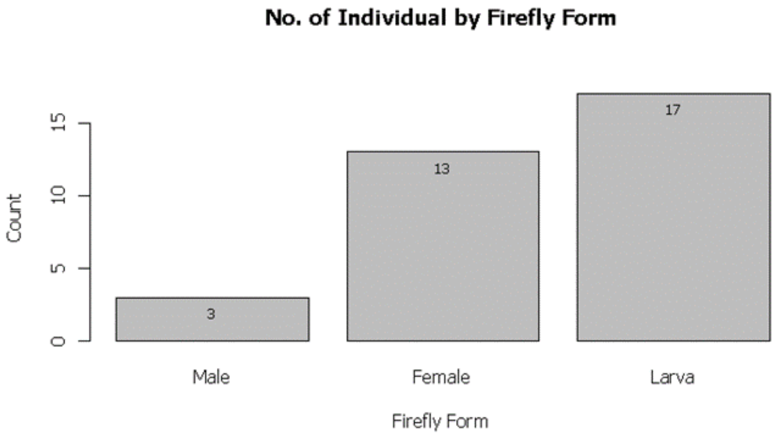

Figure 1. Numbers of fireflies sampled according to their form

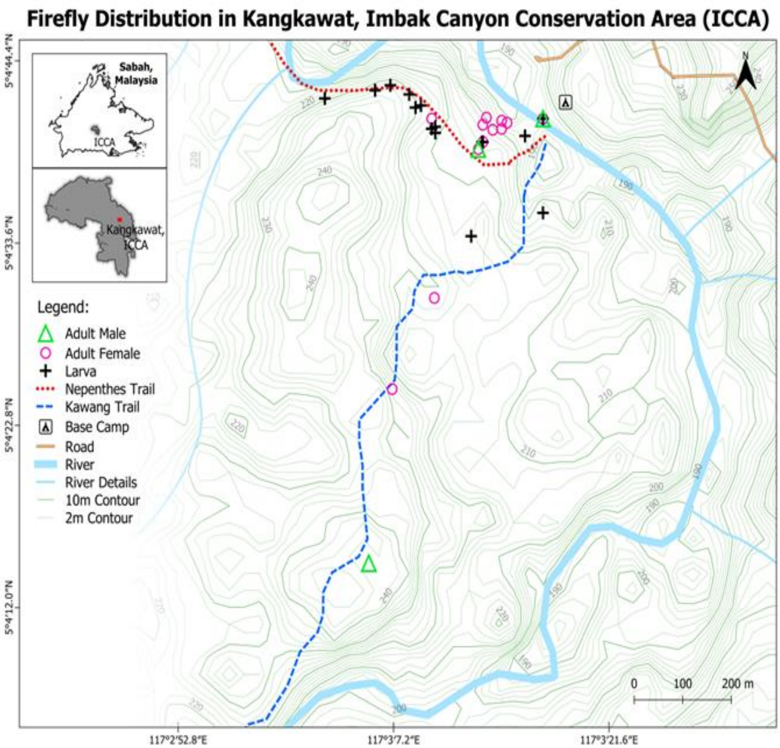

Figure 2. Locations of fireflies sampled from Kangkawat, ICCA. Five individuals were caught along Kawang Trail, 25 from Nepenthes Trail and three by the river near the

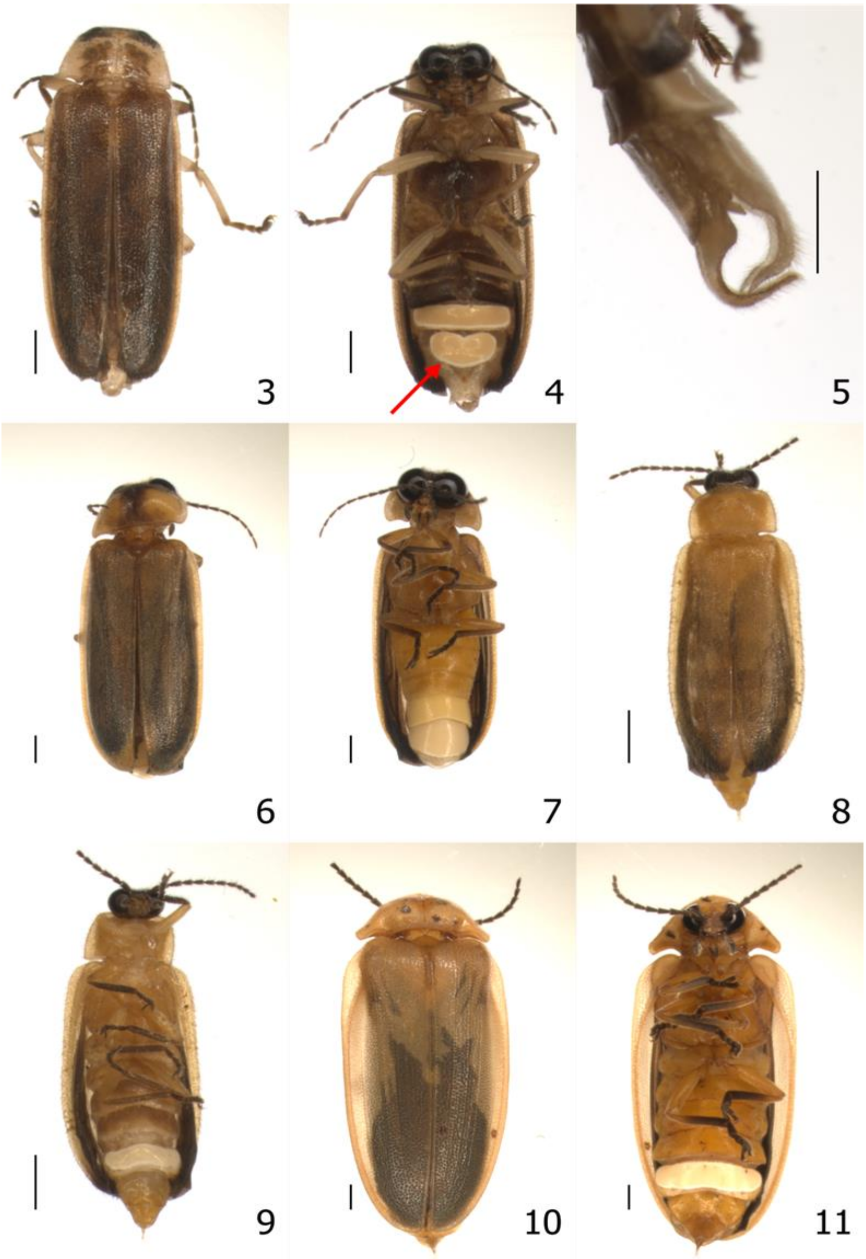

Figure 3 - 11. 3 – 5 male *Pygoluciola wittmeri* (red arrow on 4 showing LO in V7, tip of abdomen shown in 5); 6, 7 male *Luciola* sp.; 8, 9 female morphospecies 1; 10, 11 female morphospecies 2. 3, 6, 8, 10 dorsal, 5 right lateral, 4, 7, 9, 11 ventral. Scale line is 1

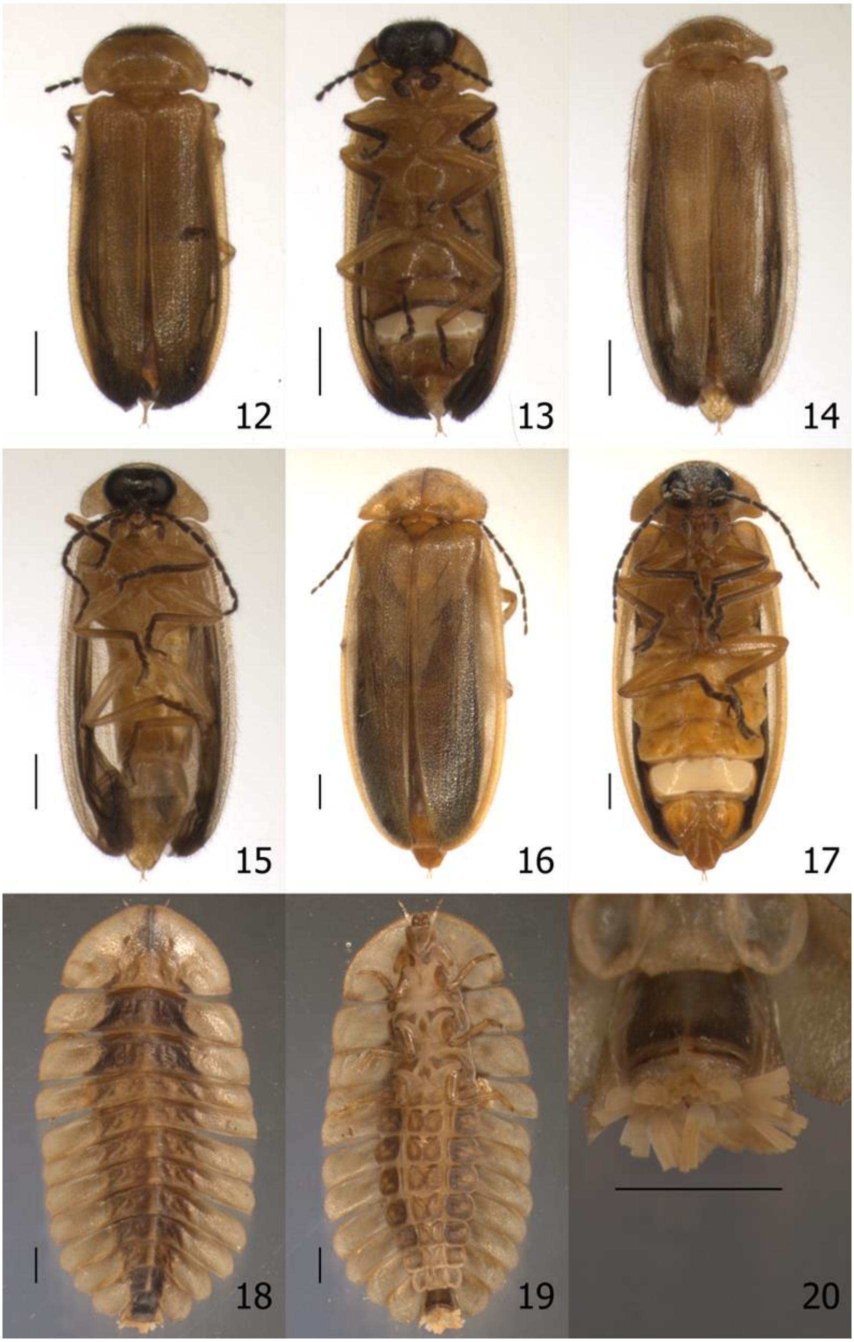

Figure 12 - 20. 12 – 13 female morphospecies 3; 14, 15 female morphospecies 4; 16, 17 female morphospecies 5; 18 – 20 larva morphospecies 1. 12, 14, 16, 18 dorsal, 13, 15, 17, 19, 20 ventral, 20 posterior end. Scale line is 1 mm.

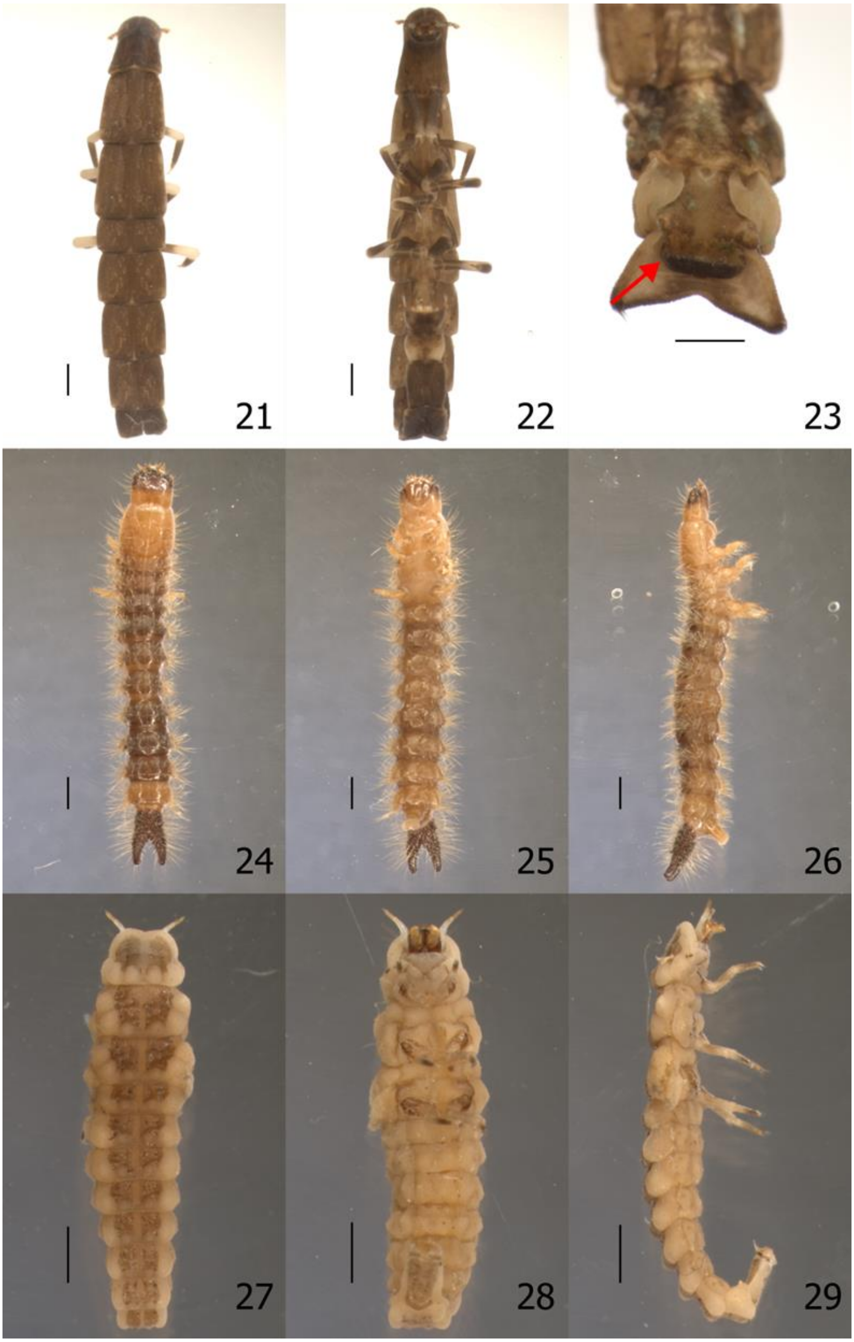

Figure 21 - 29. Larvae. 21 – 23 morphospecies 2 identified as *Pyrocoelia* sp., 22 larval abdomen curved ventrally (red arrow on 23 showing caudal grasping organ); 24 – 26 morphospecies 3; 27 – 29 morphospecies 4. 21, 24, 27 dorsal, 22, 23, 25, 28 ventral, 26,

General Ecology and Behaviour

Adult fireflies and larvae occupied different spaces and substrates. For instance, a majority of the adult fireflies were caught during flight and rarely found perching on leaves, but larvae were found on leaf litter (Figures 30 and 31), twigs (Figure 32) and leaves (Figure 33). Larvae in morphospecies 1, 3 and 4 were all found on leaf litter. *Pyrocoelia* sp. larvae (morphospecies 2) were glowing among leaf litter with only two individuals found on a twig and a leaf.
Figures 34 and 35 show that fireflies may be found in places with almost similar temperature and humidity. Male fireflies were found in places with 27.13 ± 0.32 °C and highly humid environment (95.23 ± 2.11 % relative humidity). The results are similar with female (26.97 ± 0.7 °C and 97.19 ± 2.34 %RH) and larvae (26.87 ± 0.32 °C and 98.18 ± 2.21 %RH).

In terms of flash patterns, there are only four recordings available for analysis; a single video of captured female and three of moving *Pyrocoelia* sp. larvae. The female was sedentary in a specimen bottle and emitted single-peaked pulses (Figure 36) and the *Pyrocoelia* sp. larvae emitted a long glow before it paused into darkness (Figure 37 – 39) and moved slowly by pushing its body forward using its caudal grasping organ at the posterior end (arrow on Figure 23 and Figure 32).

Figure 30. Larva morphospecies 1 found on leaf litter. Photo credit: Azrie Aliamat.

Figure 31. *Pyrocoelia* sp. larva caught moving on leaf litter. Photo credit: Azrie Aliamat.

Figure 32. *Pyrocoelia* sp. larva inching along a twig. It uses the caudal grasping organ on its posterior end to push itself forward (arrowed). Photo credit: Azrie Aliamat.

Figure 33. *Pyrocoelia sp.* larva found on a leaf (arrowed).

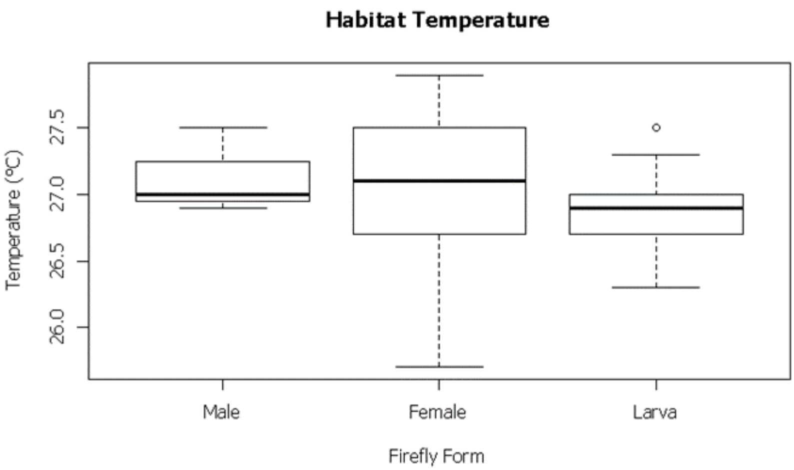

Figure 34. Boxplots of ambient temperature for each firefly form.

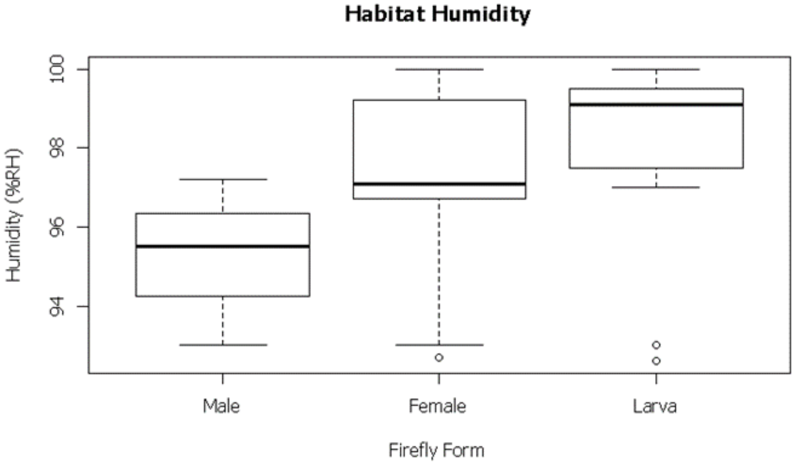

Figure 35. Boxplots of relative humidity for each firefly form.

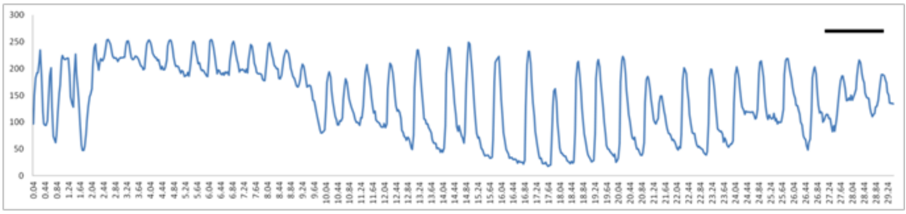

Figure 36. Female flashes in captivity. Scale line on upper right is two seconds. Ordinate: relative brightness (grayscale value), Abcissa: time in 0.04 seconds interval.

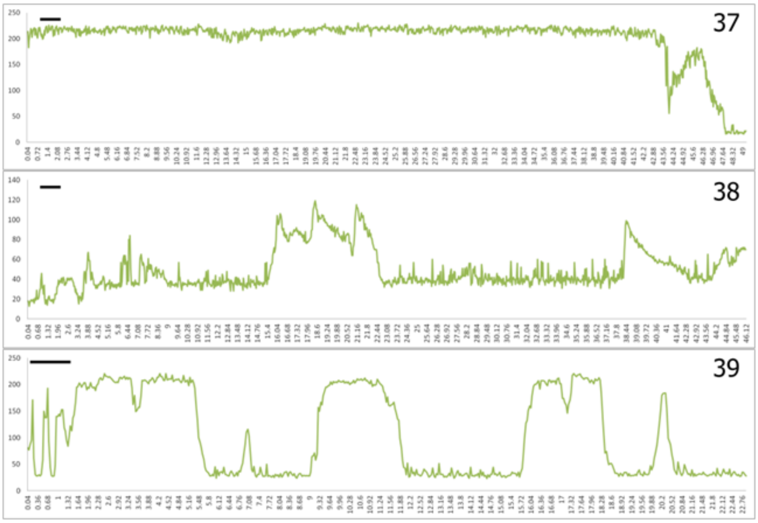

Figure 37 - 39. Larval glow. Scale line on upper left is 1.36 seconds for fig 37, 1.28 s for fig 38 and 39. Ordinate: relative brightness (grayscale value), Abcissa: time in 0.04 seconds interval.

Discussion

Due to its infrequent discovery, *Pygoluciola* fireflies were once dubbed as South East Asian rare fireflies (Ballantyne, 2008). Later, as the record expanded, it was revealed that *Pygoluciola* firefly was found in Malaysia (Ballantyne & Lambkin, 2006; Nada & Ballantyne, 2018), Philippines (Ballantyne, 2008), Australia, China (Fu & Ballantyne, 2008) and Thailand (Wattanachaiyingcharoen et al., 2016). Five out of nine species of *Pygoluciola* can be found in Borneo (Sabah and Sarawak). *Pyrocoelia* fireflies are widespread in Asia (Jeng et al., 2011; Li et al., 2005; Osozawa et al., 2015; Wang et al., 2007) and in Malaysia it was recorded in Tasik Chini (Roslan & Sulaiman, 2015), Fraser's Hill (Nada et al., 2013) and Tabin wildlife Reserve (Chung & Binti, 2008). This study presents new records of *Pygoluciola wittmeri*, *Luciola* sp. and *Pyrocoelia* sp. in Imbak Canyon and their distribution in Borneo. This has broadened the geographical knowledge of the species and the genus in general. Moreover, the species *P. wittmeri* was previously known to occupy Mahua River (Ballantyne & Lambkin, 2006) and Kionsom (Chey, 2008) but not other places in Sabah. Unfortunately, the ecology and habitat of *Pygoluciola wittmeri* are still currently unknown due to its rarity.

However, its rarity may be explained by its solitary behaviour. This is because in fireflies, there are two general classifications on how males search for their counterparts; congregating on a tree or travelling alone which is known as roving (Mahadimenakbar et al., 2018; Lewis & Cratsley, 2008). Roving can be seen in species such as *Photinus* sp. that wanders without specific direction (Lewis et al., 2004; Lewis et al., 2004). Another possibility is habitat requirement. Longton & Hedderson (2000) discuss rarity by lending 'rarity factors' set by Rabinowitz (1981) as a complex mixture of (1) strict geographical range, (2) highly specific habitat and (3) low population size. Any species that falls into the spectrum of the three criteria might become rare species and require intervention. The case with *Pygoluciola* is not obvious in this study other than the shallow number of individuals. From the distribution data, their population is small with imbalanced portion of male to female ratio. Ballantyne & Lambkin (2006) also argued that rarity might be contributed to the unexplored areas of the species and when it favours to habituate dangerous terrain. This makes them more difficult to be surveyed, hence making them rare.

Our findings also indicate that the forest floor is an important space for the growing larva. Larval stage is when they are hunting for food such as snails or slugs on the ground and mould into several instar stages (Fu & Meyer-Rochow, 2012, 2013; Liew & Schilthuizen, 2014; Madruga Rios & Hernández Quinta, 2010). Fireflies spend a good amount of time in larval form before becoming adults. For example, *Aspisoma lineatum* spends 16–19 days in larval form before going into prepupal stage (Viviani, 2001), up to 13 days for *Pyrocoelia pectoralis* (Wang et al., 2007) and 328 days for *Luciola ficta* (Ho et al., 2010). The significance of a long glow in firefly larvae had been hypothesised as a form of aposematic signal to tell predators that they are unpalatable (Vencl et al., 2016), but it is also a possible tactic to lure prey (Bechara & Stevani, 2018). The glowing strategy as aposematism tool is used by the firefly until they reach adulthood. In an experiment by Leavell et al., (2018), they demonstrated that bioluminescent is used by fireflies to ward off predators. Hence, it is very important to note that firefly conservation must start from the ground to allow feeding and growth.

Conclusion

There are three species of fireflies in Imbak Canyon; the rare *Pygoluciola wittmeri*, *Luciola* sp. and the larval form *Pyrocoelia* sp. This makes Imbak Canyon a suitable place to discover more about both species which are widely unknown, in terms of ecology, mating behaviour and feeding habit. Though the rarity of *Pygoluciola* is due to their low population, there is a possibility it was caused by the limitations faced in this study. For example, the length of study might yield different results if carried out longer than three nights or when sampling locations are not restricted based on the trail alone. Perhaps, when these limitations are corrected in future research, we will be able to discover more about their population which is true for any other 'rare' species.

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Research Article

Survey on the Small Mammals in Sg. Kangkawat Research Station Imbak Canyon Conservation Areas

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Abstract

Sg. Kangkawat Research Station is a newly established research station in the Imbak Canyon Conservation Area, Sabah which encompasses both primary and secondary forest areas. Limited data is available on the small mammal diversity for this particular area. Therefore, a survey-based study on small mammal diversity was carried out between the 29th September – 8th October 2018 along the established trails within the vicinity areas of this research station. Small mammal trapping was done using traps (mist nets, harp traps, cage traps and pitfall traps) employed randomly along the Nepenthes trail, the Kawang trail, the South Rim trail and the Pelajau trail. This study documented a total of 32 small mammal species i.e. represented by 26 species (15 spp. of new records for ICCA) of volant small mammals (Chiroptera) and 6 species of non-volant small mammals (Rodentia, Scadentia, Insectivora, Carnivora). The total number of specimens recorded was 108. A new distribution record on the Free-tailed Bat, *Chaerephon* cf. *johorensis*, was documented for Sabah and Borneo during this study.

Keywords: Small mammals; Chiroptera; Rodentia; Scandentia; Insectivora; Imbak Canyon Conservation Area; Sabah

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Introduction

The background knowledge about the pattern of mammal species richness and community composition in most parts of Borneo Island is still lacking (Bernard et al, 2013). So far, there are at least 271 known mammal species of Borneo with at least 242 species of mammals occupying various types of terrestrial habitat and 63 species of terrestrial mammals that are endemic species of Borneo (Phillipps & Phillipps, 2018). Mammal surveys are important to document patterns of species richness, diversity and compositions in different sites, together with different forest conditions (Bernard et al, 2013). This vital information will facilitate sound decisions related to biodiversity conservation (Bernard et al, 2013).

Few surveys on mammals have been done in Imbak Canyon Conservation Area (ICCA) covering localised areas such as Mt. Kuli research station (Bunya et al., 2012; Matsubayashi et al., 2011; Ong et al., 2013). Extensive mammals' surveys have been done covering the many areas in ICCA and its surrounding secondary logged forests using camera traps (Bernard et al, 2013). Those studies have contributed to the checklist of mammals in ICCA where 45 species of small mammals were documented (Ong et al., 2013). In this study, small mammals refer to small-sized mammals including volant (bats) and non-volant small mammals. There are at least 182 species of small mammals in Borneo (Order Chiroptera – 99; Order Scandentia – 45 spp.; order Rodentia – 29 spp.; order Insectivora – 1 sp.; order Eulipotyphla – 8 spp.) (Phillipps & Phillipps, 2018) and ICCA has recorded approximately 14% of the Borneon species of small mammals (25 spp. – 11 spp. Chiroptera, 10 spp. Rodentia and 4 spp. Scandentia) (Bunya et al., 2012; Matsubayashi et al., 2011; Bernard et al, 2013; Ong et al., 2013).

A survey on small mammals was carried out in the Sg. Kangkawat research station, ICCA from 29 September to 8 October 2018 covering the base camp area and four main sites in Sg. Kangkawat Research Station: Nepenthes trail, Kawang trail, South Rim trail and Pelajau trail. The forest habitat surrounding Nephentes trail, Kawang trail and South Rim trail are categorized as primary forest and forest areas in Pelajau trail are mainly secondary forest. This study aimed to add the small mammals' inventory data in the ICCA region, specifically to initiate the inventory data in Sg. Kangkawat research station. The assemblages of small mammals in Sg. Kangkawat research station was documented based on four main orders: order Chiroptera, Rodentia, Scandentia, and Insectivora. Data from this study can be used in species monitoring and biodiversity conservation.

Material and Methods

Study area

ICCA is one of the Yayasan Sabah forest management areas located in the central part of Sabah. The ICCA is approximately a 300 km^2 crescent-shaped elongated valley (Bernard et al, 2013). It can be accessed from the district of Telupid (appx. four hours from Kota Kinabalu) with approximately another four hours journey from Telupid town to ICCA. The ICCA was gazetted as a Class I (Protection) Forest Reserve in 2009, logging activities were totally prohibited in the area ever since. The forest habitats surrounding the fringes of the ICCA are generally heavily disturbed as it had been logged in the past and these areas are located in proximity to some human settlements and plantations (Bernard et al, 2013). However, the interior forests inside the canyon of the ICCA are still relatively pristine. The habitat within that area is mostly covered with lowland dipterocarp rainforest and upper montane forest, including patches of montane heath or “Kerangas” forest (Sugau et al., 2012; Suleiman et al., 2012; Bernard et al, 2013). In Sg. Kangkawat Research Station, there are four established trails used for the present study namely Nepenthes trail, Kawang trail, South Rim trail and Pelajau trail. Nepenthes trail, Kawang trail, and South Rim trail are within the primary forest region. The base camp and Pelajau trail is located within the ICCA buffer zone with medium to heavily disturbed forest habitats surrounding the fringes of ICCA.

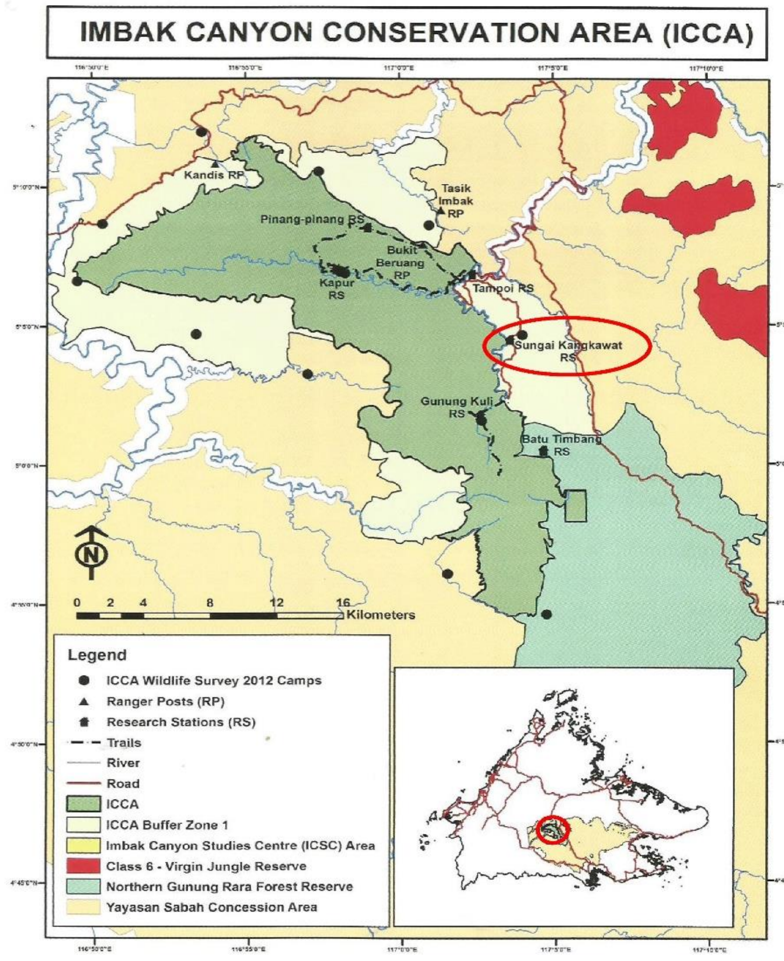

Figure 1. Imbak Canyon Conservation Area (ICCA) in central Sabah, the northern part of Malavsian Borneo.

Field Methods

Samplings of bats were done using five mist nets and four sets of four-bank harp traps for nine trapping nights, employed randomly in Nepenthes trail, Kawang trail, South Rim trail and Pelajau trail. In one sampling point, mist nets and harp traps were deployed with approx. 100m metres interval between points. Both the mist nets and harp-traps were set across trails, narrow pathways in the forest, hill, streams, forest edge and cleared areas in the forest. In addition to that, double-stacked mist-nets, with a total of six shelves and extending up as canopy mist net for one night in Pelajau trail. It was deployed approx. 15 to 20 metres above the forest floor. Nets and harp-traps were set across trails, narrow pathways in the forest, hill, streams, forest edge and cleared areas in the forest. The nets and harp-traps were used to capture bats that occupy the forest understorey and a canopy mist net was set at the canopy level to capture bats that occupy the canopy flyways. Both nets and traps were checked frequently from 1900 hrs to 2200 hrs, and finally at 0600 hrs in the morning.

Bats were identified in the field following the identification key by Phillipps & Phillipps (2018), Payne, Francis & Phillipps (1985) and Kingston, Lim & Zubaid (2006). The external morphological measurements including sex, Forearm (FA), Ear (E), Tail Ventral (TV) and Hind Foot (HF) of each bat were recorded using a digital calliper in millimetres (mm) and body mass were weighed using spring balance in grams (g). The morphological measurement (mm) of each bat was taken using a digital calliper and weighed (g) using spring balance. Released bats were marked on their right wing using biopsy punch 3mm and some individuals were kept as voucher specimens. Three individuals per species were taken as voucher specimens and preserved in 95% alcohol. Wet specimens were dissected exposing the stomach and intestine before being preserved in 95% alcohol as voucher specimens. The tissue samples such as liver and muscle tissues were minced and preserved into a lysis buffer. Blood samples were collected and ectoparasites found on the specimens were preserved in 70% ethanol. Photographs of selected bats were taken and kept for reference.

The sampling of non-volant small mammals was done using metal cage traps and pitfall traps for three days. The dimension of the metal cage traps used was 28cm X 18cm X 14cm and a total of 100 cage traps were deployed in transect line sampling with 5 metres interval between each traps and set along the trails in Nepenthes trail, Kawang trail, South Rim trail and Pelajau trail. Banana and salted fish were used as bait to further increase the effectiveness of the cage traps. Pitfall traps were set up using a 5 X 10 grid design and the dimension of each pitfall trap used was 267mm X 232mm X 232 mm for height, length and width. All the pitfall traps were drilled with holes on the base to allow water to flow through and prevent drowning of animals. Metal fences were set up between each pitfall traps to allow funnelling of animals and maximise the capture rate of the traps. Post sampling procedure for pitfall traps includes refilling of the traps holes to prevent any injury and accidental falling of wildlife in the holes.

Traps were checked and rebaited twice a day at 0900 hours until 1030 hours and 1500 hours until 1700 hours. Captured animals were taken to the camp, anaesthetized and processed. Captured animals were measured morphologically using digital callipers in millimetres (mm) for the Head Body (HB), Tail Ventral (TV), Ear (E) and Hind Foot (HF) measurements. Body mass was weighed using spring balance in grams (g) and species identification was done following Phillipps & Phillipps (2018) and Payne et al. (1985). Marking of individuals was done by applying nail polish on small parts of the fur to document recaptured individuals. Prior to release, photographs were taken for each species representative for future references. Selected individuals were euthanized and preserved as voucher specimens. The conservation status of the small mammals captured in the present study were determined based on the IUCN Red list of globally threatened species (IUCN, 2020).

Data analysis

Sampling saturation was assumed to be met when the observed cumulative number of mammal species reached an approximate asymptote with the cumulative number of individuals captured. Additionally, the sampling saturation was assessed by calculating the sampling completeness ratio (i.e., observed species number/estimated species number) using the mean of four commonly used abundance-based species richness estimators (i.e., ACE, CHAO1, ICE and JACK1) computed using EstimateS Version 9.1.0. (Edwards et al., 2009; Bernard et al, 2013). Here sampling saturation was assumed when the sampling completeness ratio approached one (Bernard et al, 2013).

Results

Order Chiroptera: Sampling efforts Species richness and composition

Ninety-eight individuals of Chiroptera (bats) from 26 species representing six families, namely Pteropodidae, Hipposideridae, Molossidae, Nycteridae, Rhinolophidae and Vespertilionidae, were captured in this study. The species accumulation curves for the number of individuals against species of bats recorded in Sg. Kangkawat Research Station showed an increasing pattern (Figure 2). The mean estimated species richness computed with EstimateS was 35.17 (ACE=34.29; CHAO1=31.94; JACK1=36.67; ICE=37.76), which resulted in a sampling completeness ratio of 0.74. From these findings, it is suggested that sampling saturation was moderate and more species are yet to be discovered from longer trapping periods and efforts at different areas in the research station.

Table 1. Observed and estimated species and sampling efficiency (%) of the bat communities (N = 100) in the Sg. Kangkawat Research Station, ICCA.

	Observed species	ACE	CHAO1	JACK1	ICE
Total	26	34.29	31.94	36.67	37.76
		(75.82)	(81.40)	(70.90)	(68.86)

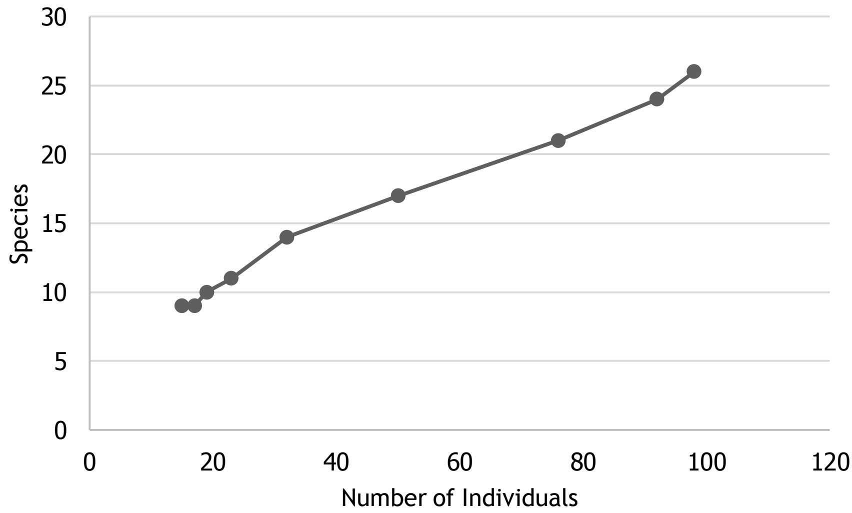

Figure 2. Species accumulation curves based on the number of individuals against species of bats recorded in Sg. Kangkawat Research Station.

Six species of small fruit bats and 20 species of insectivorous bats were recorded during this study. Species from family Rhinolophidae and Hipposideridae were the recorded highest number of individuals in Sg. Kangkawat research station. Species *Hipposideros cervinus* recorded the highest relative abundance with 14 individuals (14.29%). This was followed by *Rhinolophus acuminatus* (11.22%), *Rhinolophus sedulus* (9.18%), *Balionycteris maculata* (8.16%), *Rhinolophus creaghi* (7.14%), *Cynopterus brachyotis* (6.12%), *Myotis ridleyi* (5.10%), *Rhinolopus borneensis* (4.08%), *Hipposideros ater* (4.08%), *Hipposideros diaderma* (4.08%), *Kerivoula intermedia* (4.08%), *Cheiromeles torquatus* (3.06%), *Hipposideros dyacorum* (2.04%), *Kerivoula papillosa* (2.04%), *Kerivoula pellucida* (2.04%), and *Macroglossus minimus* (2.04%). Nine species with 1.02%

relative abundance were *Chaerephon* cf. *johorensis*, *Cynopterus minitus*, *Dyacopterus spadiceus*, *Kerivoula hardwickii*, *Kerivoula minuta*, *Megaerops ecaudatus*, *Nycteris tragata*, *Rhinolophus philippinensis* and *Rhinolophus trifoliatus*.

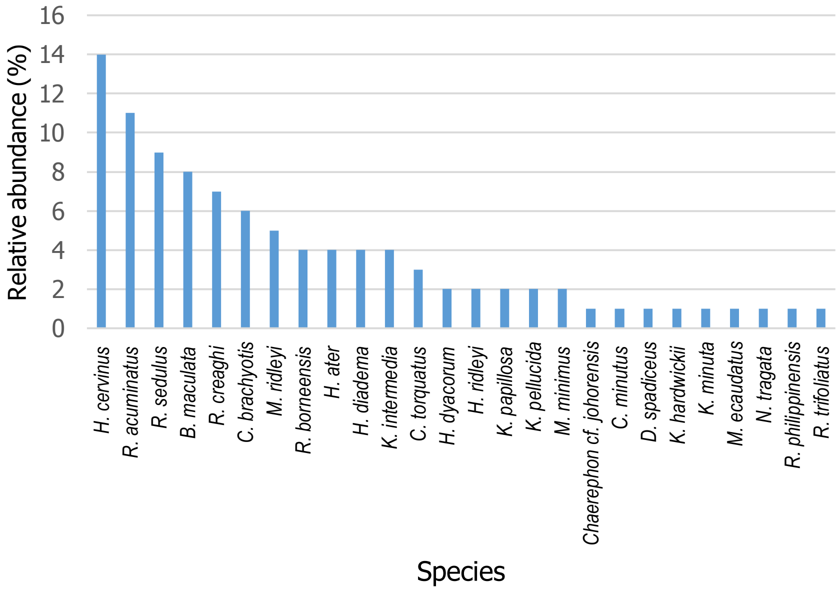

Figure 3. Relative abundance of bats in Sg. Kangkawat Research Station.

In this study, two species of vulnerable bats were recorded namely *Chaerephon* cf. *johorensis* and *Hipposideros ridleyi* (IUCN Red List – Vulnerable, VU). Meanwhile, seven species of bats recorded in this study were listed as Nearly Threatened (NT) species (*Dyacopterus spadiceus*, *Cynopterus minutus*, *Nycteris tragata*, *Kerivoula intermedia*, *Kerivoula minuta*, *Kerivoula pellucida*, and *Myotis ridleyi*). Most of bats (18 species) recorded in this study are listed as Least Concern (LC) in the IUCN Red List. One endemic species of bat, *Rhinolophus borneensis,* was recorded in this study. In comparison with the survey done by Bunya et al. (2012), this study recorded 15 new records of bats species for ICCA, namely *Cynopterus minutus, Chaerephon* cf. *johorensis, Cheiromeles torquatus, Dyacopterus spadiceus, Hipposideros ridleyi, Kerivoula hardwickii, Kerivoula intermedia, Kerivoula minuta, Kerivoula pellucida, Macroglossus minimus, Megaerops ecaudatus, Myotis ridleyi, Rhinolophus borneensis, Rhinolophus creaghi,* and *Rhinolophus philippinensis.*

Table 2. Summary and status of bats caught in Sg, Kangkawat Research Station.

Family	Species	No. of individuals	Localities	IUCN Red List	Distribution (Phillipps & Phillipps, 2018)
Pteropodidae	*Balionycteris maculata*	8	Nepenthes, Kawang, South Rim, Pelajau,	LC	Common
	Cynopterus brachyotis	6	Pelajau	LC	Common
	Cynopterus minutus	1	South Rim	NT	Common
	Dyacopterus spadiceus	1	Pelajau	LC	Common
	Macroglossus minimus	2	Nepenthes	LC	Common
	Megaerops ecaudatus	1	Pelajau	LC	Common
Molossidae	*Chaerephon* cf. *johorensis*	1	Pelajau	VU	Scarce
	Cheiromeles torquatus	3	Basecamp, Pelajau	LC	Common
Nycteridae	*Nycteris tragata*	1	South Rim	NT	Common
Hipposideridae	*Hipposideros ater*	4	Nepenthes	LC	Common
	Hipposideros cervinus	14	Nepenthes, South Rim, Pelajau	LC	Common
	Hipposideros diadema	4	Nepenthes, South Rim, Pelajau	LC	Common
	Hipposideros dyacorum	2	Pelajau, Nepenthes	LC	Common
	Hipposideros ridleyi	2	Nepenthes	VU	Common
Rhinolophidae	*Rhinolophus acuminatus*	11	Nepenthes, South Rim	LC	Common
	Rhinolophus borneensis	4	Nepenthes, South Rim, Pelajau	LC	Endemic
	Rhinolophus creaghi	7	Nepenthes, Kawang, Pelajau	LC	Common
	Rhinolophus philippinensis	1	Pelajau	LC	Common
	Rhinolophus sedulus	9	Nepenthes, South Rim, Pelajau	LC	Common
	Rhinolophus trifoliatus	1	Nepenthes	LC	Common
Vespertilionidae	*Kerivoula hardwickii*	1	Nepenthes	LC	Common
	Kerivoula intermedia	4	Nepenthes, Pelajau	NT	Common
	Kerivoula minuta	1	Pelajau	NT	Common
	Kerivoula papillosa	2	South Rim	LC	Common
	Kerivoula pellucida	2	Pelajau	NT	Common
	Myotis ridleyi	5	Pelajau, South Rim	NT	Common

Order Rodentia, Scandentia, Insectivora: Species composition

Ten individuals of small mammals from order Rodentia (2 spp.), Scandentia (2 spp.), Insectivora (1 sp.) and one small carnivore were recorded during the three days trapping. The trapping success recorded (i.e. number of individuals caught divided by the total number of trap-nights) was 3%. The order Rodentia was represented by *Maxomys rajah* (n = 4), and *Maxomys whiteheadi* (n=1). For the order Scandentia, two individuals represented by the endemic Northern Long-footed Treeshrew, *Tupaia longipes* and one individual of the large treeshrew, *Tupaia tana*. One species from order Insectivora, *Echinosorex gymnura* and one small carnivore, the common palm civet, *Paradoxurus hermaphroditus* were recorded during this survey. Meanwhile the trapping success for pitfall traps in three trapping days was 0%.

Table 3. Summary and conservation status of non-volant small mammals in Sg. Kangkawat Research Station.

Order	Species	Common Name	Frequency n	Trail	IUCN Red list status	Distribution
Rodentia	*Maxomys rajah*	Rajah Sundaic Maxomys	4	Nepenthes; Pelajau	VU	Common
	Maxomys whiteheadi	Whitehead's Sundaic Maxomys	1	Pelajau	VU	Common
Scandentia	*Tupaia longipes*	Northern Long-footed Treeshrew	2	Nepenthes	LC	Common Endemic
	Tupaia tana	Large Treeshrew	1	Nepenthes	LC	Common
Insectivora	*Echinosorex gymnura*	Moonrat	1	Pelajau	LC	Common
Carnivora	*Paradoxurus hermaphroditus*	Common Palm Civet	1	Nepenthes	LC	Common

Discussion

Chiroptera

Survey using 15 mist-nets (10 nets in Slope trail, three nets in Summit trail and two in Waterfall trail) and 5 harp-traps (three traps in Slope trail, one trap in Summit trail and one in Waterfall trail) on bats done in Mt. Kuli Research Station had documented 11 spp. of bats (9 insectivorous bats and 2 frugivorous bats) (Bunya et al, 2012). Meanwhile, the present study using 21 mist-nets (five nets in Nepenthes trail, Kawang trail, South Rim trail, Pelajau trail, and one canopy net at basecamp) and 16 four traps (four traps in Nepenthes trail, Kawang trail, South Rim trail, and Pelajau trail) had documented 26 spp. of bats in Sg. Kangkawat Research Station with 15 spp. of new records for ICCA. Interestingly, one bat species that was only recorded in Peninsular Malaysia was found in this study. The Northern Free-tailed Bat, *Chaerephon* cf. *johorensis* is a new record to Sabah and Borneo. This species is listed as Vulnerable in IUCN Red List and reported to occupy the upper canopy level. This study suggests that more studies on bats targeting canopy level species are needed for more sampling coverage and species discoveries. The next direction from this study is to confirm the identity of this species using morphological analysis and molecular analysis.

Based on feeding guild, insectivorous bats made up of 80.61% of bats assemblages in Sg. Kangkawat Research Station. The assemblages of bats in Sg. Kangkawat Research Station was dominated by Rhinolophidae (6 spp, 26 individuals) and Hipposideridae (5 spp., 33 individuals). In general, most *Rhinolophus* and *Hipposideros* are narrow space active gleaning foragers that actively forage in the forest understorey (Phillipps & Phillips, 2018). *Hipposideros cervinus* and *Rhinolophus acuminatus* recorded the highest species abundance. Both species were mostly caught using harp traps at forest understorey. Both species are widely distributed and locally common in lowland forests of Sabah. *Hipposideros cervinus* is the most common insectivorous bats in Borneo's caves while *Rhinolophus acuminatus* were reported to roost under palm leaves (Phillipps & Phillips, 2018).

In Borneo, there are at least 18 species of frugivorous bats (Phillipps & Phillipps, 2018) and six species of small fruit bats were recorded in this study. Fruit bats made up 19.39% of bat assemblages in this study. Most of fruit bats caught in this study are common fruit bat species with *Cynopterus minutus* listed as Nearly Threatened in the IUCN Red List. Small fruit bats are abundant throughout Borneo. They play significant roles in seed dispersal and pollination in Borneo (Phillipps & Phillipps, 2018).

Structure of forest habitat influenced the assemblages of bats in the tropical forest ecosystem. The bat assemblage tends to be more diverse in preserved habitats and in environments with higher structural complexity (Falcão, Espírito-Santo, Fernandes & Paglia, 2018). The assemblages of bats in Sg. Kangkawat Research Station may be structured based on the forest habitat. The combination of pristine forest habitat inside the ICCA and heavily disturbed forest habitats surrounding the fringes of the ICCA may provide diverse assemblage's structure and species exploration for bats. Studies reported that habitat structures such as fragmented and continuous forest showed inconsistent responses at the assemblage level of bats such as species richness, diversity, and composition (Cosson, Pons, & Masson, 1999; Estrada & Coates-Estrada 2002; Faria, Laps, Baumgarten, & Cetra, 2006; Meyer, Struebig, & Willig, 2016; Wordley et al., 2018). For example, cave-dwelling hipposiderid and rhinolophid bats were less abundant in repeatedly logged sites than in primary forest (Furey et al., 2010; Meyer, Struebig, & Willig, 2016). In the current study, hipposiderid and rhinolophid bats dominate the assemblages of bats in Sg. Kangkawat Research Station. In addition, 35% of recorded bat species in Sg. Kangkawat Research Station are at risk of extinction. With this, ICCA provides important habitats for bats and further studies are needed to understand the responses at the assemblage level of bats in various habitat types in ICCA.

In this study, sampling efforts of bats were limited by rainy nights. For better species coverage, sampling at sub-canopy and canopy level is important to avoid bias in the sampling of bats Sg. Kangkawat Research Station. The sampling period should be lengthened and could include the use of various sampling methods such as bat detectors in various localities in ICCA. This is important to enhance understanding of the diversity of bats in ICCA, specifically in Sg. Kangkawat Research Station.

Non-volant Small mammals

For non-volant mammals, the most abundant species was *Maxomys rajah*. *Maxomys rajah* and *Maxomys whiteheadi* are listed as Vulnerable in IUCN Red List. Endemic species, *Tupaia longipes* was recorded in this study. All the species of non-volant small mammals recorded here also appear to be commonly found in most sites in ICCA as all species had been documented in previous studies (Ong et al., 2013). In previous studies, four species of order Scandentia, one species of order Insectivora and 10 species of order Rodentia (including 3 spp. of porcupines) had been documented in ICCA (Matsubayashi et al., 2011; Bernard et al, 2013; Ong Kay York et al., 2013). During this study, one small carnivore, *Paradoxurus hermaphroditus* was caught in the cage trap. Previous camera trap studies done in ICCA had documented seven species of Viveridae civets and *Paradoxurus hermaphroditus* was not recorded in those studies.

There are a few suggestions to improve the coverage of non-volant small mammals species for future studies. Firstly, the sampling period of non-volant small mammals trapping should be lengthened in the future. Throughout this field sampling, all the cage traps were placed on the ground and this may reduce the possibility to capture other small mammals that are arboreal (Khan et al., 2017). Placing the traps according to their microhabitat, niche and foraging areas will prompt capture of different species (Khan et al., 2017). Although pitfall traps were prepared during this sampling, no samples were recorded. The use of fences may facilitate the pitfall traps and selection of sites more forest cover may increase the capture rate. The use of camera trap methods may contribute to more species coverage such as tufted ground squirrel and mousedeers.

Conclusion

This study documented 26 species of volant small mammals (Chiroptera) and 6 species of non-volant small mammals (Rodentia, Scadentia, Insectivora, Carnivora). A noteworthy finding in this study was the documentation a new distribution record of the Northern Free-tailed Bat, *Chaerephon* cf. *johorensis* for Sabah and Borneo. This suggests that Sg. Kangkawat Research Station and the ICCA in general are useful for mammal conservation and hold high potential for small mammal studies and species discovery. There are possibilities that more species of small mammals from Sg. Kangkawat Research Station will be recorded in future surveys of longer sampling periods and efforts at different areas of the research station.

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Short Notes

An observation on the ecology and behaviour of *Metallyticus splendidus* on a dead dipterocarp tree in Sabah, Malaysia (Mantodea, Metallyticidae)

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Abstract
Metallyticus is a genus of rare mantids, occurring mostly in SouthEast Asia. Five species have been described. However, their ecology and behaviour remain virtually unknown. In this study, we describe a small population of *Metallyticus splendidus* Westwood, 1889 on a dead dipterocarp tree standing in disturbed tropical rainforest around Danau Girang Field Centre, Sabah, Malaysia. At dawn, in the afternoon and at night, four individuals, two adults and two nymphs, were monitored. Our findings confirm earlier behavioural observations: they hold their bodies flat when running. We did not observe any lurking behaviour: the mantids were walking fast across the tree stem and in tree holes. *M. splendidus* was found at dawn, in the afternoon, and at night only on this single dead tree in a plot of 50 X 50 m. This suggests that *M. splendidus* is day and night-active and that its habitat is restricted to dead standing trees. We failed to find other individuals on other dead as well as living trees. Our findings show that the habitat of *M. splendidus* could be restricted to large dead trees, giving novel insights into the ecology of Metallyticidae.

Keywords: *Mantodea, mantis,* Metallyticus, *rainforest, ecology*

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Introduction

Metallyticus Westwood, 1835 is the only genus within the family Metallyticidae (Mantodea) and occurs mostly in Southeast Asia (Giglio-Tos 1927, Wieland 2008; Patel & Singh, 2016). The genus can be easily recognized by some autapomorphies among extant mantids, such as iridescent body coloration and the enlargement of the first posteroventral spine of the fore femora (Wieland 2008, Brannoch et al., 2017). Five species have been described (Wieland, 2008). However, their ecology and behaviour remain poorly known (Patel & Singh, 2016). Little research has been conducted on *Metallyticus*, with only a single recent synopsis on the genus having been published, combining earlier observations and collected specimens (Wieland, 2008).

In the early 20th century, Robert Walter Campbell Shelford described *Metallyticus* behaviour (Shelford, 1903). Shelford described that *Metallyticus* species live on tree bark where they hunt cockroaches. Unlike other mantis species, their bodies lie flat against the substrate when running. He also stated that these species can run fast and, unlike other mantids, are probably hunters rather than lurkers. However, relevant information, such as its natural habitat as well as the composition of the vegetation, were not described properly. There are, however, other descriptions of its habitat and exhaustive, long-term observations of this species under artificial conditions (Schütte et al., 2013; Schwarz, 2018). Both articles suggest that *M. metallyticus* thrives both on dead as well as living trees. To confirm these findings, more research is needed on *Metallyticus* ecology and behaviour to confirm his observations and provide new insights.

In this study, we examined a small population of *Metallyticus splendidus* Westwood, 1889 on a dead dipterocarp tree standing in disturbed tropical rainforest around Danau Girang Field Centre, Sabah, Malaysia. At dawn, in the afternoon and at night, four individuals (two adults and two nymphs) were monitored. Additionally, we identified all plant species present in a 10 X 10 m plot around the tree. Our results show that *M. splendidus* is day- and night-active. The habitat of *M. splendidus* could be restricted to large dead trees, a fact not previously known for Metallyticidae.

Materials and Methods

On a dead dipterocarp tree within a 50 X 50 m plot (5°24'50.6"N 118°02'21.8"E) in seasonally inundated riverine forest in the lower Kinabatangan Valley, the *Metallyticus* mantids were caught using insect nets as well as by hand. All individuals were measured with a caliper and recognized individually by length. From all plants in a 10 X 10 m plot with the tree at its center, branches with leaves were collected, imaged at 1200 dpi and later identified using specimens in the herbarium at Naturalis Biodiversity Center.

Results

Description of the habitat

All individuals were found on a dead *Vatica rassak* Blume of approximately 9 m tall (Figure 1). The diameter at breast height (dbh) was 82 cm. The wood was dry with various holes presumably made by insect larvae. The core of the tree, which had rotted away, was not examined for mantids and other insects, since we lacked the proper equipment.

To examine the habitat, all plant species were identified in a plot of 10 X 10 m with the tree at its center. The following plant species were found: *Dalbergia ferruginea* Roxb. (Fabaceae), *Dillenia excelsa* (Jack) Martelli ex Gilg. (Dilleniaceae), *Helminthostachys zeylanica* (L.) Hook. (Ophioglossaceae), *Crateva religiosa* G.Forst. (Capparaceae), *Nauclea orientalis* (L.) L. (Rubiaceae) and *Lygodium salicifolium* C.Presl (Schizaeaceae). The tree was surrounded by tall dipterocarp trees (*Dipterocarpus* C.F.Gaertn. and *Vatica* L.) with buttress roots.

Figure 1. The habitat of *Metallyticus splendidus* near Danau Girang Field Centre. 1: The Vatica rassak (Korth.) Blume tree all mantids were found on. 2: The other side of the dead tree. 3: M. splendidus individual 3 on the tree (center of the image). 4: Some of the holes the dead tree was riddled with.

Description of individuals

In all individuals, the coxae of the raptorial forelegs were metallic green and the alae were smoky, concluding all were *M. splendidus* according to a key to the species by Giglio-Tos (Giglio-Tos, 1927; Wieland, 2008). To reduce ecological impact, the animals were not harvested for collections or identifications. Instead, identification and measurements of the head-to-abdomen length were performed near the tree (Table 1), and the animals were released afterwards. Pictures of the individual mantids are shown in Figure 2.

Figure 2. Total of *M. splendidus* individuals found. Individuals 1 and 2 are juveniles. Individuals 3 and 4 are adult females.

Table 1. Measurements and sightings of the *M. splendidus* individuals. Individuals 1 and 3 were seen at all three points of time. Individuals 2 and 4 were not seen during the night.

	Individual 1	Individual 2	Individual 3	Individual 4
Head-to-abdomen length (mm)	19.6	20.8	25.9	31.0
Stage	nymph	nymph	adult	adult
Seen at dawn (9:00)	yes	yes	yes	yes
Seen in the afternoon (15:00)	yes	yes	yes	yes
Seen at night (21:00)	yes	no	yes	no

Behavioural observations

As shown in Table 1, *M. splendidus* was found at dawn, in the afternoon, and at night. The mantids were not seen on the ground, but only at a tree height between 1.5 and 3 meters on bark. When running, their bodies were held flat against the tree surface, unlike other mantis species. We did not observe any lurking behaviour. When approached, most individuals tried to run away fast. No individuals were found on other trees in the forest, even though we worked in a 50 X 50 m plot (on a different research project) for 22.5 hours during 2 consecutive days.

Discussion

We observed the same behaviour described by Shelford (1903). *M. splendidus* was found on tree bark. Since we did not find any cockroaches, we did not observe hunting behaviour. Unlike other mantis species, their bodies were held flat against the substrate when running. We did not observe lurking behaviour. This partly contradicts captive observations of *M. splendidus*, where individuals were mostly hiding in crevices, and also lurking there for prey during the day (Schwarz, 2018). However, we did not examine the crevices on the dead trees. Earlier observations gained so far show that *M. splendidus* indeed lurks for prey, darting out of crevices when a prey approaches (Schwarz, 2018). When *M. splendidus* leaves its shelter, predation might not be the primary goal since its striking colours could easily attract predators.

M. splendidus could be found at dawn, in the afternoon and at night only on the single dead tree in a plot of 50 X 50 m. This suggests that *M. splendidus* is day and night-active and that in this specific habitat is restricted to dead standing trees. Other observations, however, point out that *M. splendidus* does not only live on dead standing trees, but that it inhabits the trunk of larger dipterocarp living trees as well (Schütte et al., 2013; Schwarz, 2018). *M. splendidus* seems to have a preference for older, bigger trees with a relatively smooth surface, since they like to hide in the cavities formed by crippling of the bark (Schütte et al., 2013). The bark breaks or cripples only after the tree reaches a certain age, restricting habitat of *M. splendidus* presumably to older, larger trees.

We did not find individuals in other dead trees nor did we find them in living trees. A possible explanation for not finding individuals on other dead standing trees could be that the *M. splendidus* as well as dead standing trees were both scarce in the area where we performed our research. Additionally, *M. splendidus* often hide in cavities and other holes formed in the trunk of trees and only hunt for a short period (Schwarz, 2018). The absence of *M. splendidus* on living trees could be explained by the absence of a tree species that satisfied their preferences or that *M. splendidus* could inhabit higher parts of the trunk. This remains to be tested. Therefore, we suggest that the natural habitat of *Metallyticus splendidus* seems to be restricted to dead trees with prey animals that feed on dead wood, such as cockroaches and termites. We would also like to point out that the quick behaviour, size, and metallic colours may allow *Metallyticus* to mimic *Ampulex* wasps, which are predators of cockroaches, a finding which has been postulated by Schwarz (Schwarz, 2018). However, this remains to be further investigated. The fact that we found multiple individuals on a single tree appears contradictory to the lifestyle of many mantis species, which tend to be cannibalistic (Lawrence, 1992). This may suggest that *Metallyticus* is a non-cannibalistic mantis. For further research, we suggest long-term monitoring and observation of this or similar *Metallyticus* populations.

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Author contributions

Maarten Lubbers and Sofie Hovius conducted behavioural experiments, measurements and tree measurements. James Byng identified all the plant species in the 10 x 10 m plot to species level. Menno Schilthuizen helped to identify the individual mantids to species level. Rayzigerson Rodney Chai provided feedback to the manuscript.

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Research Article

The occurrence of infectious intestinal protozoans in primates of the Lower Kinabatangan floodplain, Sabah, Malaysia

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Abstract

Primate parasite study is an important subject in primate research, especially with the ongoing threats from anthropogenic disturbances such as land conversion and deforestation. This study is conducted to investigate the occurrence of *Cryptosporidium* and *Giardia* in primates of the Lower Kinabatangan Wildlife Sanctuary (LKWS), Sabah, Malaysia. Fecal samples collected were tested with immunochromatographic test kits to rapidly screen for *Cryptosporidium* spp. and *Giardia* spp. in samples from 45 long-tailed macaques and 40 proboscis monkeys. The overall rate of infection for *Cryptosporidium* spp. for both species is moderately high at approximately 44.71% (n = 38), with 17.64% (n = 14) individuals are positive with *Giardia* spp., while 38.82% of the individuals (n=33) tested are not infected with either *Cryptosporidium* spp. or *Giardia* spp. Parasite documentation is an integral aspect of primate research, as the information will provide insights on the health status and disease risk of non-human primate populations, thus helping scientists to make better conservation plans for wildlife.

Keywords: *Cryptosporidium* spp., *Giardia* spp., gastrointestinal parasite, primates, proboscis monkey, long-tailed macaques

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Short Notes

Effect of Different Solvent Extractions on Total Phenols, Tannins, and Flavonoids Content of Indigenous Medicinal Plant *Blumea arnakidophora* Mattf. from Sabah.

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Abstract

This research represents the first study on the effect of different solvent extractions on the total phenols, tannins, and flavonoids content of indigenous medicinal plant *Blumea arnakidophora* from Sabah. A total of three solvent types were used in this study: 80% methanol, hot water and distilled water. Determination of phytochemical contents mentioned above was determined using Folin-Ciocalteu Reagent (FRC) method and Aluminium Chloride Colorimetry (ACC) method. The highest total phenols content (71.7 ± 7.0 mg GAE/g) and flavonoids content (33.7 ± 0.6 mg CE/g) were obtained from the 80% methanol extract from the leaves, whereas the highest tannin content (4.9 ± 0.7 mg GAE/g) was obtained from hot water extract from the leaves. From the statistical analyses, the phenols content extracted from the leaves with distilled water showed significant difference ($p < 0.05$) with hot water and 80% methanol extracts. The tannin content and flavonoid content extracted from the stems and leaves did not show any significant difference ($p > 0.05$) among the extraction solvent used. This work provides a preliminary result on selecting an effective extraction solvent for phytochemicals investigation on *B. arnakidophora*.

Keywords: *Blumea arnakidophora*, Total Phenols, Tannins, Flavonoids, Sabah

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Introduction

The indigenous people in Sabah have practised collecting plants as herbal medicine to be consumed since modern medicine was not easily available in the past (Kulip, 2003). *Blumea arnakidophora* Mattf., or commonly known as *Tawawo* among the indigenous people in Sabah, is a shrub that originated from Southeast Asia. *Tawawo* is believed to be rich in biologically active substances which have good anti-oxidant and anti-microbial effects. The extracts of *Tawawo* were used by the Sabah people to relieve fever and the leave-soaked water was used as herbal bath for mothers after giving birth (Ahmad & Ismail, 2003). This kind of traditional medicinal knowledge was transferred from generation to generation without knowing the phytochemicals content and the actual potential of the plant. To date, there is no scientific report on the phytochemicals content of the medicinal plant *B. arnakidophora*. This work represents the pioneer study on the total phenols, tannins, and flavonoids content of different extraction solvents from *B. arnakidophora* in Sabah.

Materials and Methods

Approximately 200 g of specimens were collected from Mount Alab sub-station (5°49’47’’N, 116°20’30’’E), Sabah, Malaysia in 2013. The voucher specimens were deposited in the BORNEENSIS Herbarium of Institute for Tropical Biology and Conservation (BORH), Universiti Malaysia Sabah as well as in Sabah Parks’ Herbarium. These specimens were cleaned with distilled water to remove impurities prior to drying in an oven at 40°C for two days. The extraction was conducted according to Majuakim et al. (2014) with slight modification. Dried samples (0.1 g) were extracted with 30 ml 80% methanol and 30 ml distilled water respectively, for two hours on an orbital shaker (200 rpm). Hot water extracts were obtained following Wang et al. (2006) with slight modification. Dried samples (0.1 g) were mixed with distilled water, stirred with magnetic stirrer and boiled. The obtained 80% methanol extracts, distilled water extracts, and hot water extracts were then filtered with Whatman No. 1 filter paper and ready to be used for further analysis. Total phenols were determined using Folin-Ciocalteu method adapted from Velioglu et al. (1998). Determination of total flavonoids content was carried out using Aluminium Chloride Colorimetry method (Zhishen et al., 1999). Determination of total tannins content was performed using Folin-Ciocalteu method (Tamilselvi et al., 2012). Each analysis was carried out in triplicate and the data were presented as mean ± standard deviation (SD). All the total phenols, tannins, and flavonoids data were analysed using one-way ANOVA and the level of statistical significance was set at $p < 0.05$ (SPSS version 23.0).

Results and Discussion

The results of total phenols, tannins, and flavonoids content from the leaves and stems of the specimen in different extraction solvents are shown in Figure 1, Figure 2, and Figure 3, respectively. The 80% methanol extract from leaves showed the highest total phenols (71.7 ±7.0 mg GAE/g) and flavonoids content (33.7 ± 0.6 mg CE/g). Highest tannins content (4.9 ± 0.7 mg GAE/g) was recorded from the leaves of hot water extract. The lowest total phenols (6.4 ± 0.7 mg GAE/g), (tannins 1.2 ± 0.2 mg GAE/g), and flavonoids (4.7 ± 0.3 mg CE/g) content was found in distilled water extract from the stems. It may be attributable to the higher non-phenol compounds present in the distilled water extracts. Our findings are in accordance with published literature where the lower yields were obtained from the stems, compared to the leaves (Stankovic et al., 2011). Extraction yields are highly dependent on the solvent with varying polarity, pH, temperature, extraction time, and composition of the sample (Do et al., 2014). The highest yields have been found in 80% methanol extracts maybe because the combination of water and organic solvent facilitated the extraction of chemicals that are soluble in water and/or organic solvent. Hot water extract from the leaves gave the second highest yield of total phenols and flavonoids content, with no significant difference as compared to the highest total phenols and flavonoids yield from 80% methanol. Besides, hot water extracts gave the highest tannins content. Temperature may have contributed substantially to increase the extraction of chemicals' yield. Under the same extraction time, temperature, solvent and composition of sample are the vital parameters for extraction yields (Spigno et al., 2007). These results suggest that aqueous methanol is the best solvent choice depending on the target compound of interest. We would like to recommend hot aqueous methanol to be used for future work in order to obtain optimized yield of extracts. Future study regarding the bioactive properties of *Blumea arnakidophora* such as anti-oxidant and anti-microbial is also recommended as to provide deeper scientific proof to support medicinal usage among indigenous people in Sabah.

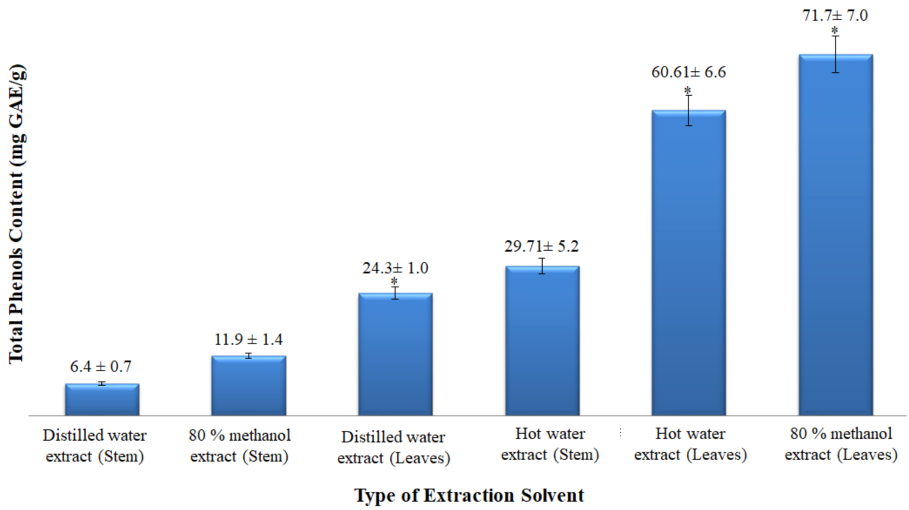

Figure 1. Comparison of total phenols content in different types of extraction solvent.

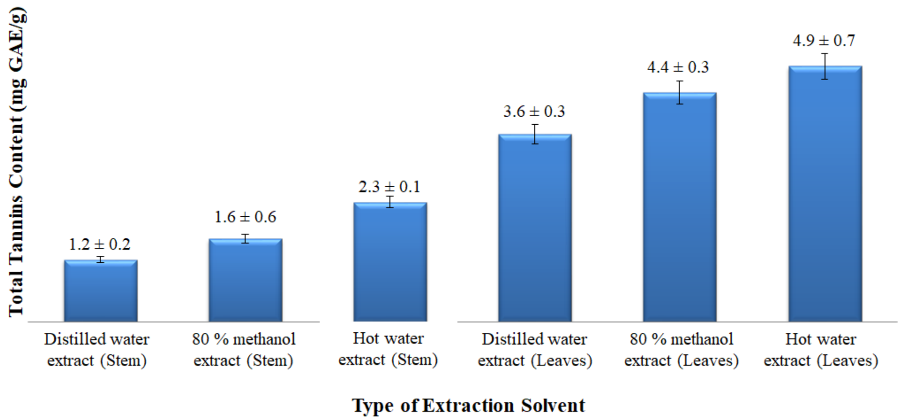

Figure 2. Comparison of total tannins content in different types of extraction solvent.

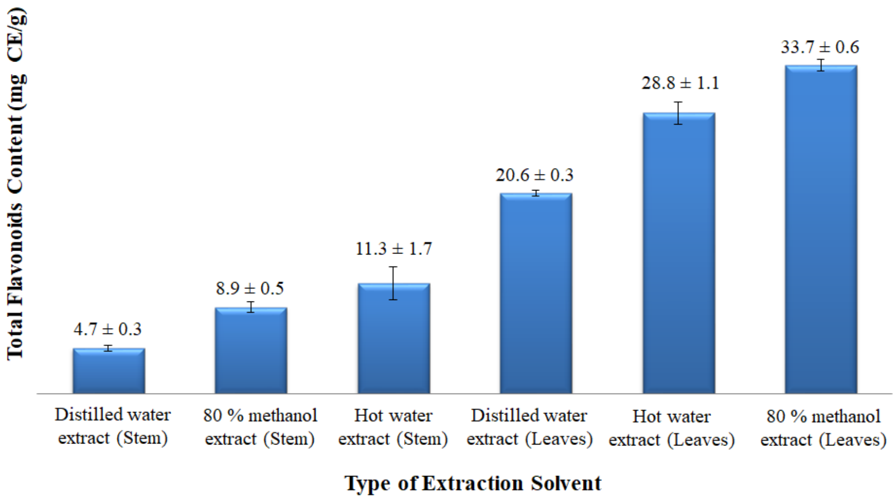

Figure 3. Comparison of total flavonoids content in different types of extraction solvent.

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Research Article

Tourist Satisfaction towards Kota Kinabalu, Sabah Using Importance-Performance Analysis (IPA) As a Tool to Determine Urban Ecotourism Potential

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Abstract
The Importance-Performance Analysis (IPA) is widely used in many fields of study as it produces simple and straightforward results. However, it is rarely used by managers of ecotourism and urban green spaces. Importance-Performance Analysis (IPA) was adopted from a destination perspective to understand industry demand. This study explores the visitors' satisfaction level on ecotourism attributes i.e. attraction, urban green spaces and accessibility that affect tourist satisfaction towards Kota Kinabalu, Sabah, Malaysia using IPA scheme. A total of 384 tourists to Kota Kinabalu were provided with a list of environmental features and asked to rate the importance of and satisfaction with each attribute. IPA was performed to compare mean scores and identify areas of concern. The analysis identified eight (8) attributes which were applauded with excellent performance on highly important features and should maintain its competitiveness as a tourist destination. Six (6) attributes resulted under the poor performance on an extremely important category; indicates the areas that should be given improvement interventions, while four (4) attributes were identified as possible overkill that implies divergences of resources elsewhere are needed. Finally, six (6) attributes faired as low in priority and effort may not be necessary on those features. Although six (6) out of 24 attributes were found to be less advantageous, an interview simultaneously conducted during the survey however found that 97% of respondents perceived that Kota Kinabalu city has the potential as an Urban Ecotourism destination. This study resulted in some findings for those at managerial level to pursue and areas that should be improved as it provides a greater understanding on the Urban Ecotourism potential in Kota Kinabalu industry, by using the Importance-Performance Analysis (IPA) tool as it facilitates the interpretation of data. This study fosters that ecotourism product does

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exist in Kota Kinabalu city, and steer the industry towards sustainable development in urban centres.

Keywords: Importance-Performance Analysis (IPA), Kota Kinabalu, Tourist motivation, Tourist satisfaction, Urban Ecotourism

Introduction

Sabah is known for its mega biodiversity thus the abundant ecotourism sites, focused mainly in the outer part of the city offering unique and niche market to tourists. With world class recognition by UNESCO, RAMSAR or even as National Heritage or National Park, tourists throng the destinations as marketed by tourism managers. As such, overcrowding or carrying capacity issues shall prevail without proper planning for certain areas of interest. Latip (2016) noted that environmental degradation is perceived to continue from tourists' activities in the Kinabalu Park, Sabah through ongoing tourism activities. A few studies showed that the steady increase number of visitors to the islands in Tunku Abdul Rahman Park, Kota Kinabalu is also a contributor to the detriment of the marine environment (Kaur, 2006; Kunjuraman, 2015). To reduce overcrowding at certain specific tourist attractions, the Sabah State Government is always looking for ways to overcome this problem. Introduction of new market niche and attractions are essential to best manage overcrowding and carrying capacity problem (Ministry of Tourism, Culture and Environment Sabah, 2017). Joppe & Dodds (2000) mentioned that urban ecotourism could assist ecological and cultural protection, through which the target is to increase environmental awareness and local economic development in cities. Other than protection and prevention, urban ecotourism also have elements that contribute towards conservation through restoration of natural areas degraded by previous human activities (Hingham & Lück, 2002).

In 1996, Mok & Armstrong noted that there were knowledge limitations on new travel destinations among tourists thus the dependency on social media groups for information and in determining destination attributes. Destination attributes described by Truong & King (2006) indicated that attraction attributes could be distinctively separated between natural attractions (sea, forest, mountains, lakes and river etc.) and man-made attractions (museums, palace, ancient monuments, theme parks, and casinos etc.). The importance of assessing accessibility and accommodation facilities were noted as an important attribute of any tourism industry (Upadhyaya, 2012). Later on, a study by Lo et al. (2013) categorized four main attributes i.e. (1) Cultural/Heritage, (2) Social, (3) Economic and (4) Environment and these were important destination image indicators. Collectively, strengths and weaknesses of destination attributes lead to competitiveness success of a travel destination (Enright & Newtown, 2005, Chalal & Devi, 2015). Performance of a travel destination thus is determined by tourist perception and satisfaction. Tourism is an economically promising industry however, it is a very exhaustive and consumptive trade (Joppe & Dodds, 2000). Economic impact is not the only important impact tourism can have as it also impacts the environment, people and culture. Tourism requires development of infrastructures, and pollution comes from the increased number of visitors (Kozak, 2003). It was also noted in another study that this industry also damages the environment in various ways especially with regards to water resources and solid waste (Firehock, 2015).

Various literature have mentioned that natural biodiversity inarguably has many functions for humans and the ecosystem. Natural biodiversity has a positive effect on the functioning and stability of ecosystems where human and nature support each other for a living (Tilman et al., 2014). In Sabah, Kota Kinabalu city's urban forests and green spaces function as wildlife habitats, and act as nature conservation, protection, recreation and utility for the community and environment (Mojiol, 2006). Over the years, urban expansion was unstoppable and natural areas were jeopardized to make way for development, changing land use and land cover pattern and placing natural biodiversity at risk. However, depending on the uniqueness of the earth surface combined with the perceived value of an ecosystem, a good minimum size of forest cover that supports high native diversity could be determined (Firehock, 2015). This sheds some hope of preserving urban green spaces that still exist, becoming the very reason tourists travel to Sabah.

Urban ecotourism shares the same goals as the conventional ecotourism term, however the former is located in the city. This growing trend reconciles concrete and nature. It is the new hype among travelers who seek travel experience and at the same time pursue opportunities to give back to the community. Cities around the world have always been the most popular tourist destinations and the centre of travelers' destination due to various reasons. High population density within a small area makes it possible for multicultural exchanges, attracting different types of tourists (Bock, 2015). Cities are also the entry and exit point of countries through modern transportation systems. Bock (2015) mentioned that modernization including Information and Communication Technology (ICT) has facilitated information dissemination among tourists, and impacted tourist behaviour and characteristics. For the past 20 years, ecotourism has been a major tourism motivation in Sabah and has grown rapidly.

With time, the industry has raised concerns over the sustainability of the trade while not restricting physical and social development for the local people. Is Urban Ecotourism the answer for tourism sustainability in Kota Kinabalu?

In order to preserve nature in the city without deterring the booming tourism industry, managers should look into various aspects to better manage and plan for sustainable tourism in Kota Kinabalu. Understanding current travel characteristics, motives and behaviour of tourists are important to better strategize tourism products and marketing (Chalal & Devi, 2015; Van Vuuren & Slabbert, 2015). Human characteristics and behaviour changes over time and it is important to stay updated on current information and trends and for this, latest studies should always be welcomed by managers. Changes in travel characteristics, behaviour as well as motives could result in changes of tourists' perception and expectation during their travels. Tourist satisfaction eventually takes place after experiencing a travel and it is commonly the driving force behind the competitiveness and performance of a travel destination (Kozak, 2003; Mat Som et al., 2012). Therefore, it is important to understand the current market demand in Kota Kinabalu to correctly place marketing strategies for the benefit of all stakeholders. This paper adopts the Importance-Performance Analysis (IPA) scheme in order to simultaneously investigate the motivation and satisfaction of tourists towards Kota Kinabalu city from a "destination" perspective, through which environmental features and settings were profoundly explored. It also intends to understand the city's potential as another urban ecotourism destination. Results could guide tourism managers to improve sustainability of the tourism industry through strategic recommendations of this study.

Importance-Performance Analysis (IPA)

This paper assumes a method introduced by Martilla & James (1977) i.e. Importance-Performance Analysis (IPA) as a tool to measure the performance and satisfaction of tourists regarding their recent travel to Kota Kinabalu city. Researchers in the field of tourism try to identify and explain the factors that affect the choice of destination as well as the satisfaction of tourists after their trip. Tourist satisfaction issues in tourism industry must be taken into serious consideration as the number of empirical studies relating to tourist satisfaction is limited and less documented (Salleh et al., 2011; Al-Ababneh, 2013; Hussin & Kunjuraman, 2014). Tourist satisfaction reflects tourism industry performance in the particular area of interest. Tools are therefore needed to help managers to grasp and evaluate by looking at respondents' expectation (importance) and satisfaction (performance). The IPA method is superior to a performance-only approach as it measures both expectation and satisfaction of respondents. IPA has been widely documented and used in diverse context including marketing (Ennew et al., 1993; Matzler et al., 2003), healthcare (Dolinsky & Caputo, 1991; Nitse & Bush, 1993) and tourism (Uysal et al., 1991; Duke & Persia, 1996; Wilkins, 2010; Söresson & von Friedrichs, 2013). Chu & Choi (2000) mentioned that IPA aids to identify customers' level of satisfaction with the attributes that were derived by their expectation regarding the attribute's performance. IPA was used as early as 1985 by Lewis to gain tourist's perception towards the hotel industry, followed by another study on customer satisfaction towards Sheraton Hotels in 1989 and resulted in tourism policy formulation. Tourism sectors on specific tourism services, e.g. whale shark tourism, ski-resort, outdoor recreation etc. (Ziegler et al., 2012; Ahmad Puad et al., 2012) are also known to use this method but lacks in terms of studies on adopting a destination perspective (Edward & George, 2008; De Nisco et al., 2014) and in protected areas (Wade & Eagle, 2003). According to Wade & Eagle (2003), it is known that national parks rarely monitor visitors' satisfaction or when they do, park performance was normally measured without reviewing the importance of the attributes towards the visitors. Although the IPA are widely used in various fields to determine a service performance, it is rarely used to enhance management (Parker & Simpson, 2018). The IPA manages to express the relationship between two dimensions -- expectation and satisfaction. It determines champions and under-servicing fields. Service sectors i.e. the tourism and hospitality industry has noted that IPA is an easy and simple tool to determine fields to improve or reduce when resources are limited (Babu et al., 2017). Straightforward visual results of the IPA assist to interpret attributes, and are an efficient way for managers to have evidence-based action plans.

Methodology

Data Collection

Kota Kinabalu is the capital city of Sabah state in Malaysia. Sabah is renowned for its beautiful and pristine nature thus attracting tourists from around the globe. This study was conducted through self-administered survey questionnaire that was developed to identify factors influencing international and domestic tourist travel to Kota Kinabalu. A total number of 384 samples were collected between December 2017 and December 2018 at the Kota Kinabalu International Airport, Jesselton Point Waterfront, i.e. exit points of the city and Gaya Street, where tourists ending their vacation in the city were interviewed, with 95% confidence interval and 5% margin error (Salant & Dillman, 1994). Based on Sabah Tourism Board (2016), the estimated number of tourists exceeds 500,000 people thus the total number of sample required is 384 respondents (Krejcie & Morgan, 1970).

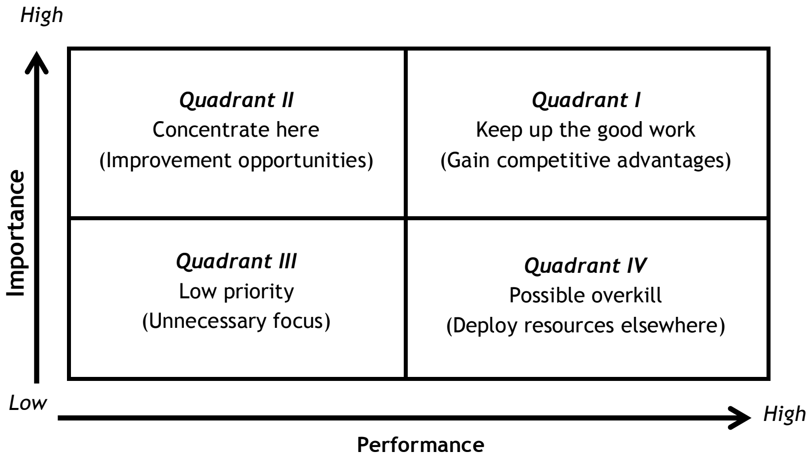

Figure 1. The IPA scheme

The questionnaire was developed through literature reviews and later on divided into three main categories i.e. attraction (Rabanny et al., 2013; Chalal & Devi, 2015; Van Vuuren & Slabbert, 2011), green barrier (Mihanyar et al., 2015; Rabanny et al., 2013) and accessibility (Kuong & Truong, 2017; Chalal & Devi, 2015; Van Vuuren & Slabbert, 2011). Prior to the pilot survey, questionnaire reliability was tested and showed significant *p*-value less than 0.05 and suitable Cronbach's value, α = 0.877 which expressed suitable internal consistency (Pallant, 2016). The questionnaire retained all questions and another seven (7) attributes were added as perceived of importance, gained during the pilot survey. The added questions were of importance as the issues / attributes arising from respondent's point of view and could add value to the study when probed further. The questionnaire was again tested for reliability and validity before the actual survey, and showed significant p-value = 0.00 and acceptable Cronbach's value, α = 0.961.

The survey instruments were mainly aimed to identify travelers' perception towards the performance of Kota Kinabalu as a tourism destination using a close-ended questionnaire, in four languages (Chinese, English, Japanese, and Korean); reviewed by proofreader service. The surveys were also assisted by translators consisting of tour guides and research assistants that helped respondents better understand the purpose of the study. The questionnaire was divided into two parts i.e. expectation and satisfaction of destination attributes and demographic variables of the respondents which helps to describe performance of destination with regards to social and environmental sustainability. The first part of the questionnaires covered attractions of Kota Kinabalu city i.e. the nature attractions (seven items), management of ecotourism destination (seven items) as well as access to ecotourism destinations (10 items) in the city. Respondents were required to indicate their agreement with the statements provided and were assessed with a 5-point Likert scale to get the best spread of results (Kozak, 2001; Saib et al., 2016). The instrument represented two (2) scales for measurement, i.e. to measure performance and another scale to measure the importance of the attributes. The last part poses questions regarding demographic profiles of respondents including a question regarding their perceived opinion on ecotourism potentials of the city. One sample t test and paired sample t- test were conducted to find if there is any significant difference in the mean importance and performance of destination attributes. Data collected were analyzed using SPSS version 24.0.

Data Analysis

All 384 questionnaires were transferred into Microsoft Excel datasheet. Demographic data and travel characteristics of all respondents were analyzed using this software and presented in the results (Parker & Simpson, 2018). Mean data of performance and satisfaction for each attribute were analyzed and recorded.

All data were transferred to Statistical Package for Social Sciences (SPSS) software and correlation, reliability and significance between the importance and performance were checked for all 24 attributes (Parker & Simpson, 2018; Cohen, 1988). The IPA scale is presented graphically as a grid with four quadrants and centered using the grand mean of the importance and grand mean of the performance for all attributes. Each attribute mean value is plotted on a graph with performance on the x-axis and importance on the y-axis. The grand means for performance and importance scores is the point of intersection between axes representing both performance and importance. This points then divides graphs into four (4) grids (quadrants). These quadrants deliver transparency between expectation (importance) and satisfaction (performance) of respondents. It assists in showing priority for management and action plans on the attributes.

The IPA approach uses graph quadrants by comparing the mean scores of the attributes for importance-performance in two-dimensional grids. Four quadrants represent four different management suggestions (Figure 1). Both high in performance and importance items falls under Quadrant I (Keep up the good work) shows opportunities for gaining or maintain competitiveness advantages, while dimensions poor in performance but high importance attributes represents opportunities for great improvement (Concentrate here – Quadrant II). Quadrant III (Low priority) indicates that no necessary efforts should be focused in that area as both performance and importance are very low. Finally, attributes in Quadrant IV shows high performance, low importance and are considered unnecessary and should be deployed somewhere else (Wu et al., 2010).

Results and Discussion

Sample characteristics

Findings shows that a majority of respondents were female (56%), between the ages of 22-37 years (64.5%), and topped by tourists from South Korea (29.3%), a vacation trip as their travel purpose (37.4%) and spent between RM3,000 – RM4,000 (35.9%) per person for this travel to Kota Kinabalu. A major 97.4% of the respondents perceived that Kota Kinabalu city has the potential to be an Urban Ecotourism destination.

Observing both expectation and satisfaction of tourists is the efficient way to assess the success of a travel destination. Positioning means scores vertically and horizontally on scale assists in judgement, in which the cross-point was set at the grand mean importance and grand mean performance values (Martilla & James, 1977; De Nisco et al., 2014; Saib et al., 2017).

Perceived importance and performance of different items were obtained through mean scores of tourists' perception and results for this study as shown in Table 2. The highest mean score of 3.89 for importance was "personal safety and security" and "meeting locals" while the highest mean score for importance was "unspoiled nature", scored 3.71. Malaysian government tax was identified as the lowest mean score for both importance and performance. The analysis also showed that none of the performance mean scores exceeds the importance mean scores for each item which indicates that performance did not exceed tourists' travel motivation to Kota Kinabalu city. Table 3 shows that there is a significant difference in the mean importance and mean performance of destination attributes as perceived by tourist to Kota Kinabalu. All 24 items mean scores were plotted on the IPA matrix as shown in Figure 2. The grand mean scores for both importance (3.7833) and performance (3.4754) were used as reference in the grid for IPA charting.

Table 1. Demographic profile and travel characteristics

Gender	%
Female	**56.0**
Male	44.0

Top 5 countries of residence	%
Korea	**29.3**
China	23.8
Malaysia	9.9
Other EU Country	7.3
Japan	6.6

Travel purpose	%
Touring	**37.4**
Travel stopover	22.3
Destination Travel	20.1
Pass Through	7.3
Business trip	4.8
Visiting friends / relatives	4.8
Others	3.3

Age group	%
22 - 37 years old	**64.5**
38 - 52 years old	24.9
18 - 21 years old	9.9
53 - 71 years old	0.7

Total expenses (per pax)	%
RM 3,000 - 4,000	**35.9**
RM 2,000 - 3,000	21.6
RM 1,000 - 2,000	17.2
< RM 1,000	16.5
> RM 4,000	8.8

KK potential as Urban Ecotourism destination	%
Yes	**97.4**
No	2.6

Importance-Performance Analysis (IPA)

The IPA matrix (Figure 2) shows that the highest number of eight (8) items falls into the *keep up the good work* (Quadrant I), that includes unspoiled nature, uniqueness of nature, interaction with local people, quality of destination, culture and history, recreational activities offered, destination access and involvement of locals in ecotourism. Highest in both importance and performance scores indicates that these are strengths of the attributes owned by Kota Kinabalu city. It is also the destination appeal of tourists where destination marketers should focus on. Well-kept nature correlates with the quality of the ecotourism sites; thus, these two items should be maintained or better still enhanced and marketed well to attract more tourists to the city. Preserved and maintained natural ecosystem in the city for tourism could also create conservation opportunities for this city, and ecotourism works both ways. Decision makers of the city should consider protecting the city's nature as it is the reason tourists visit Kota Kinabalu. Observation also shows that involvement of local communities in ecotourism as well as diversity of local culture and history are high in importance for tourists, however, did not score well enough in performance. Tourists' expectation on these two-local community-involving items were high before coming to Sabah, however their personal experience did not match their expectations. These are the areas that should be focused on by tourism players to improve their commitment and services offered. Focus on core strength would gain competitive benefits in sustainability practice and create better image. Educating tourism players about the importance of sustainability practices is a great opportunity that should be taken on. All eight items in this quadrant should be placed appropriately for Kota Kinabalu city to gain competitive advantages to other travel destinations and would result in repeat visits (Ziegler et al., 2012). Strengthening all items in this quadrant could mean more economic and tourism benefit for the state and its people.

Quadrant II (*concentrate here*) captured six (6) items i.e. overall cleanliness of destination, personal safety and security, transport networks within the city, basic infrastructure facilities at destination, quality of accommodation and environmental awareness among local people. These items were perceived to be high in importance however did not perform well. Destination managers should be looking into these areas as destination strength opportunities for improvement is very substantial. Personal safety and security as well as overall cleanliness were the two (2) items that was highlighted as they were the items that were close to the performance grid line, thus should be scrutinized properly to increase their performance. Cleanliness of the city was also found to be a prolonged issue that has yet to be solved by the local authority (Kunjumaran et al., 2015). Taken as a whole, all these elements in this quadrant seem to represent the first areas of intervention in order to improve the perceived tourist's satisfaction. Attributes mentioned in this category have high potential in giving a good destination image if these are improved, and could move to Quadrant I.

Quadrant III (*low priority*) which depicts low in both importance and performance gathered six (6) items; local government tax, cultural and other events offer, destination guides (map and signs), local cuisine, shopping and entertainment, overall experience gained, and overall expenditure spent. Placing efforts and resources here would be exhausting and may offer little advantage to the urban ecotourism industry. Although items seem unimportant at this moment, there is always opportunity for improvement especially the elements of overall experienced gained with the overall expenditure spent during their travel in the city. Specific segmentation study could be done to explore the possibilities for improvement to create a niche market of gastronomy and entertainment of local culture as well as how to improve experience satisfaction of tourists. Overall, these items appear less significant for now if compared with items in other quadrants. When resources are limited, managers could focus on attributed charted in Quadrant II before focusing in this quadrant.

Finally, four (4) items that were low in motivation, but high in performance are management of ecotourism destinations, linkages between destinations, number of destinations and the size of each ecotourism destination offered. This quadrant (*possible overkill*) meant that resources are better focused on other issues. Items here are perceived to be good but not an important attraction element. However, managers should maintain their effort level here as opportunity arises to generate more tourist interest (motivation) on these items which would eventually boost its position in the quadrant.

Table 2. Mean scores of tourists' perception

Attributes / Items	*Importance Mean*	*sd.*	*Satisfaction Mean*	*sd.*
Environmental and setting features				
Unspoiled nature	3.86	1.019	**3.71**	0.897
Nature uniqueness	3.85	0.968	3.60	0.879
Overall cleanliness	3.88	0.991	3.44	0.895
Diversity of culture & history	3.82	0.962	3.53	0.880
Meeting locals	**3.89**	0.946	3.63	0.884
Cultural & other events	3.76	0.934	3.46	0.863
Recreational activities	3.79	0.927	3.56	0.848
Management of ecotourism destination				
Destination quality	3.84	1.017	3.69	0.851
Destination variety	3.70	1.013	3.62	0.864
Destination size	3.70	0.951	3.52	0.855
Environmental awareness amongst local people	3.83	0.979	3.40	0.907
Involvement of local people in ecotourism	3.82	1.005	3.50	0.909
Destination linkages	3.73	1.000	3.51	0.897
Destination management	3.77	1.014	3.52	0.909
Access to ecotourism destination				
Destination access	3.79	1.032	3.55	0.944
Destination guides (maps & signs)	3.73	0.973	3.36	0.894
Transport network (infrastructure & service)	3.84	1.003	3.36	0.918
Destination facilities (basic infrastructure)	3.80	0.961	3.35	0.909
Accommodation quality	3.80	0.938	3.44	0.947
Local cuisine, shopping & entertainment	3.73	0.951	3.35	0.929
Personal safety & security	**3.89**	0.980	3.46	0.993
Malaysian government tax	**3.50**	1.029	**3.12**	0.989
Overall expenditure	3.73	0.916	3.37	0.959
Overall experience	3.75	0.972	3.36	1.006

Table 3. Table showing One-Sample t-Test for Mean Importance and Performance of Destination Attributes.

One-Sample Statistics				
	N	**Mean**	**Std. Deviation**	**Std. Error Mean**
Importance mean	24	3.7833	0.08386	0.01712
Performance mean	24	3.4754	0.13194	0.02693

One-Sample Test						
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Importance mean	221.027	23	0.000	3.78333	3.7479	3.8187
Performance mean	129.042	23	0.000	3.47542	3.4197	3.5311

As such, management of ecotourism destinations, linkages between ecotourism sites within Kota Kinabalu city, the number of destinations in the city as well as the size of each ecotourism destination could be better enhanced. At the same time, conservation and preservation of the natural ecosystem in the city could be a positive sign that could create an opportunity for awareness and education among tourists and locals. Gaining more motivation and expectation in this area would mean opportunity for attributes to be charted in Quadrant I in the future. When tourist expectations are met, satisfaction would follow, in which the city is doing good at the time the study conducted.

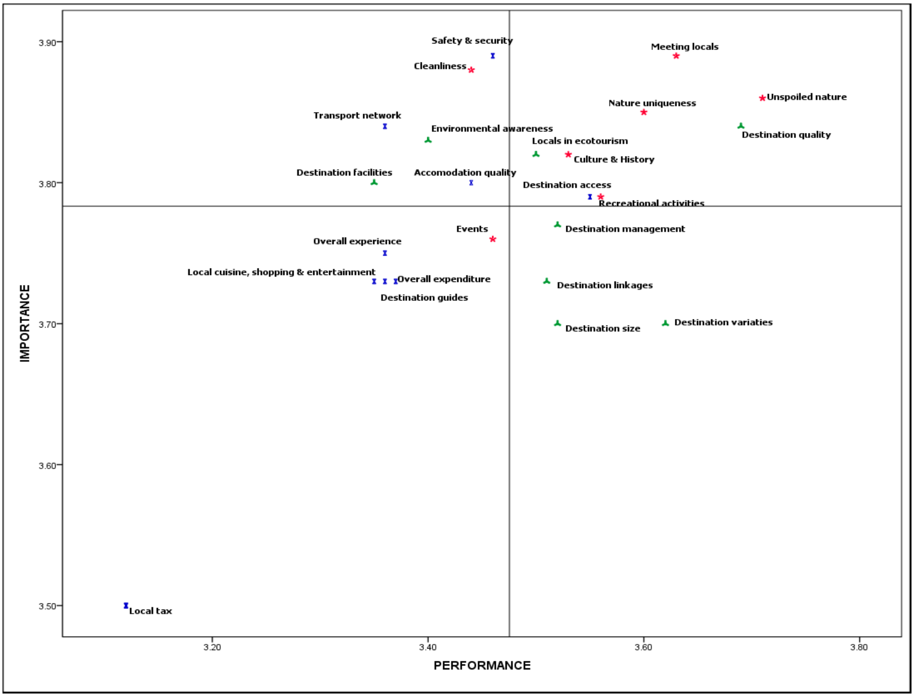

Figure 2. Performance-importance matrix

Managers of Kota Kinabalu city tourism must understand this study to gain insight of competitive advantage. This method demonstrates that tourism managers could adopt an easy and straightforward approach when managing and planning the urban ecotourism concept for Kota Kinabalu city. It clearly shows opportunities and priorities to be taken based on destination advantages, i.e. resource allocation tool to lessen the gap between importance and performance to ensure sustainably of the industry for Kota Kinabalu city. This is supported by a previous study that IPA has been shown to provide service managers with information regarding satisfaction measurement and prioritizing of resources (Wade & Eagles, 2003).

Conclusion

Importance-performance analysis (IPA) is an easy and important tool that helps managers and planners alike to manage the tourism destination in Kota Kinabalu as it simultaneously assesses motivation and satisfaction of respondents. This tool managed to identify that tourists to this city perceived that Kota Kinabalu has the potential as an urban ecotourism destination, as it has unique nature that is currently the main tourist attraction and at the same time satisfies the expectation of tourists. This study concludes that the features of unspoiled and unique natural environment, destination quality, chance of interaction with local community, participation of local people in ecotourism activities, destination access, recreational activities, and diversity of culture and history are the strengths of tourism products in Kota Kinabalu city. These features should be focused on to better strategize and market Kota Kinabalu as an urban ecotourism destination. Managers could also better strategize focus areas, according to importance in order to gain maximum economic benefit, based on their existing manageable resources. In conclusion, this study managed to grasp a better understanding of the current market demand through a concurrent motivation and satisfaction study of tourists, using IPA as a measurement tool. Tourists were satisfied with their travel to Kota Kinabalu especially with the attraction that the city offers followed by the environmental settings of tourism destinations. The study also shows a high percentage (97%) of respondents agreed that Kota Kinabalu city has the potential to be developed as an urban ecotourism destination. This study could be a benchmark for future further studies that could also be extended to other tourism and sustainability grounds.

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Research Article

Inventory of Marine Fauna on Reef Balls Structures of Selingan Island, Sandakan, Sabah, Malaysia

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Abstract

Selingan Island is well known as a turtle sanctuary in Sandakan, Sabah. However, beach erosion has affected both infrastructure and turtle nesting grounds on the island. As one of the solutions, stone revetment and reef ball structures were deployed at the southeast part of the island in 2005 and 2007, respectively. The uneven stony surface of reef ball structures creates tiny pockets of space for attachment and colonization of coral larvae and sessile invertebrates. The objectives of this study are to determine the condition of the reef ball structures and to identify the types of marine fauna within these structures. The field surveys were carried out in May and December 2017. The survey area covered the 120 m length of balls structures for inventory of marine fauna using random quadrat sampling and observation of the reef balls condition. The survey areas were divided into Part 1 (1-40 m), Part II (40-80 m) and Part III (80-120 m) from the shoreline of the island. There was only one reef ball unit damaged and others were intact with encrusting marine invertebrates and other associated marine life. The structures of the reef balls play an important role as an artificial marine habitat. A total of 3,583 individual (298 inv/m^{-2}) of invertebrates (barnacles, bivalves, limpets and gastropods) were identified and 26 marine fauna species comprising of fishes, algae and corals associated with the reef balls structures. The marine fauna was expected to be higher if the survey could be done at the different tidal cycles, weather conditions and increase number of the survey. The findings provide insight of marine fauna at the reef balls structure in Selingan Island and enhance baseline data for marine resources management in the marine protected area of Turtle Island Parks.

Keywords: reef balls, habitat, fauna, marine protected area, Selingan Island

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Introduction

The shoreline protection such as submerged breakwater, sea walls, stone revetment and artificial reefs are installed along the shoreline to protect the beach and property from erosion. These structures act as additional physical substrate for various marine fauna and enhance biodiversity in the coastal areas (Harris, 2001; Sherman et al., 2002). For example, encrusting invertebrates are commonly found organisms on a man-made structure such as sea wall (Lee et al., 2009; Lai et al., 2018) and reef balls (Barber & Barber, 1996) and further improve the attenuation of wave energy, enhance water quality and as food sources for humans (Nelson, 2004).

Selingan Island is one of the three Turtle Islands, located about 40km from Sandakan (Sabah) on the edge of the Malaysia-Philippines international border. This island is very important as it provides nesting beaches for the endangered green turtle (*Chelonia mydas*) and the critically endangered hawksbill turtle (*Eretmochelys imbricata*). The annual nesting recorded for the green and hawksbill turtles range between 3000 to 8000, and 50 - 179, respectively (Joseph, 2017). Selingan Island has a long history of sea turtle conservation, where it was started in the 1930s by the North Borneo British Company, and in 1977 Selingan together with the other two islands (Gulisaan & Bakkungaan Kecil) was gazetted as the Turtle Islands Park (Chan & Liew, 1997), currently under the management of the Sabah Parks. However, beach erosion in the southern part of the island is the biggest challenge faced by the local authority. This contributes to loss of the turtle's nesting area and damages on infrastructure such as the Sabah Park's office and jetty (Razak et al., 2015). As a solution, Sabah Parks has deployed two types of shoreline protection; the stone revetment and reef balls.

The Sabah State Government allocated about RM1, 880,000.00 to install 290 units of reef balls (Goliath balls) at the southeast part of Selingan Island in 2007. These reef balls were set up as a submerged breakwater and as an additional structure to the stone revetment deployed in 2005. Most reef balls used as shoreline protection are deployed in deeper water, are constantly submerged and located further offshore (Sherman et al., 2002; Harris, 2009). Reef balls were identified as the best option for this island after considering the turtles' access to the beach, aesthetics, and tidal range condition. Based on the Sabah Parks information, the length of the reef balls is estimated at 470 m. However, a satellite image from Google Earth (2020) indicates that the length of the exposed reef ball was only 180 m and the others in the area are probably buried by the sand at the south of the island. The objectives of this study are to determine the condition of the reef balls as shoreline protection and to identify marine fauna present within the reef ball's structures.

Materials and Methods

The reef ball layout at Selingan Island ($6^0$10'20.63" N, $118^0$03'37.32" E) is in L mirror shape arrangement and built almost parallel to the beach at the south of the stone revetment (Figure 1). The reef balls were supplied by Reef Ball Asia Sdn. Bhd. to Sabah Parks to tackle beach erosion by reducing current and wave action to the beach. The reef balls were set up into three segmented breakwater sections and use three rows of Reef Ball ™ units for each segment. Reef balls imitate a natural system with varying size of holes. The holes in the interior cavity are smaller than the exterior to create a whirlpool and upwelling effect to nourish marine life attached to the reef (Banerjee, 1994; Reef Ball Foundation, 2017).

The field surveys were carried out on 23 to 24 May 2017 and 27 to 28 December 2017. The survey area was divided into three parts (Figure 1); Part 1 (1- 40 m), Part II (40-80 m) and Part III (80-120 m) of the island. The reef balls survey area started from the shoreline towards the offshore covering about 120m length of the reef balls. The condition of the reef balls was recorded and compared with a survey done in 2011 (Sabah Parks & UMS, 2013). A total of 24 quadrats (50 cm x 50 cm) were randomly placed on the top and middle part of the reef balls to estimate the total number of individual marine fauna. At the same time, gliding and snorkelling for other associated marine fauna around the reef balls structures were carried out by taking photographs for further identification to the lowest taxa (Calumpong & Menez, 1997; Wood & Aw, 2002). No sample was taken as this study site is located at a marine protected area.

Results and Discussion

The 11 years of reef balls deployment in Selingan Island has played an important role in shoreline protection and preserved the turtle nesting areas for the island (Chen et al., 2018). During low tide, the reef ball structures are totally exposed, partially exposed and submerged at Part 1, Part II and Part III, respectively. The reef balls provide a physical structure and substrate to support primary and secondary production (Lee et al., 2009; Harris, 2001; Lai et al., 2018). Throughout the surveys, the reef balls installed in the Turtle Islands Parks were intact and in good conditions except for one broken reef ball unit encountered at Part II.

Reef ball structures and marine fauna at Part I

The most dynamic area of Selingan Island is located at the south of the island where the formation of a sandbar was periodically observed (Chen et al., 2018). Sand accumulated on the reef balls changed based on the direction of wind-waves and local currents. In 2011, the reef balls at part I was buried by sand (Figure 2a) and connected to the island (Sabah Parks & UMS, 2013).

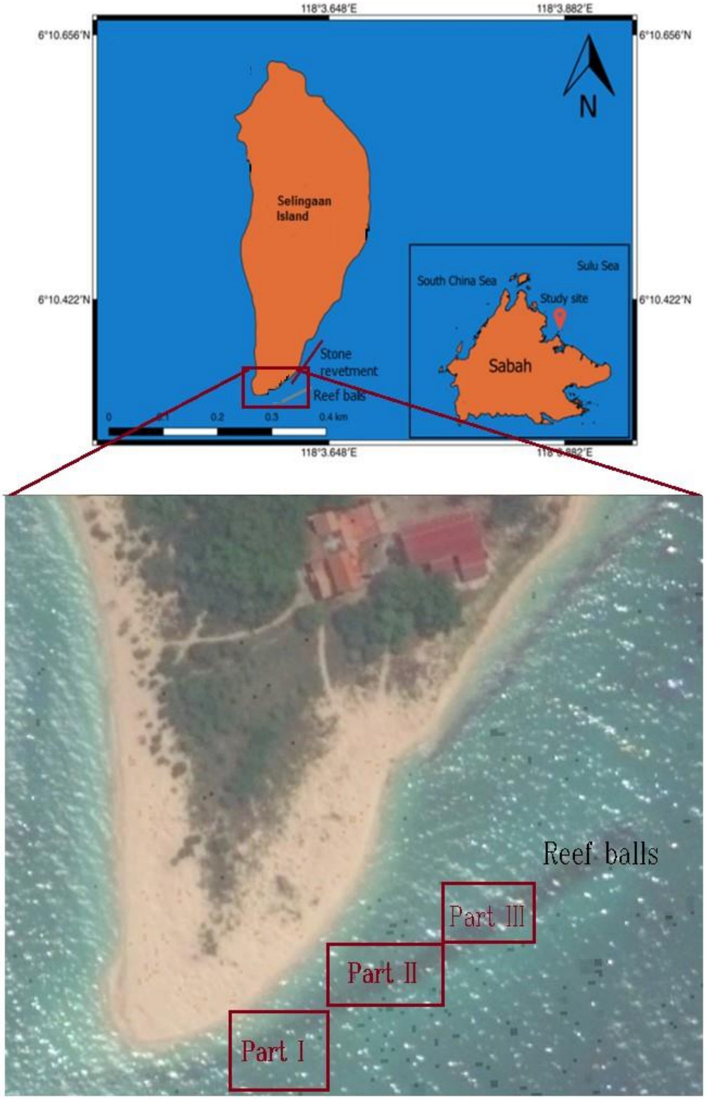

Figure 1. Location of the reef balls and survey area at southeast of Selingan Island (Source: Google Earth 2020)

In in 2017, half of the reef balls structures in Part I were exposed and separated about 5 m from the shoreline during the survey (Figure 2b). The submerged crevices top of the reef balls provides a hiding habitat for snails (Figure 2c) while oysters and barnacles dominated the bottom part of the reef balls (Figure 2d). Part I of the survey area has a lower number of marine fauna as the reef balls have longer exposure time to the sun during low tide. The level of the exposure is dependent on the tidal condition, local currents influencing the sediment transport and seasonal monsoons (Saleh et al., 2013).

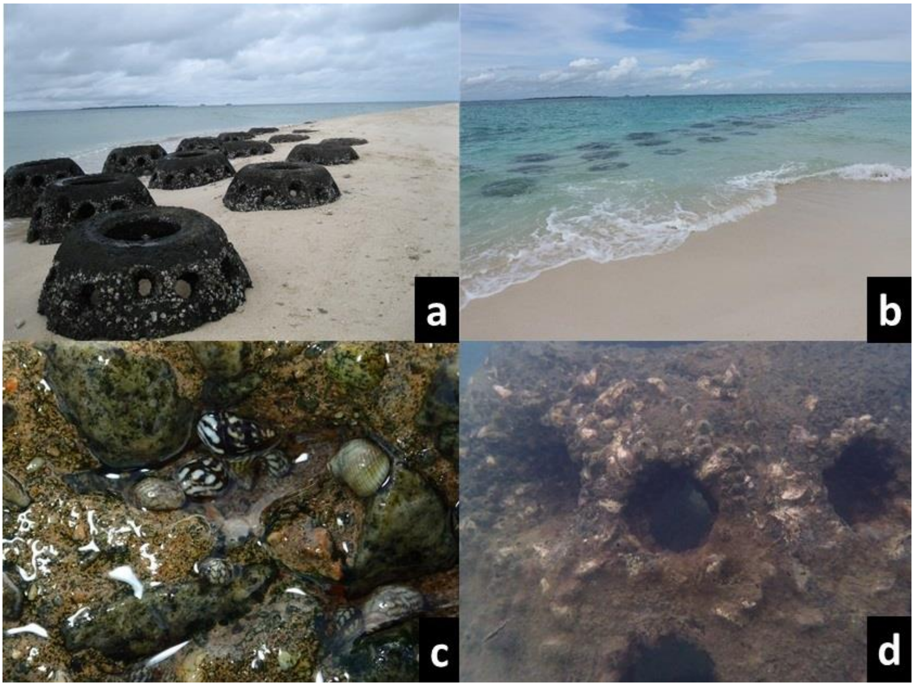

Figure 2. Reef balls in Part I partially covered by sand, (a) exposure during love tide, and (b) submerged during high tide. Various types of sea snails found on the top area of the reef balls (c), and oysters found on the submerged area of the reef balls (d).

Reef balls structures and marine fauna at Part II

Strong waves during storms and exposed to the air during low tide may limit marine organisms occupying the upper part of the reef ball structures in Part II. Both the outer and inner surfaces of reef balls were occupied with oysters, barnacles and limpets (Figure 3a). Most oysters and barnacles were dominated at the top and middle of the reef ball structures while re-suspended sand buried the base (lower part) of the reef balls. Limpet and sea snail species play a major role in controlling the algal community since algae are their main diet (Dayton, 1971; Lubchenco, 1978; Nicotri, 1977).

The sand can be transported elsewhere if the surrounding current pattern and wave actions change. The damaged reef ball (Figure 3b) and small coral colonies were covered by sand at the base of the reef balls (Figure 3c). School of juvenile fish were observed swimming within reef balls structures (Figure 3d).

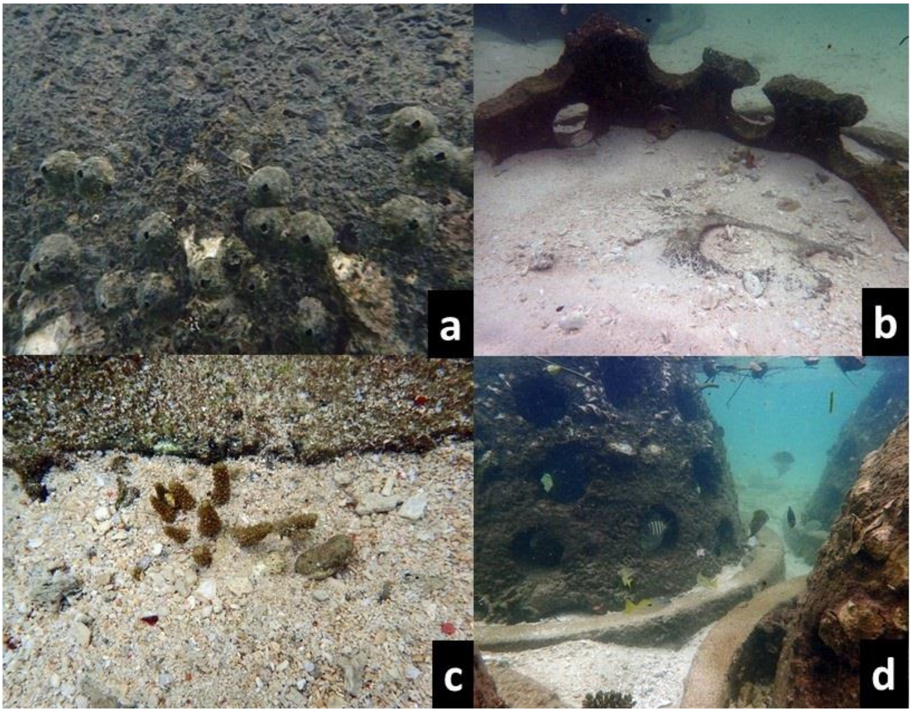

Figure 3. Reef balls in Part II. (a) reef balls structures dominated by barnacles and (b) only one unit of reef ball was damaged. (c) Small coral colonies growing on the base and partially covered by sand and (d) juvenile fish from various species swimming within reef balls.

Reef ball structures and marine fauna at Part III

Full structures of the reef balls were observed at Part III. Several reef balls have signs of scouring processes at the base of the reef balls and provide a larger substrate area for epiphytic species (algae, cyanobacteria, biofilm and diatoms) to growth. Present of epiphytic species increase food availability and promote settlement of the other associated marine fauna such as rabbitfish and butterflyfish (Figure 5a) which is a health indictor of coral colonies and to support the population of corallivores (Hourigan et al., 1988). The water is clear where algae and corals (Figure 5b) adapt with the surrounding environment. The highest abundance and diverse marine life are found in Part III compared to Part Iand Part II (Figure 4). Most of the species listed in Table 2 are found in Part III.

The highest associated marine fauna species identified at the reef balls belong to the class of Actinopterygii (ray-finned fish) such as damselfishes, parrotfish, wrasses and butterflyfish with estimated average size less than 12 cm in length. Other species are blenny fish that live within crevices or soft corals (Figure 4c) while black damselfish known as territorial marine fish swim around reef balls. Echinoidea (*Diadema* sp and *Heterocentrotus* sp) were spotted hiding among the reef ball’s crevices in Part II and Part III (Figure 4d).

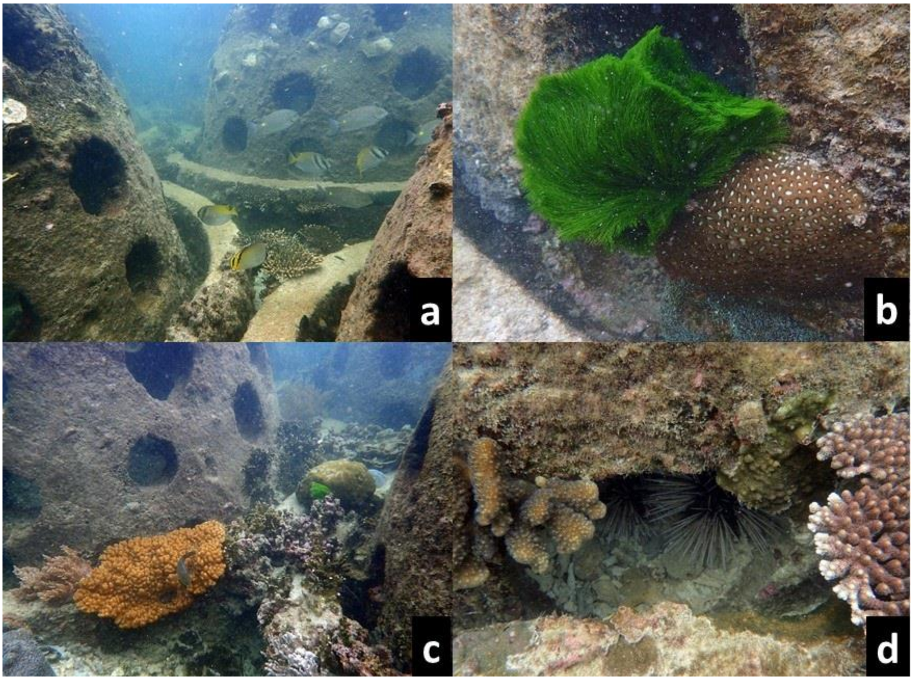

Figure 4. Diverse of organism living among reef balls at Part III. (a) Rabbitfish and butterflyfish swimming within the reef ball. The surface of reef balls provided a substrate for (b) green algae, hard corals and (c) soft coral to settle and thrive. Reef ball provides a structural hideout for invertebrate such as (d) sea urchin.

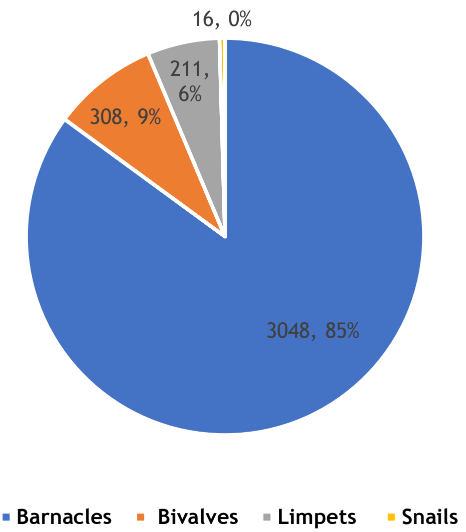

Figure 5. Percentage and number of individual of invertebrates found on reef balls from 24 quadrats.

Inventory of the marine fauna at reef balls area

Marine fauna on hard structures can be ranked according to their ability to colonise and compete for space which are greatly influenced by the historical components, predation, reproduction and abundance of settling larvae (Osman, 1977). During their larval stage, the survival, growth and colonization depends on the ability to cope with the surrounding environment (Garland & Zimmer, 2002). These species also prefer sand-rock or seawalls as substrate areas (Batomalaque et al., (2010) Lee et al., 2009; Lai et al., 2018). A total of 3,583 individual marine fauna were counted within the 24 quadrats (Table 1). A total of 3,048 individuals (83.57%) from the total fauna identified are barnacles (*Tetraclita multicostata*, *Tetraclita porosa* and *Tetraclita* sp.) (Table 1: Figure 5). On the other hand, 308 individuals (8.60%) of bivalves, consist of *Saccostrea cucullata*, *Xenostrobus* sp. and *Isognomon perna*. Limpets consist of 22 individuals (5.89 %) from the genus of *Cellana, Patelloida*, *Siphonaria* while 16 (0.33%) individuals of snails from the genus of *Nodilittorina* sp., *Tubro* sp. There were also unidentified species from the group of limpet and snails (Figure 5; Table 1).

Table 1. Inventory of invertebrates from 24 quadrats on the reef balls structure

Class	Common name	Species	No of organisms
Maxillopoda	Barnacles	*Tetraclita multicostata*	2593
		Tetraclita porosa	447
		Tetraclita sp.	8
Bivalvia	Oysters	*Isognomon perna*	27
		Saccostrea cucullata	171
		Xenostrobus sp.	110
Gastropod	Limpets	*Cellana rota*	1
		Cellana sp.	25
		Patelloida saccharinoides	20
		Patella sp. (1)	22
		Patella sp. (2)	3
		Siphonaria atria	13
		Siphonaria javanica	45
		Siphonaria sp. (1)	19
		Siphonaria sp. (2)	36
		Unidentified (1)	26
		Unidentified (2)	1
	Sea snails	*Nodilittorina* sp.	2
		Turbo sp.	5
		Unidentified genus (1)	7
		Unidentified genus (2)	2

A total of six classes (Gastropod, Holothuroidea, Bivalvia, Actinopterygii, Anthozoa and Echinoidea) of associated marine fauna were identified (Table 2). Bivalvia (*Tridacna* sp) and various types of Anthozoa (hard and soft corals) were found on the base of the reef balls as this area is constantly submerged and less exposed to wave actions (Figure 3c). A variety branching, tabletop and massive corals grow on the reef balls that may create a microhabitat for juveniles of rabbitfish, parrotfish snapper, silver pomfret and butterflyfish (Figure 4a and Table 2). Some corals that grow inside the reef balls provide extra habitat within the reef balls. Reef balls also provide hard substrate surface to colourful anemone species and macroalgae such as red and green algae (Figure 4b). The marine fauna identified (Table 2) are generally small in size. These indicate that the reef ball structures may provide a temporal or nursery habitat in Turtle Island Parks.

Table 2. Inventory of associated marine fauna within reef balls

Class	Common name	Genus / Species	Malay name
Bivalvia	Giant clam	*Tridacna maxima*	Kima
	Giant clam	*Tridacna crocea*	Kima
Gastropod	Cowrie	*Cypraea* sp	siput
Holothuroidea	Black sea cucumber	*Holothuria atra*	Timun laut
	Black sea cucumber	*Halothuria leucospilota*	Timun laut
Echinoidea	Long spine sea urchin	*Diadema setosum*	Landak laut
	Pencil urchin	*Heterocentrotus* sp	Landak laut
Actinopterygii	Indo-Pacific sergeant	*Abudefduf vaigiensis*	
	Silver pomfret	*Pampus argenteus*	Bawal perak
	Ocellaris clown fish	*Amphiprion ocellaris*	Nemo
	Golden spot rabbit fish	*Siganus guttatus*	belais
	Two bar rabbit fish	*Siganus doliatus*	belais
	Parrotfish	*Scarus* sp	bayan
	Longfin damselfish	*Stegastes diencaeus*	
	Black spot snapper	*Lutjanus fluviflamma*	Pisang-pisang
	Copper band butterflyfish	*Chelmon rostratus*	
	Lined butterflyfish	*Chaetodon* sp	
	Cleaner wrasse	*Labroides dimidiatus*	
	Moon wrasse	*Thalassoma lunare*	
	Blenny	*Salarias* sp	
	Saw jawed monocle bream	*Scolopsis ciliata*	
Anthozoa	Table coral	*Acropora* sp	
	Coral	*Montipora* sp	
	Stony coral	*Oxypora* sp	
	Leather coral	*Sinularia* sp	
	Sea anemone	*Heteractis* sp	

Conclusion

There was no major change of the reef ball physical structure in Selingan Island between 2011 and 2017 except for encrusting invertebrates on reef balls. The dynamics of sand at southern part of the island affect the reef ball structures and the distribution of marine fauna. Reef ball structures located closer to the beach (Part I) was partially buried by sand as a scouring process occurs further offshore (Part III). Temporally accumulation of sand occurs in this area as several marine fauna were buried alive while the scouring process creates a hiding space for many marine life at the base of the reef balls.

The reef balls at Selingan Island play an important role as a refuge site, food source, settling substrate and habitat of various marine fauna. A total of 3,583 individual invertebrates on the reef ball structures and 6 classes of associated marine fauna were recorded during this survey. The most abundant species are barnacles followed by bivalves, limpets and snails. Diversity of marine fauna increased from Part I to Part III of the survey areas.

The reef balls in Selingan Island provide shoreline protection and enhance the marine habitat for Turtle Island Marine Park. The presence of butterflyfish indicates a healthy habitat condition within the reef ball structures. The finding provides baseline data and an insight of marine fauna within the reef ball structures. A number of fauna could not be identified to the lower taxa due to poor pictures quality for species identification. The inventory of the marine fauna can be improved by increasing survey areas and time of observation. Tidal cycles and seasonal monsoons need to also be considered for the next survey.

Acknowledgements

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Research Article

Bat Diversity in Imbak Canyon Conservation Area: Note on their Echolocation Calls and Ectoparasites

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Abstract

Imbak Canyon Conservation Area (ICCA) is one of the conservation areas managed by the Sabah Foundation, which comprise of mixed vegetation forest landscape. A bat survey was conducted at ICCA from August 16th to 26th, 2017. A total of 141 individuals of bats representing 17 species were recorded from the eight nights of mist netting and harp trapping at various sites within the conservation area. Echolocation calls from 120 individuals of insectivorous bats representing 13 species were recorded, with 90% accuracy in relative amount. The captured bats were screened for ectoparasites from Order Diptera (91%), Mesostigmata (5%) and Ixodida (1%), and indicate that there is 66.7% prevalence. The results from the survey are paramount in enhancing information and knowledge on Bornean bats and their obligate ectoparasites.

Keywords: Bats, Conservation, Diversity, Echolocation, Ectoparasites

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Introduction

Bats are the second most species-rich mammalian Order in the world with over 1,400 described species (Burgin et al., 2018; Simmons & Cirranello, 2020). Regionally, Southeast Asia hosts about 378 species of bats (see Görföl et al., 2013; Soisook et al., 2013; Douangboubpha et al., 2014; Douangboubpha et al., 2016; Ith et al., 2015; Tu et al., 2015; Soisook et al., 2015; Soisook et al., 2016; Kuo et al., 2017; Tu et al., 2017; Soisook et al., 2017), of which 32% of the Southeast Asian bats are found in Malaysia, and at least 26% of these are found in Borneo (Payne et al., 1985; Francis, 2008; Phillipps & Phillipps, 2018). These figures indicate the significance of Malaysia as one of the centres for Old World bat diversity. However, more than a quarter of these bats are red listed by IUCN and many more have a declining population trend (IUCN, 2018). Bat populations have declined over the past decades, globally and regionally, largely due to habitat loss (Mickleburgh et al., 2002; Frick et al., 2019).

Regarded as the most abundant mammal in the tropics and sub-tropical forests (Findley, 1993; Patterson et al., 2003), bats are a vital component of an ecosystem. They are important seed dispersers, pollinators, and suppressors of arthropod populations, including agricultural pests (Fleming, 1998; Kunz et al., 2011). Regardless of their diversity and significance towards ecosystems, bats are still considered as a marginalised component of biodiversity, subsequently underestimating their role in ecosystems. Various species of these nocturnal flying mammals are highly dependent on forest covers. Their presence correlate with availability and suitability of roosting sites, signifying the impact of habitat loss toward species that exploit tree cavities and foliage as roost (Schulze et al., 2000).

In Borneo, more than half of the insectivorous bats are dominant in the forest interior. Their wings and echolocation calls are designed for manoeuvrability and detection in a cluttered environment (Schnitzler & Kalko, 1998; Kingston et al., 2003), contributing to their superiority in a cluttered environment, however, energetically costly in open spaces. Besides exploring the eco-morphology of bats, another component that offers important information to understand the biology, systematics and phylogenetics aspects of bats is the bat obligate ectoparasites (Fritz,1983). Like other mammals, bats are susceptible to parasitism and information on bat-obligate parasites are scarce in certain regions including Malaysia (e.g. Azhar et al., 2015). Hence, understanding the host-parasite association might provide better insights to further understand the complex ecology of bats.

Like most part of Southeast Asia, the continuous loss of forest landscape in Borneo have gained growing attention among biologists and conservationists in exploring the values of secondary and regenerated forest as a potential ground to facilitate the recovery of a local biodiversity. These prospective areas may provide substantial areas and resources to support viable bat populations, eventually promoting population recovery. ICCA is one of the optimal areas portentous for such capacity. The heterogeneous landscape within this conservation area could provide refuge, and potentially contribute to population recovery of various faunal species. Several bat surveys have been conducted at various sites in ICCA with the most recent one conducted in August 2017, in conjunction with the scientific expedition at Batu Timbang Research Station organised by Yayasan Sabah. The results from this survey will complement results from previous bat surveys in ICCA. Herein, results from the recent survey and the compilation of bat species, echolocation calls, and ectoparasites recorded from ICCA are reported.

Methodology

Study sites

ICCA is among prominent forest areas in Sabah managed by Yayasan Sabah. The area is covered by various types of vegetation including dipterocarp forest, tropical heath forest, and montane forest. This area was gazetted in 2009 as a Class I Forest Reserve to protect the vigorous ecosystem and its content. Bat trapping was done at various trails around the Imbak Canyon Study Centre (05°05.623'N, 117°02.371'E) and Batu Timbang Research Station (05°00.197'N, 117°04.762'E). Among the trails covered during the survey were Big Belian Trail, Nepenthes Trail and Waterfall Trail at Imbak Canyon Study Centre, and Rafflesia Trail and Lanap Trail at Batu Timbang Research Station (Figure 1).

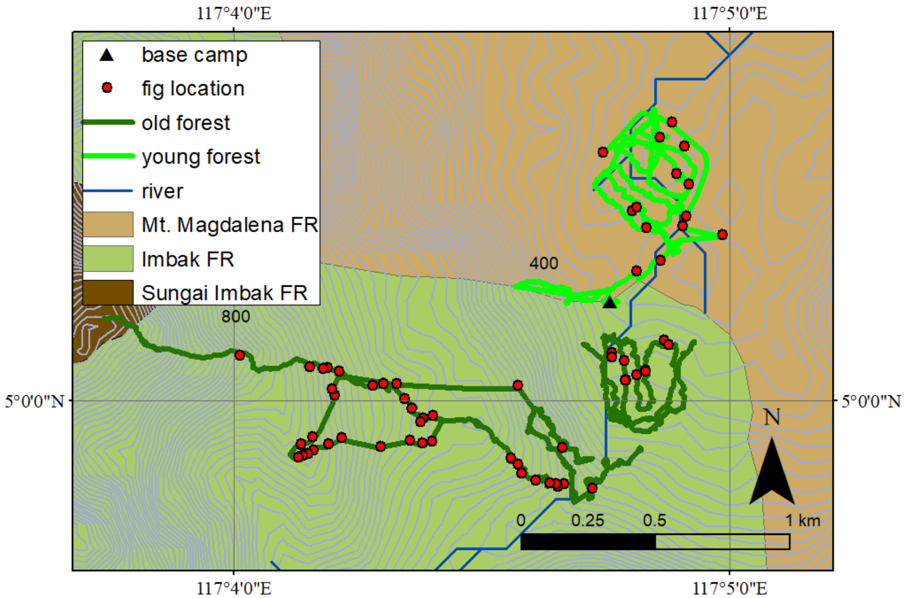

Figure 1. The trapping sites composed of primary forest, riverine forest, kerangas and regenerated forest.

Trapping and Sample Processing

Bat trappings were done using four four-bank harp traps (Francis, 1989) and an average of eight mist nets (four shelves; 36 mm mesh size). Both nets and traps were positioned in the forest understorey, across jungle trails and streams. The nets and traps were moved to a new location each night to avoid habituation by the bats, which may cause the capture rate to dwindle (Kunz et al., 2009). Mist nets and harp traps were set at dusk before the first bat emerged and were checked every 15-30 minutes until 2200 hours, depending on the intensity of capture. During the day, each trail was explored to locate active roosts. Roosting bats were captured using mist nets and hand nets. Captured bats were held inside individual cloth bags and identified following Payne et al., (1985) and Phillips & Phillips (2016). Biometric measures such as body mass (g) and forearm length (mm) were taken for each captured individual. In addition to this, sex and reproduction stage for each captured bat was recorded. Echolocation calls of the insectivorous bats were recorded using Pettersson M500 USB Ultrasound Microphone. Calls were recorded by releasing the bats in a flight tent. Captured bats were released at the capture point once measurements and recordings were completed.

Ectoparasite screening was done by examining each bat host under an intensive light source specifically at the fur area of the body, wing membranes and uropatagium. All visible ectoparasites were removed and placed in vials containing 70% ethyl alcohol, using separate vials for each bat host. Each vial was labelled with field number and host information. Meanwhile, taxonomic assignment for the ectoparasites was done following Jobling (1930), Theodor (1967), Maa (1962; 1971) and Azhar et al. (2015). Voucher specimens for the host and ectoparasites were stored at the Institute for Tropical Biology and Conservation. Ectoparasite prevalence was calculated in percentage, for each species and later to be total up for the sampled population, using given formulation (**P**):

$$\mathbf{P} = \frac{\sum I}{\sum F} \times 100\%; \text{ where}$$

Σ^{I} is the number of infected individual from each species

Σ^{F} is the total number of bats captured in this study

Results

Bat species richness of Imbak Canyon Conservation Area

In total, 141 bat individuals were captured during this survey. The bats accumulated represent 17 species from 5 families, Pteropodidae (three genera; three species), Emballonuridae (one genus; two species), Rhinolophidae (one genus; seven species), Hipposideridae (one genus; two species) and Vespertilionidae (two genera; four species). To date, the results for the accumulated number of bat species from the current survey and previous surveys is 27 species (Table 1).

Table 1. Number of individuals for each bat species captured using various sampling methods from the current study.

Family	Species	Common Name	Number of Individuals
Pteropodidae	*Cynopterus brachyotis*	Lesser Dog-faced Fruit Bat	1
	Penthetor lucasi	Lucas's Short-nosed Fruit Bat	1
	Macroglossus minimus	Dagger-toothed Long-nosed Fruit Bat	2
Emballonuridae	*Emballonura alecto*	Small Asian Sheath-tailed Bat	10
	Emballonura monticola	Lesser Sheath-tailed Bat	4
Rhinolophidae	*Rhinolophus acuminatus*	Acuminate Horseshoe Bat	1
	Rhinolophus creaghi	Creagh's Horseshoe Bat	10
	Rhinolophus borneensis	Bornean Horseshoe Bat	3
	Rhinolophus sedulus	Lesser Woolly Horseshoe Bat	2
	Rhinolophus trifoliatus	Trefoil Horseshoe Bat	1
Hipposideros	*Hipposideros ater*	Dusky Leaf-nosed Bat	3
	Hipposiders cervinus	Fawn Leaf-nosed Bat	74
Vespertilionidae	*Myotis muricola*	Nepalese Whiskered Myotis	1
	Myotis horsfieldii	Horsfield's Myotis	2
	Kerivoula papillosa	Papillose Woolly Bat	20
	Kerivoula pelucida	Clear-winged Woolly Bat	1
	Kerivoula minuta	Least Woolly Bat	5

Echolocation Calls of Insectivorous Bats

From the total number of individuals captured in the survey, echolocation calls for 120 individuals of insectivorous bats from 13 species were successfully recorded. The discriminant function analysis indicated that out of 120 individuals, 108 were grouped into the call ranges of the 13 species of bats with 90% accuracy in relative amount. Table 2 shows the analysed calls for bats of ICCA.

Table 2. Echolocation calls for the insectivorous bats recorded from this survey at Imbak Canyon Conservation Area.

Species	Call Structure	SF (kHz)	EF (kHz)	FmaxE (kHz)	D (ms)	IPI (ms)	Duty Cycle (%)	n
EMBALLONURIDAE								
Emballonura alecto	QCF-FM	48.23 ± 1.18 (47.05-49.41)	43.07 ± 2.62 (40.45-45.69)	46.14 ± 0.09 (46.05-46.23)	3.09 ± 0.56 (2.53-3.65)	26.97 ± 4.85 (22.12-31.82)	11.80 ± 2.97 (8.83-14.77)	9
Emballonura monticola	QCF-FM	48.00 ± 0 48.00	48.00 ± 3.29 (44.71-51.29)	48.63 ± 1.10 (47.53-49.73)	2.90 ± 0.26 (2.64-3.16)	16.73 ± 1.03 (15.70-17.76)	17.33 ± 1.55 (15.78-18.88)	3
HIPPOSIDERIDAE								
Hipposideros ater	CF-FM	142.10 ± 0.55 (141.55-142.65)	118.40 ± 1.74 (116.66-120.14)	142.12 ± 0.50 (141.62-142.62)	5.24 ± 0.61 (4.63-5.85)	22.18 ± 1.80 (20.38-23.98)	23.71 ± 2.96 (20.75-26.67)	6
Hipposideros cervinus	CF-FM	119.53 ± 2.64 (116.89-122.17)	108.93 ± 7.13 (101.80-116.06)	119.54 ± 2.63 (116.91-122.17)	4.28 ± 0.89 (3.39-5.17)	22.19 ± 2.68 (19.51-24.87)	19.52 ± 4.49 (15.03-24.01)	27
RHINOLOPHIDAE								
Rhinolophus borneensis	FM-CF-FM	76.66 ± 2.72 (73.94-79.38)	76.84 ± 7.33 (69.51-84.17)	84.37 ± 2.09 (82.28-86.46)	51.67 ± 7.73 (43.94-59.40)	123.64 ± 18.90 (104.74-142.54)	42.60 ± 8.80 (33.80-51.40)	9
Rhinolophus creaghi	FM-CF-FM	59.93 ± 1.95 (57.98-61.88)	64.85 ± 4.20 (60.65-69.05)	66.69 ± 1.94 (64.75-68.63)	44.10 ± 4.12 (39.98-48.22)	103.98 ± 10.77 (93.21-114.75)	42.76 ± 5.22 (37.54-47.98)	21
Rhinolophus sedulus	FM-CF-FM	57.45 ± 1.14 (56.31-58.59)	59.48 ± 2.20 (57.28-61.68)	60.75 ± 0.60 (60.15-61.35)	48.98 ± 8.38 (40.60-57.36)	94.22 ± 5.54 (88.68-99.76)	52.47 ± 10.80 (41.67-63.27)	6
Rhinolophus trifoliatus	FM-CF-FM	47.93 ± 0.58 (47.35-48.51)	50.80 ± 0.52 (50.28-51.32)	51.40 ± 0.00 51.40	39.67 ± 1.45 (38.22-41.12)	118.67 ± 4.61 (114.06-123.28)	33.49 ± 2.53 (30.96-36.02)	3
VESPERTILIONIDAE								
Kerivoula minuta	FM	162.02 ± 15.57 (146.45-177.59)	85.52 ± 8.23 (77.29-93.75)	115.59 ± 8.04 (107.55-123.63)	3.27 ± 1.56 (1.71-4.83)	22.99 ± 6.31 (16.68-29.27)	13.63 ± 3.41 (10.22-17.04)	9
Kerivoula papillosa	FM	175.16 ± 12.01 (163.15-187.17)	74.31 ± 5.63 (68.68-79.94)	107.15 ± 11.37 (95.78-118.52)	2.92 ± 0.55 (2.37-3.47)	15.81 ± 3.11 (12.70-18.92)	18.92 ± 4.28 (14.64-23.20)	15
Kerivoula pellucida	FM	227.03 ± 8.97 (218.06-236.00)	81.20 ± 0.00 81.20	154.23 ± 22.46 (131.77-176.69)	2.41 ± 0.15 (2.26-2.56)	8.68 ± 0.11 (8.57-8.79)	27.82 ± 2.05 (25.77-29.87)	3
Myotis muricola	FM	82.57 ± 4.56 (78.01-87.13)	59.17 ± 1.10 (58.07-60.27)	64.87 ± 3.96 (60.91-68.83)	1.56 ± 0.36 (1.20-1.92)	25.33 ± 2.65 (22.68-27.98)	6.19 ± 1.59 (4.60-7.78)	3
Myotis horsfieldii	FM	98.47 ± 11.44 (87.03-109.91)	52.25 ± 3.58 (48.67-55.83)	63.67 ± 2.77 (60.90-66.44)	2.11 ± 0.51 (1.60-2.62)	18.58 ± 2.13 (16.45-20.71)	11.30 ± 2.33 (8.97-13.63)	6

Sf – Start Frequency; EF – End Frequency; FmxE (kHz) – Frequency at Max Energy; D (ms) – Duration; IPI (ms) – Pulse Interval; n – number of individuals

Host-ectoparasite association in ICCA Bats Community

In total, 61 and 32 individuals of bats were recorded with ectoparasites from Imbak Canyon Study Centre and Batu Timbang Research Station, respectively. In total, 13 species of ectoparasites from six families were recorded from the 93 infested individuals, with 66.7% prevalence. Specifically, four out of ten species of bats recorded from the Imbak Canyon Study Centre come up with a total of 54 incidence of bat flies, 4 incidence of mites, and 1 incident of tick infestation. Meanwhile, seven out of 10 species recorded from Batu Timbang Research Centre came up with 32 incidence of bat flies and one incident of mite and tick infestation. For both areas where trappings were conducted, *Hipposideros cervinus* have the highest incidence of ectoparasite, followed by *Kerivoula papillosa* (Table 3). The colour plates represent each species of ectoparasites collected from the survey (Figure 2 and Figure 3).

Table 3. Taxonomic checklist of ectoparasites and their hosts recorded from this study.

Host Species	**Ectoparasite Species**										
	Brachytarsina sp.	*Raymondia* sp.	*Stylidia* sp.	*Eucampsipoda penthetoris*	Nycteribiidae sp. 1	Nycteribidae sp. 2	*Meristaspis* sp.	*Spinturnix* sp.	Unidentified sp. 1	Unidentified sp. 2	Unidentified sp. 3
Cynopterus brachyotis	-	-	-	-	-	-	-	-	-	-	-
Penthetor lucasi	-	-	-	1	-	-	1	-	-	-	-
Macroglossus minimus	-	-	-	-	-	-	-	-	-	-	-
Emballonura Alecto	1	-	1	-	-	-	-	-	-	-	1
Emballonura monticola	-	-	-	-	-	-	-	-	-	-	-
Rhinolophus acuminatus	-	-	-	-	-	-	-	-	-	-	-
Rhinolophus creaghi	3	-	3	-	-	-	-	-	-	-	-
Rhinolophus borneensis	1	-	-	-	-	-	-	-	-	-	-
Rhinolophus sedulus	-	1	-	-	-	-	-	-	-	-	-
Rhinolophus trifoliatus	-	-	-	-	-	-	-	-	-	-	-
Hipposideros ater	-	1	1	-	-	-	-	-	-	-	-
Hipposiders cervinus	7	44	11	-	2	1	-	-	-	1	1
Myotis muricola	-	-	-	-	-	-	-	-	-	-	-
Myotis horsfieldii	-	-	2	-	-	-	-	-	-	-	-
Kerivoula papillosa	-	-	3	-	-	-	-	4	-	-	-
Kerivoula pelucida	-	-	-	-	-	-	-	-	1	-	-
Kerivoula intermedia	-	-	-	-	-	-	-	-	-	-	-
Total Incidence						**92**					

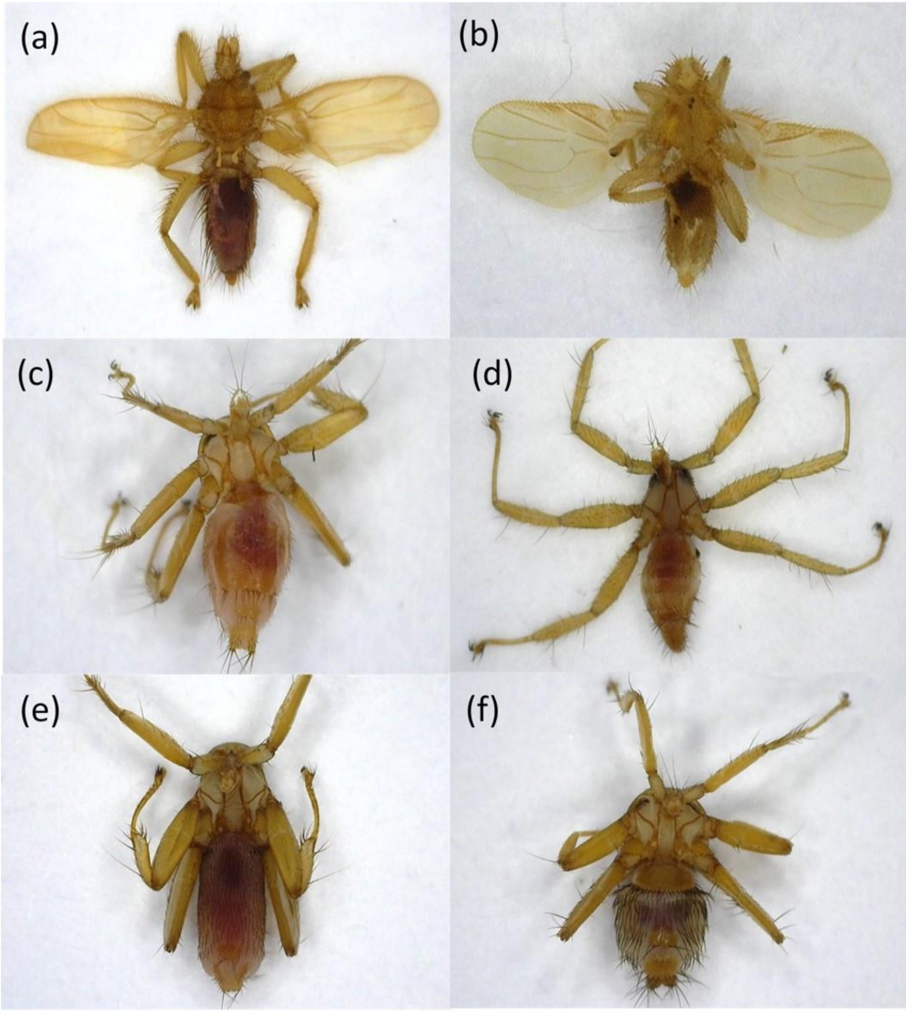

Figure 2. (a) Dorsal view of *Brachytarsina* sp._ (b) Dorsal view of *Raymondia* sp._ (c) Dorsal view of female *Stylidia* sp._ (d) Dorsal view of *Eucampsipoda penthetoris* (e) Dorsal view of Nycteribiid species 1. (f) Dorsal view of Nycteribiid species 2.

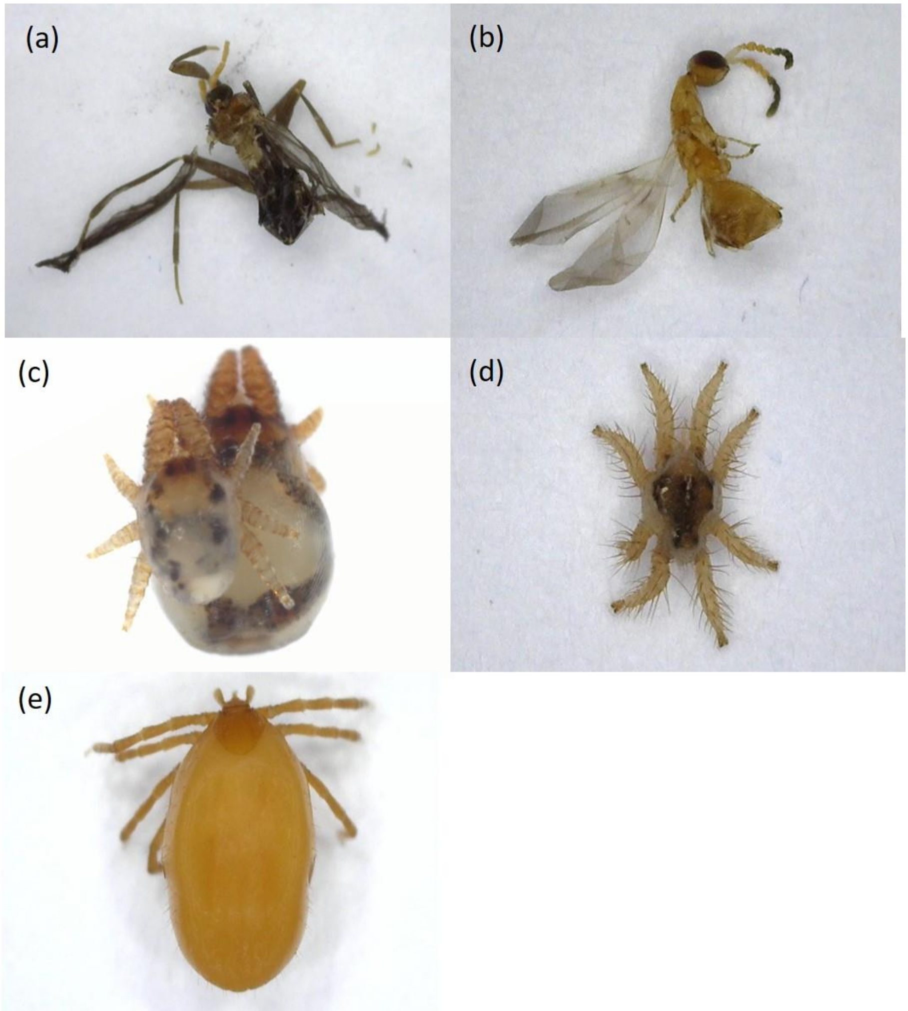

Figure 3. (a) Dorsal view of Unknown sp. 3 (b) Side view of Unknown sp. 4 (c) Dorsal view of adult and juvenile *Meristaspis* sp. (d) Dorsal view of *Spinturnix* sp. (e) Dorsal view of Unknown sp. 5.

Discussion

This study recorded a total of 17 species of bats from the eight nights of mist-netting and harp trapping. The most abundant species was *Hipposiders cervinus*, followed by *Kerivoula papillosa*. There were six species of bats recorded in singleton, namely, *Cynopterus brachyotis*, *Penthetor lucasi*, *Rhinolophus acuminatus*, *R. trifoliatus*, *Myotis muricola*, and *Kerivoula pellucida*. It is speculated that the low capture of pteropodid bats was influenced by the availability of fruiting trees and the placing of mist nets which cover only forest understorey. Hodgkison et al. (2004) mentioned that temporal variation affects the presence of pteropodids where these bats often travel to areas where food can be found in abundance. Meanwhile, the latter may also have effect on the capture rate of pteropodids where some pteropodids are more abundant in the higher forest strata (Francis, 1990; Francis, 1994). The abundance of potential roost sites found in ICCA reckon the suitability of the forest in providing resources for the bats. There were numerous roosting sites identified during the survey at ICCA, from which *Emballonura alecto*, *E. monticola* and *R. borneensis* were captured. Furthermore, ginger plants were found abundant particularly at Batu Timbang Field Station. These plants are known as one of the preferred roosts for *Kerivoula hardwickii*. However, there were no individuals of *K. hardwickii* recorded roosting in the unfurled leaves of ginger plants.

Based on the IUCN Red List of Threatened Species, six out of 27 species of bats recorded from ICCA are listed as Near Threatened, while the others were Least Concern. Conversely, these evaluations are not consistent with the protection list at local level. Based on the Sabah Wildlife Conservation Enactment 1997, none of the bats in the ICCA are listed in the protected species list except for the large flying fox, for which the hunting and selling of this species is allowed with the acquirement of a license. Bats alongside with other small mammals are often deemed as a less charismatic animal, negating their significant ecosystem services both in the natural environment and commercial industries. With growing environmental awareness and conservation driven direction of Sabah, the state government should consider taking an immediate action to plan and strategize on how to increase environmental awareness and sustainable practices among the locals. Furthermore, it is vital for the State Government to revise and remap the conservation status in the Sabah Wildlife Conservation Enactment 1997 to enhance and expand their conservation and management plans (Azhar et al., 2018).

Insectivorous bats made up 77.8% of the total bats recorded at ICCA. One of the important features of the insectivorous bats is their ability to produce echolocation, which empower their flight capacity and manoeuvrability (Schnitzler et al., 2003). Information on echolocation calls of bats in Sabah is very limited hence, accentuating the significance of the calls collected from this survey towards bat research in Sabah. The call data generated from this study is fundamental to the construction of call libraries to facilitate monitoring for this elusive taxon. On top of all, echolocation is one of the significant components derived from the multitude of selections and radiation occurring throughout millennia within the chiropterans (see Schnitzler & Kalko, 2001; Kingston & Rossiter, 2004; Jung et al., 2014).

The survey confirmed a monoxenous association between the bat fly, *Eucampsipoda penthetoris*, and the Dusky fruit bat, *P. lucasi*, indicating an evidence of host specificity and supporting previous report in Malaysia (Azhar et al., 2015). However, there were no specific information on the degree of association between bats and their ectoparasites acquired from this survey. Furthermore, *H. cervinus* was recorded with the highest infestation rate. This species is known to roost in large colony, which may have resulted in the higher infestation rate (Matthee & Krasnov, 2009). Noteworthy, there was an incidence of ixodid ticks recorded from one of the bat species captured during this survey. It is an unusual encounter because most of the hard ticks are known to infest the non-volant small mammals. However, bats have diverse roost-site selection which could have resulted this accidental incidence. Future studies should be designed to understand roosting dynamics in bats and how it influences the host-parasite association.

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Appendix 1. List of all bat species recorded from Imbak Canyon Conservation Area and their conservation status following IUCN Red List of Threatened Species and Sabah Wildlife Conservation Enactment 1997.

Family	Species	Common Name	Conservation Status	
			IUCN Red List	WCE 1997
Pteropodidae	*Pteropus vampyrus*	Large Flying Fox	NT	Schedule 3
	Cynopterus brachyotis	Lesser Dog-faced Fruit Bat	LC	-
	Penthetor lucasi	Lucas's Short-nosed Fruit Bat	LC	-
	Balionycteris maculata	Spotted-winged Fruit Bat	LC	-
	Aethalops aequalis	Borneo Fruit Bat	LC	-
	Macroglossus minimus	Dagger-toothed Long-nosed Fruit Bat	LC	-
Emballonuridae	*Emballonura alecto*	Small Asian Sheath-tailed Bat	LC	-
	Emballonura monticola	Lesser Sheath-tailed Bat	LC	-
Rhinolophidae	*Rhinolophus acuminatus*	Acuminate Horseshoe Bat	LC	-
	Rhinolophus creaghi	Creagh's Horseshoe Bat	LC	-
	Rhinolophus borneensis	Bornean Horseshoe Bat	LC	-
	Rhinolophus affinis	Intermediate Horseshoe Bat	LC	-
	Rhinolophus sedulus	Lesser Woolly Horseshoe Bat	NT	-
	Rhinolophus trifoliatus	Trefoil Horseshoe Bat	LC	-
Hipposideros	*Hipposideros bicolor*	Bicolored Leaf-nosed Bat	LC	-
	Hipposideros ater	Dusky Leaf-nosed Bat	LC	-
	Hipposideros dyacorum	Dayak Leaf-nosed Bat	LC	Schedule 2
	Hipposiders cervinus	Fawn Leaf-nosed Bat	LC	-
	Hipposideros diadema	Diadem Leaf-nosed Bat	LC	-
Nycteridae	*Nycteris tragata*	Malayan Slit-faced Bat	NT	-
Vespertilionidae	*Myotis muricola*	Nepalese Whiskered Myotis	LC	-
	Myotis ater	Peter's Myotis	LC	-
	Myotis horsfieldii	Horsfield's Myotis	LC	-
	Kerivoula papillosa	Papillose Woolly Bat	LC	-
	Kerivoula pelucida	Clear-winged Woolly Bat	NT	-
	Kerivoula intermedia	Small Woolly Bat	NT	-
	Kerivoula minuta	Least Woolly Bat	NT	-

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Research Article

Effect of Logging on the Ficus Community at Batu Timbang Research Station, Imbak Canyon Conservation Area, Sabah

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Abstract

We investigated the effect of logging on *Ficus* species at a community level in the Imbak Canyon Conservation Area (ICCA) in Sabah, Malaysian Borneo. We made comparisons of species composition, density, fig size, and host-tree size (DBH) between heavily logged and relatively old forests, and assessed factors affecting the size of hemi-epiphytic species. There were no significant differences in species composition, density, and fig size between the two habitats. There were significant differences between the DBH of host and non-host trees in both young and old forests as well as between those of host trees in young and old forests. The DBH of hemi-epiphytic species was negatively affected by the DBH of host trees. The results obtained in this study indicate that *Ficus* species, particularly hemi-epiphytes, can survive in degraded habitats that have recently been logged as well as in undegraded forests, and that their growth is not greatly affected by prior logging activities. Thus, *Ficus* exhibits both flexibility and adaptability to habitat change. This indicates that *Ficus* species make ideal plants for the restoration of logged forests considering that figs are an important food resource for numerous animal species, and can promote seed dispersal of other plants by attracting these animals into degraded habitats.

Keywords: Moraceae, hemi-epiphytic figs, forest logging, rainforest, Borneo

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Introduction

Ficus is one of the most species-rich plant genera, containing approximately 750 species that are pantropically distributed (Janzen, 1979), with around 150 species on Borneo alone (Berg & Corner, 2005). Hemi-epiphytic species account for one-third to more than a half of all *Ficus* species in any given locality and are an important component of forest ecosystems (Harrison et al., 2003). Their seeds are dispersed among the branches of host trees by arboreal and/or volant animals, where these plants start their life as epiphytes, until their aerial roots grow and connect them to the ground (Putz & Holbrook, 1986). Climbers also need host trees for physical support. Owing to the large crop size produced by hemi-epiphytic species and their seasonal fig (inflorescence) availability, *Ficus* are keystone plants in terms of food resources for more than 1,000 animal species worldwide (Shanahan et al., 2001). Thus, *Ficus* is an ecologically important genera and is closely related to the survival of other plants and animals in forest communities.

Forest logging is the critical factor in forest degradation in Bornean rainforests (Reynolds et al., 2011). Mechanical logging drastically alters forest structure and species composition of the dominant plant family, which in rainforests comprises dipterocarps (Ancrenaz et al., 2010), leading to a reduction in food resources for frugivorous and folivorous animals (Johns, 1986, 1988). Therefore, the effects of logging on *Ficus* may directly impact both plant and animal species diversity and composition in any given forest ecosystem. The spatial distribution of fleshy-fruited plants following logging is determined by seed dispersal via animals (Wunderle Jr, 1997). Most animals that feed on figs are potential seed dispersers for this plant, because fig seeds are numerous, tiny (ca. 1 mm) and mostly egested in faeces without destruction, with the exception of some animals, e.g. mice and green pigeons (Compton et al., 1996; Lambert, 1989a; Shanahan et al., 2001). However, only large animals can disperse the seeds of large fig species, e.g. *Ficus punctata*, because these species usually have thick outer flesh, and most small animals leave the seeds inside, untouched (Shanahan, 2016). Given that large animals are usually negatively affected by logging (Meijaard et al., 2005; Ancrenaz et al., 2010), fig size could also influence *Ficus* species composition and spatial distribution, especially in degraded habitats. Therefore, the species composition, spatial distribution, and fig size of each species will reflect the effect logging has on *Ficus*. For host-dependent species, the host tree is a key factor for their survival and growth (Putz & Holbrook, 1986), so the characteristics of host trees should also be considered.

Despite the importance of this matter, to the best of our knowledge there are no such data available. Therefore, in this study, we investigated the effect of logging on *Ficus* species at a community level in the Imbak Canyon Conservation Area (ICCA), in Sabah, Malaysian Borneo. We specifically addressed the following: 1) a comparison of species composition, density, fig size and host-tree size between heavily logged and relatively old forests, and 2) factors affecting the size of hemi-epiphytic *Ficus* individuals.

Materials and Methods

Study site

This study was conducted between 18 and 23 August 2017 in the forests around Batu Timbang Research Station (BTRS, 5°00'N, 117°04'E), near the border of Imbak Canyon Forest Reserve and Mt. Magdalena Forest Reserve, in the south-eastern section of the Imbak Canyon Conservation Area (ICCA, 5°04'N, 117°06'E). The ICCA covers an area of approximately 30,000 hectares. Most of the habitat within the ICCA comprises lowland dipterocarp rainforest and upper montane forest, including montane heath forest patches (Sugau et al. 2012, Suleiman et al. 2012). The ICCA was formerly a part of the Yayasan Sabah Concession Area, and in the past the habitat around the periphery of the ICCA was heavily logged. The forests around the BTRS were logged several times during the 1980s and the 2000s (Yap, S.W. personal communication). Logging activity was totally prohibited when the ICCA became a Class I (Protection) Forest Reserve in 2009. The forests inside the canyon are relatively pristine (Latif & Sinun, 2012).

Survey methods

We established plots consisting six transects (250 × 250 m at 50 m intervals) andsearched for *Ficus* species along the transects in heavily logged (hereafter referred to as ‘young’) forest and old forest habitats (Figure 1). In addition to these plots, we also searched them using transects in each area. When we detected a *Ficus* species, we recorded the species name, coordinates (using a GPS: Garmin 64S, Garmin International, Olathe, Kansas, USA), diameter at breast height (DBH, cm), height (using a laser range finder: Laser 550AS, Nikon, Tokyo, Japan), host-tree species, and the host tree’s DBH. For hemi-epiphytes, we also measured the DBH of the largest aerial roots that reached the ground. We regarded the height of the position of colonisation as the height of hemi-epiphytes, while for climbers we regarded the height of the crown as the height. The nomenclature of plant species, plant growth form, and taxonomic rank followed Berg & Corner (2005).

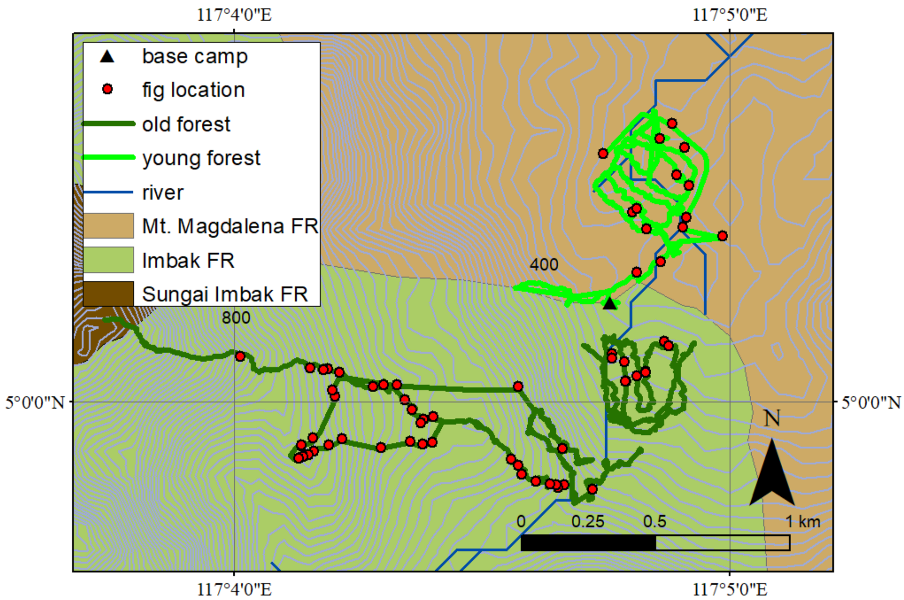

Figure 1. Map of the surveyed area and all fig locations

Data analysis

We assessed the similarity of *Ficus* species composition between the two habitats (young and old forest) using Jaccard's similarity index (Jaccard, 1912; Koleff et al., 2003). A value of zero indicates completely dissimilar sets; a value of 1 indicates identical sets. The difference in densities between the two habitats was assessed by comparing the number of *Ficus* individuals in each habitat with the expected number of individuals if they were distributed equally in the two habitats, using Fisher's exact test.

We investigated whether there were differences in fig size between the two habitats using a simulated distribution of indices that would be expected if there was no effect of habitat differences, by performing an exact permutation test estimated by Monte Carlo (9,999 replications) using the perm package in R 3.4.2 software (R Development Core Team, 2017). We calculated the fig size index as diameter (mm)*length (mm)/100 for each species. Fig sizes were based on Lambert (1989b) and Nakabayashi (2015, including unpublished data). We also compared the DBH of host trees of host-dependent species, such as hemi-epiphytes and climbers, with that of non-host trees, and also the DBH of host trees between the two habitats, by using exact permutation tests with Bonferroni corrections.

We assessed the factors affecting the size (DBH) of hemi-epiphytic species using generalised linear mixed models (GLMMs) with Gamma distributions. We used the restricted maximum likelihood with the lmer function to fit the GLMMs. Random effect was individual, and the fixed effects were habitat type (young or old forest), colonisation height, fig species, and DBH of host trees. We evaluated the support for all models using the Akaike information criterion (AIC) and found the best fit models with the lowest AIC value. We tested whether the coefficient estimates in the best model deviated from zero using the Wald test. GLMMs and the Wald test were executed using the lme4 package in R 3.4.2 software.

Results

In total, we surveyed 8.1 km in young forest areas and 12.6 km in old forest areas. We defined 5 m on either sides of a transect as the visible range, and therefore the total surveyed area in young and old forests was 8.1 and 12.6 ha, respectively. We found 14 and 20 (total 27) *Ficus* species in young and old forests, respectively (Table 1, 2). There were three and 12 unidentified species in young and old forests, respectively. It was unclear whether these unidentified species included the same species. The growth form of 18 out of 27 identified species was hemi-epiphytic (66.7%), five species were climbers (18.5%), two species were shrubs (7.4%) and two species were trees (7.4%). We found 18 and 51 (total 69) individuals, including 15 unidentified species, in young and old forests, respectively. The growth form of 44 out of 55 species-identified individuals was hemi-epiphytic (80.0%), seven were climbers (12.7%), two were shrubs (3.6%) and two were trees (3.6%).

Table 1. Attributes of *Ficus* species detected during this expedition; N = number of individuals

subgenus / section / subsection	species	growth form[a]	N	DBH±SD (cm)	height±SD (m)	density (ha^{-1})	
						surveyed area[b]	Sarawak[c]
Urostigma							
Urostigma							
Conosycea	*F. binnendijkii*	H	2	6.0	38.8±11.3	0.10	0.15
	F. callophylla	H	2	103.8±96.3	20.0	0.10	0.02
	F. consociata	H	3	14.2±11.3	23±7.9	0.15	0.08
	F. delosyce	H	1			0.05	0.42
	F. dubia	H	2	12.3±4.8	35.0±10.0	0.10	
	F. globosa	H	1			0.05	
	F. kerkhovenii	H	6	11.6±10.1	32.0±5.0	0.29	0.27
	F. microcarpa	H	1	100	30.0	0.05	
	F. pellucido-punctata	H	2	4.5±1.5	29.0±13.0	0.01	0.05
	F. pisocarpa	H	2	10.5±4.5	28.5±10.5	0.01	0.08
	F. spathulifolia	H	2	16.5±7.5	27.8±0.8	0.01	
	F. stricta	H	5	7.0±6.6	27.3±8.7	0.24	
	F. stupenda	H	5	24.0±21.3	25.2±11.2	0.24	0.12
	F. subcordata	H	1	11.0	22.0	0.05	0.08
	F. subgerderi	H	2			0.01	0.4
	F. sundaica	H	4	37.8±33.9	37.7±4.8	0.19	
Urostigma	*F. caulocarpa*	H	2	53.5±46.5	17±10	0.01	0.02
	F. virens	H	1	50.0	26.0	0.05	0.05
total of H	18 species		44			2.13	2.99

Continue on next page

***Table 1**. Continued*

Ficus						
Ficus						
Frutescentiae	*F. deltoidea*	C	1			0.05
Synoecia						
Kissosycea	*F. punctata*	C	2	12.0		0.10
Rhizocladus						
Punctulifoliae	*F. spiralis*	C	1	1.5	21.5	0.05
Trichocarpeae	*F. trichocarpa*	C	1	7.0	25.0	0.05
Sycidium						
Palaeomorphe	*F. tinctoria gibbosa*	C	2	4.5±1.5	19.0±3.0	0.10
Sycomorus						
Sycocarpus						
Sycocarpus	*F. beccarii*	S	1	1.0	3.0	0.05
	F. treubii	T	1	25.0	6.0	0.05
	F. uncinata	S	1	11.0	7.0	0.05
Sycomorus						
Sycomorus	*F. variegata*	T	1			
- -	unidentified spp	H/C	15			
Total	27 species		55 (70)			2.66 (3.43)

a: H, hemi-epiphyte; C, climber; S, shrub; T, tree

b: 20.7ha

c: 120 ha, only hemi-epiphytes at Lambil Hills National Park. Harrison et al. (2003)

Table 2. Attributes of *Ficus* species detected in each habitat. The numbers in parentheses in the N column indicate surveyed area.

growth form	species	N		fig size index
		young (8.1 ha)	old (12.6 ha)	
H				
	F. binnendijkii		2	4.0
	F. callophylla		2	0.6
	F. consociata	1	2	2.9
	F. delosyce		1	0.4
	F. dubia		2	7.9
	F. globosa		1	4.2
	F. kerkhovenii		6	1.6
	F. microcarpa	1		0.7
	F. pellucido-punctata		2	2.1
	F. pisocarpa	1	1	1.4
	F. spathulifolia		2	0.4
	F. stricta	2	3	2.5
	F. stupenda	2	3	42.5
	F. subcordata	1		15.8
	F. subgerderi		2	1.3
	F. sundaica	1	3	2.7
	F. caulocarpa	1	1	0.3
	F. virens		1	0.5
C				
	F. deltoidea		1	0.1
	F. punctata	1	1	56.1
	F. spiralis	1		0.4
	F. trichocarpa	1		2.5
	F. tinctoria gibbosa		2	-
S				
	F. beccarii	1		-
	F. uncinata		1	0.8
T				
	F. treubii	1		-
	F. variegata	1		3.8
	unidentified spp.	3	12	
	Total species	**14**	**20**	
	Total N	**19**	**51**	
	density (ha^{-1})	**2.35**	**4.05**	

Density (individuals/ha), including unidentified species, was 2.35 and 4.05, (total 3.43), in young forest and old forest, respectively. There was no significant difference in density between the two habitats (p=0.11), although the density in the old forest tended to be higher than that in the logged forest. The Jaccard similarity index between the species composition of the two habitats was 0.75. The fig size index was 11.0±5.1 (mean±SD) in the young forest, while that in the old forest was 7.2±3.6 (Figure 2). There was no significant difference in fig size index between the two habitats (p=0.14).

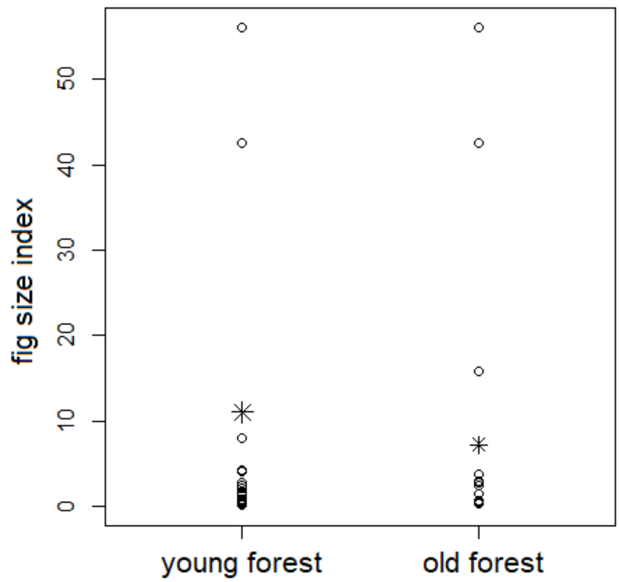

Figure 2. Fig size index of the two habitats. Asterisks indicate mean values.

Table 3. Attributes of the host trees of hemi-epiphytic and climber *Ficus* species

Family	species	N	%	DBH ± SD (cm)	family N	family %
Achariaceae	*Ryparosa acuminata*	1	2.7	30.0	1	2.7
Calophyllaceae	*Calophyllum* spp.	2	5.4	42.0±21.0	2	5.4
Dipterocarpaceae					24	64.9
	Dipterocarpus spp.	4	10.8	93.3±20.5		
	Dryobalanops lanceolata	1	2.7	170.0		
	Parashorea spp.	2	5.4	80.0±30.0		
	Shorea johorensis	1	2.7	68.0		
	Shorea pauciflora	3	8.1	176.7±17.0		
	Shorea platyclados	5	13.5	161.7±12		
	Shorea spp.	6	16.2	131.7±43.7		
	Vatica oblongifolia	1	2.7	170.0		
	Vatica sp.	1	2.7	180.0		
Fagaceae	*Lithocarpus* spp.	3	8.1	63.3±18.9	3	8.1
Lauraceae	*Eusideroxylon zwageri*	3	8.1	53.3±11.8	3	8.1
Myrtaceae	*Decaspermum fruticosum*	3	8.1	30.0	3	8.1
Rubiaceae	*Neonauclea* sp.	1	2.7		1	2.7
	Total	37	100.0	93.1±55.4		100

We found 37 host trees belonging to seven families (Table 3). Due to the small sample size of identified host trees (n=5), we excluded host species or genus from the analysis. The most common host was the genus *Shorea* of the Dipterocarpaceae, which accounted for 40.5% of all host trees. Family Dipterocarpaceae accounted for 64.9%, followed by Fagaceae, Lauraceae, and Myrtaceae (all 8.1%). The DBH of the host trees was 93.1±55.4 cm (mean±SD), but 40 to 50 cm was the most common size in both habitats (Figure 3). The DBH in the young and old forests was 51.1±30.5 cm (mean±SD, n=10) and 111.2±59.2 cm (n=32), respectively. The DBH of non-host trees in young and old forests was 17.9±19.6 (n=39) and 33.0±41.8 (n=284). There were significant differences between the DBH of host and non-host trees in both young ($p < 0.01$) and old forests ($p < 0.01$), as well as between those of host trees in young and old forests ($p < 0.01$) (Figure 4).

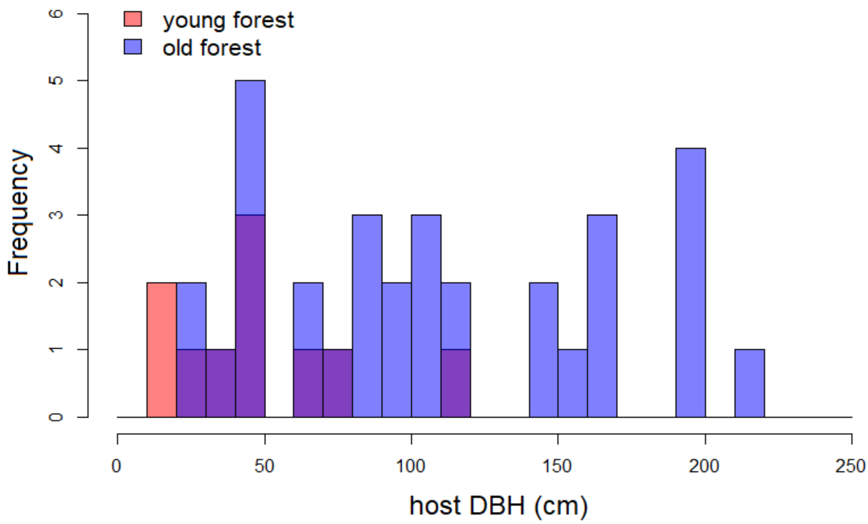

Figure 3. Distribution of DBH of the host trees. Overlapped areas show different colour (purple).

The GLMM analysis showed that the size (DBH) of hemi-epiphytic species was affected by the DBH of host trees, habitat type, and colonisation height, with an AIC value of -354.5, followed by the model with height as its fixed effect, with an AIC value of -351.1. The third best model was the null model, with an AIC value -347.6. The species did not affect the DBH of hemi-epiphytes. Only the DBH of host trees was a significant fixed effect in the best model according to the Wald test, but the colonisation height was marginally significant (Table 4).

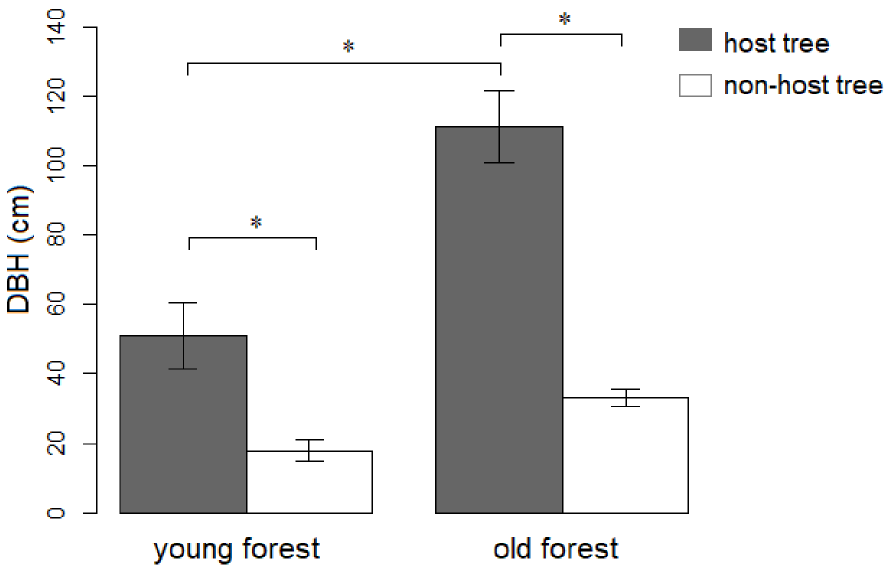

Figure 4. DBH of the host trees of hemi-epiphytic and climber *Ficus* species and non-host trees in the two habitats (mean ± SE). Asterisks indicate significant differences ($p < 0.01$).

Table 4. Attributes of the best model of the GLMM analysis on the DBH of the hemi-epiphytic *Ficus* species

parameter	coefficient±SE	t-value	p value
intercept	0.41±0.19	2.22	0.03
young forest	0.08±0.15	0.56	0.58
colonisation height	0.01±0.001	1.76	0.07
DBH of host tree	-0.004±0.001	-2.9	0.004

Discussion

Although the species diversity and richness around Batu Timbang Research Station (BTRS) cannot simply be compared with other sites, because of the short survey period (six days) and small area surveyed (20.7 ha), we found quite a diverse range of *Ficus* species, especially those belonging to subsection Conocycea, which comprises only hemi-epiphytic species (Table 5). The density of hemi-epiphytic species in the BTRS, in terms of both species and community level, and the *Ficus* species richness around the BTRS during the study period, were basically the same as seen at other sites on Borneo, except for the subgenus *Ficus* (Table 5). These results indicate that the *Ficus* species richness and density of hemi-epiphytic species found around the BTRS is very common on Borneo (Table 1, 5).

Table 5. *Ficus* species richness in five sites on Borneo. GP, Gunung Palung National Park; KP, Kutai National Park; MK, Mount Kinabalu National Park; LH, Lambir Hills National Park. Data from Laman & Weiblen (1998).

subgenus and section (N species on Borneo)	GP	KP	MK	LH	Batu Timbang
survey effort	1996 & 1997	-	3.5 months	120 ha	6 days 20.7 ha
Urostigma					
Urostigma (5)	1	2	2	1	2
Conosycea (36)	27	23	16	19	16
Malvanthera (1)	0	0	0	0	0
Pharmacosycea					
Oreosycea (5)	0	1	0	0	0
Sycomorus					
Sycomorus (3)	0	1	0	0	1
Ficus	28	25	60	34	8
Total	56	52	78	54	27

Based on the high value of the Jaccard similarity index, the young and old forest habitats had similar *Ficus* species composition. The density and fig size did not differ between the two habitats, and species producing large figs (*F. punctata* and *F. stupenda*) were found in both habitats. There were relatively young individuals of *F. stupenda* in both young (DBH = 4 cm) and old (7 cm) forests, and therefore the seed dispersal system of large fig species is working in these areas, regardless of their logging history. Habitat degradation by logging can negatively affect most animals, including important seed dispersers such as hornbills (Meijaard et al. 2005), but some animals, for example palm civets (Nakabayashi et al., 2014), take advantage of the higher levels of light in these habitats in terms of the food resources available, such as flowers, fruits, new leaves and herbivorous insects (Fowler et al., 1993). Such animals are important seed dispersal agents in degraded habitats (Corlett, 2017). The similar species composition and lack of differences in tree density and fig size between the young and old forests in the BTRS indicate that, in this area, animals act as seed dispersal agents for *Ficus* species, including large-fig species.

Dipterocarpaceae comprised the most common hosts in the BTRS area; this result is consistent with results from other study sites (Harrison et al., 2003). Several studies have indicated that DBH is the most important host factor for some hemi-epiphytic *Ficus* species, rather than bark roughness or host species (Laman, 1996, Harrison et al., 2003), and the results of the present study corroborate this pattern, as the size of host trees (DBH) was significantly larger than that of non-host trees in both habitats. Although preferred host size varies among hemi-epiphytic species (Laman, 1996), we were unable to assess this because of the small sample size. Host size seems to be determined by relative tree size in a given environment, because the host DBH in the old forest was significantly larger than that in the young forest (Figure 3, 4), and there was a similar species composition between the two habitats. The results of the current study suggest that even in recently logged forests, host-dependent species depend on relatively large trees rather than specific species as their host. Considering that habitat type (old or young forest) did not affect density or species composition in the BTRS area, it appears that host-dependent species can colonise relatively disturbed habitats if there are suitable potential host trees and seed dispersal agents.

The size (DBH) of host-dependent species was negatively affected by the DBH of host trees. This result indicated that host-dependent species grow well when they colonise relatively small host trees. Water stress is the critical limiting factor for the germination of hemi-epiphytic *Ficus* species seeds, but once they are established on their hosts, the level of light is the most important factor for seedling growth (Laman, 1995). Although not significant, the parameters of young forest and colonisation height were selected as the fixed effects of the best model (Table 4), and both of these factors are linked to a high level of light. Other than light level, physical factors of large hosts might also affect the size of host-dependent species, especially hemi-epiphytes. Once the aerial roots from epiphytic hemi-epiphytes reach the ground, they begin to thicken. They then usually produce horizontally growing roots around their host tree to increase their physical support (Putz & HolBrook, 1986). When hosts are large, they may consume energy to obtain horizontal support, inhibiting diameter growth. Our results suggest that logging history would not strongly affect the growth of hemi-epiphytes across species, and that their growth is dependent on host size.

Conclusion

The results obtained in this study indicate that *Ficus* species, particularly hemi-epiphytes, can survive in degraded habitats that have recently been logged as well as in undegraded forests, and that their growth is not greatly affected by prior logging activities. Thus, this genus exhibits both flexibility and adaptability to habitat change. This indicates that *Ficus* species make ideal plants for the restoration of logged forests. In an Indian agricultural mosaic landscape, sapling density and species richness of plants growing under isolated *Ficus* trees was higher than under non-*Ficus* trees (Cottee-Jones et al., 2016). Successful seed dispersal is one of the critical factors that limits tropical forest restoration (Wunderle Jr 1997, Cole et al., 2010, Holl et al., 2013). Figs are an important food resource for numerous animal species (Shanahan et al., 2001) and can promote seed dispersal of other plants by attracting these animals into degraded habitats. However, the present study was based on a short-term survey; therefore, more long-term, fundamental studies in this area are needed to obtain a greater understanding of the ecology and ecological roles of *Ficus* in this region and on Borneo as a whole.

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Review Article

Biological and therapeutic potential of the edible brown marine seaweed *Padina australis* and their pharmacological mechanisms

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Abstract

Seaweeds have an important place in the ancient systems of medicine. In addition, they also find significant mention in farming and in nutritional diet due to their benefits such as, availability, cheaper price, renewable potential and the advantage of being easily accessible. There are over 10,000 species of seaweeds that reflect their immense diversity. They are further used for both, their flavour and nutritional properties. Edible seaweeds are rich sources of bioactive compounds. In the last three decades, the discovery of metabolites with biological activities from macroalgae has increased significantly. *Padina australis* has been reported to possess several therapeutic activities including, antioxidant, anti-inflammatory, antibacterial and larvicidal effects. In addition, studies have also reported on the antidiabetic and antihypertensive potential of *Padina australis*. Till date, there are limited or no scientific reviews that have been published on the pharmacological and therapeutical activities of *Padina australis* in specific. Thus, there is a need for such a review to appreciate the various biological actions of this potent seaweed.

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This review, in this direction, attempts to explore the various therapeutic activities of the brown marine seaweed *Padina australis*, from the current published literature along with their pharmacological and molecular mechanisms, underlying its therapeutic activities. The main limitation of this review is that ancient texts, leisure magazines and traditional manuscripts were not searched.

Keywords: *Padina australis*, seaweed, antibacterial, antioxidant, anti-inflammatory, larvicidal, anti-diabetic

Introduction

The inefficiency to contain deadly diseases has stimulated the urgent need for the identification and discovery of effective newer substances from nature and plant sources. From the current natural resources, the marine landscape has a great potential for medicinal drug discovery and investigation (Chandini et al., 2010). Seaweeds occupy a major proportion of the edible substances and they are employed very often in South East Asian diet. They are also used as therapeutic agents for various ailments. Marine seaweeds and their organic extracts are known to contain a variety of bioactive substances with diverse health benefits. There are large libraries of chemical compounds that have been isolated and characterised from marine herbs and seaweeds. There is a huge variation among the amount and quality of the chemical substances present in a specific species of seaweed owing to their habitat and location of existence. These also depend on geographical origin or area of cultivation. The other factors that affect the chemical and nutritional constituents are harvest season, environmental variations, physiological variations and water temperature (Ortiz et al., 2006). There is a renewed and increasing interest towards herbs and weeds from the sea in the past few decades. This is primarily due to the vast array of biomolecules that are present within them. Plenty of studies have been carried out on several seaweeds, which have proven to possess potential therapeutic activities ranging from free-radical scavenging to regulating inflammation in body tissues. Recent studies in the field of medical and pharmaceutical research have revealed promising compounds, isolated from marine seaweeds. A recently published study highlights the importance of seaweeds from oceans namely, from the genus Padina, which could be employed as an additional source in the manufacture of silver Nano substances, which can be eventually employed therapeutically for various bacterial infections (Bhuyar et al., 2020a). Although, some of the seaweeds are toxic in nature, there exist a large number of seaweeds that have exhibited enormous potential as therapeutic or medicinal substances. A range of bioactive group of compounds are found in these seaweeds, which range from flavonoids, sugars, fats, and amino acids. These substances have been proven to demonstrate several activities in the biological system. Moreover, these are also used in the development of new pharmaceutical agents. Thus marine seaweeds occupy an important place as a source of rich bioactive compounds (Manilal et al., 2010). A recent study reported the free-radical scavenging and antibacterial potential of the red seaweed, *Kappaphycus alvarezii* when evaluated against several strains of harmful bacteria (Bhuyar et al., 2020b). The Malaysian marine ecosystem is unique and understudied compared to other marine ecosystems. Brown macroalgae species are constantly reported as potential sources of bioactive compounds with various therapeutic effects. For example, *Padina australis* which is a member of the Phaeophytes has shown potential antibacterial effects due to the presence of its bioactive compounds.

Marine brown algae along the coast of Malaysia have remained largely unexploited. Therefore, it is worthwhile to review the various therapeutic effects of the marine seaweed *Padina australis*. This review strives to provide a detailed account of all the current knowledge on the therapeutic effects of *Padina australis* which is found abundantly in Malaysian coastal waters.

Seaweeds have been widely used in pharmaceutical and food industries for decades due to its renewable properties. There are around 10,000 species of seaweeds found worldwide and they are all classified into three major classes which are red algae (Rhodophytes), brown algae (Phaeophytes) and green algae (Chlorophytes) (Mohsin et al., 2013). Seaweeds can be easily found all around the world, especially in Asian countries such as Japan, Philippines, Korea, Malaysia and Indonesia (Wang et al., 2013). Among the three major classes of seaweed, brown algae appear to be a popular food in Japan, Korea and China because seaweed is part of their main diet and they take it daily in most of their meals (Yan et al., 2007). Besides playing a significant role in the Asian diet and food substances, the brown algae also functions as an antioxidant that helps in preventing degenerative diseases such as cancer or cardiovascular disease by neutralizing the free radical mechanism (Yan et al., 2007; El Gamal, 2010). Furthermore, the brown algae has also been studied for its antibacterial effect which is shown through the inhibition of the growth and activity of the bacteria (bacteriostatic) or by destroying the bacteria (bactericidal). For example, *Padina australis* which is a member of the Phaeophytes had shown potential antibacterial effects due to the presence of several bioactive compounds. Moreover, the bioactive compounds of Phaeophytes have shown to have larvicidal effects (Canoy & Bitacura, 2018).

The aims of this study were to look out the functions of components extracted from *Padina australis*.

Morphology of the plant

Padina australis (Figure 1.) belongs to the Dictyotaceae family which is edible brown algae (Yan et al., 2007) *Padina australis* is a broadly flabellate plant with a stupose holdfast. *Padina* is the only genus of brown algae which is calcified. Both surfaces of the thallus are lightly calcified, especially at the stipe (Wang et al., 2013).

Figure 1. External morphology of *Padina australis* Hauck. (Dictyotaceae)

The erect thalli are flabelliform with a diameter up to 15cm. Its thalli are yellowish green to yellowish brown in colour. Besides, the thalli can also be divided into many segments. The thalli of *Padina australis* have bilayer thickness of an approximate of 11 µm to 120 µm thick at the base and 95 µm to 100 µm at other parts. The stipe is moderately long with a length of 2cm and width of 3mm (Szlachetko et al., 2014). Phaeophycean hairs are found alternatively on both sides of the thallus along the stipe in concentric rows, with the outer cortical origin of growth. *Padina australis* is found to grow in the deeper sublittoral region, attached on rocks, corals or sands and sometimes seen epiphytic on the other microalgae. This species grows mainly in tropical and subtropical waters instead of temperate waters (Tronholm, Leliart & Sanson, 2012). *Padina australis* has two types of sori which are the non-indusiate antheridial sori that form patches mixing between the oogonial sori and the indusiate oogonial sori which form discontinuous lines. Both of the sori lined up continuously far adjacent to the hairlines on the inferior surface. The reproductive sori are located at the middle of the narrow glabrous zone, normally on the lower blade surface (Szlachetko et al., 2014). The locality of this plant is in Cape York, Queensland, Australia. The presence of *Padina australis* is distributed worldwide which it can be found in most Asia countries like Indonesia, Philippines, Thailand, Japan, Taiwan and others. Besides Asian countries, it can also be found in Ivory Coast, Cameroon, Gabon and Angola of West Africa, Hawaiian Islands of the Pacific Islands and also Queensland of Australia (Wang et al., 2013).

Taxonomical classification

Table 1. Taxonomical classification of *Padina australis*

Kingdom	Chromista
Phylum	Ochrophyta
Class	Phaeophyceae
Order	Dictyotales
Family	Dictyotaceae
Genus	*Padina*
Species	*Padina australis*

Therapeutic activities of Padina australis

Antibacterial

Antibiotics have been widely used to treat or cure bacterial disease in aquaculture. However, the use of antibiotics may cause the development of antibiotic-resistant bacteria and toxicity to the environment due to the misuse or overuse of antibiotics (Lee, 1995). Therefore, the use of seaweeds in preventing and treating bacterial disease had gradually increased because seaweeds are cheap and renewable sources that we can obtain easily from nature. Thus, seaweeds can be used as an antibacterial agent with greater effectiveness, minimal adverse effect, better bioavailability and are less toxic. The production of secondary metabolites in seaweeds are varied according to environment changes such as geographical location, light, temperature, species, maturity and seasons (Perez, Falque & Dominguez, 2016). The secondary metabolite found in *Padina australis* which possess antibacterial activity includes phenol and its derivative. Flavanoid is a derivative of phenol which can act against gram-positive bacteria (*Bacillus cereus* and *Staphylococcus aureus*) and gram-negative bacteria (*Escherichia Coli* and *Pseudomonas aeruginosa*) (Chkhikvishvili & Ramazanov, 2000). The phenolic extracts of *Padina australis* inhibit the growth of bacteria by damaging the cytoplasmic membrane and thus leads to the leakage of cell contents. The hydrogen ion of phenol and flavonoids attack the phosphate group and this leads to the breakdown of phospholipid molecules of the bacteria's cell well into carboxylic acid, glycerol and phosphoric acid. As a result, the growth of bacteria is retarded and eventually dies (Chkhikvishvili & Ramazanov, 2000).

There are many methods to evaluate the antibacterial activity of the metabolites of seaweeds. Normally, the studies on the antibacterial activity of seaweeds are either only in vivo or only in vitro, but sometimes in vitro screening will be conducted first and then followed by an in vivo study (Chkhikvishvili & Ramazanov, 2000). The *in vivo* assays are rarely used to screen the antibacterial activity of the seaweeds as there are many restrictions in *in vivo* studies. While for in vitro studies, agar disc diffusion test, growth inhibition assay, minimum inhibitory concentration (MIC) determination and minimum bactericidal concentration (MBC) are included (Perez, Falque & Dominguez, 2016). The disc diffusion test can only give the qualitative result as the size of the inhibition zone can be affected by molecular size, molecular mass and polarity of the extracts. In comparison, MIC and MBC assay are more important to give quantitative result on the antibacterial activity of the extracts (Perez, Falque & Dominguez, 2016). MIC is used to investigate the bacteriostatic concentration of the seaweed extracts while MBC assays are used to determine the bactericidal concentration of the seaweed extracts against the respective pathogenic bacterial strains. Hence, the lower the MIC and MBC values, the higher the antibacterial potential of the seaweed extracts (Vinayak, Sabu & Chatterji, 2011).

Padina australis has shown its inhibition against beta-lactamase negative *E. coli* ATCC 25922, *Pseudomonas aeruginosa, Staphylococcus aureus* and *Bacillus cereus*. The percentage of the inhibition of *Padina australis* extracts against *Escherichia coli* ATCC 35218 is 77.78% and this result is obtained through the disc diffusion susceptibility testing. The lowest MIC value for *Padina australis* extracts against *Escherichia coli* ATCC 25922, *E. coli* ATCC 35218, *Pseudomonas aeruginosa, Staphylococcus aureus* and *Bacillus cereus* were

0.833, 1.677, 0.261, 0.417 and 0.130 mg/ml respectively. Besides, the methanolic extracts of *Padina australis* have shown the lowest MBC value (0.182 mg/ml) when compared to the dichloromethane and n-hexane extracts against *Bacillus cereus*. The results showed that the MBC values are greater than the corresponding MIC values which indicates the bactericidal effect of the *Padina australis* extracts can only be exhibited when a higher amount of extracts is used. Since *Padina australis* only exhibited its bactericidal potential on Bacillus cereus, so this implies that *Padina australis* has narrow-spectrum antibacterial activity (Chkhikvishvili & Ramazanov, 2000).

Padina australis is proven to possess bacteriostatic and bactericidal activity towards the gram-positive and gram-negative bacteria by damaging the cytoplasmic membrane of the bacteria. However, *Padina australis* is an antibacterial agent with narrow spectrum bactericidal activity which only acts against one specific type of bacteria (Chkhikvishvili & Ramazanov, 2000).

Antioxidant

Reactive oxygen species (ROS) molecules or ions formed by the incomplete one-electron reduction of oxygen and ROS plays a significant role in regulating the signal transduction, microbial activity of phagocytes and gene expression. However, excessive production of ROS by endogenous or exogenous factor may lead to the formation of oxidative stress, loss of cell function and ultimately apoptosis and necrosis. Therefore, it is important to maintain the balance between the free radical productions and the antioxidant defences in the human body as this balance is vital for the cell function, regulation and adaptation to diverse growth conditions and health condition (Vinayak, Sabu & Chatterji, 2011).

In humans, there are two types of defence against free radical damage, the first line defence is formed by the enzymes such as superoxide dismutases (SOD), catalases (CAT), glutathione peroxidases (GPX) and small molecules antioxidants like ascorbic acid, tocopherol and uric acid, while the presence of the antioxidants will be responsible for the second line defence (Vinayak, Sabu & Chatterji, 2011).

Over the years, seaweed and its extract have generated a huge interest in the pharmaceutical industry as a fresh source of bioactive compound with immense medicinal potential. Seaweeds are rich in antioxidant compounds such as carotenoids, polyphenols, pigments, enzymes and diverse functional polysaccharides. Among all the antioxidants found in seaweeds, polyphenols are found abundantly, especially in brown seaweeds (Phaeophyte) (Mandal et al., 2011). The seaweed polyphenols are also known as polytannins. They are a heterogeneous group of molecules that display a broad range of biological activities. These polyphenols are a class of powerful chain-breaking antioxidant which have the ability to scavenge ROS, inhibit lipid peroxidation and chelate the metal ions (Rice-Evans et al., 1995; Kahkonen et al., 1999; Duthie & Crozier, 2000; Vinayak, Sabu & Chatterji, 2011). The concentration of the phenolic compound is also shown as having a linear correlation with the antioxidant activity according to Stankovic *et al* (Chkhikvishvili & Ramazanov, 2000) Thus, high antioxidant activity can be shown in seaweeds such as *Padina australis* that has high phenolic content (Li et al., 2017).

ROS scavenging activity, metal ion chelation, ability to inhibit lipid peroxidation and maintenance of endogenous defence systems of poly phenols accounts for the high antioxidant activity of *Padina australis* (Figure 2).

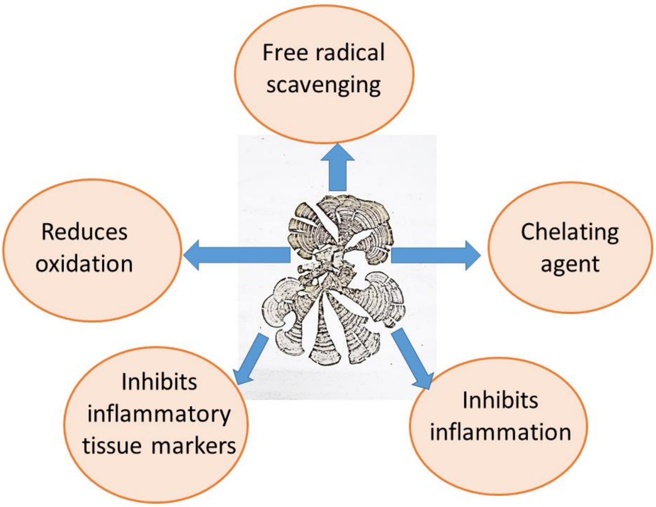

Figure 2. Different antioxidant mechanisms of *Padina australis*

To test the antioxidant activity in seaweeds, 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) assay is used in which the antioxidant activities can be measured quantitatively based on the intensity of the purplish colour of the DPPH compound (Li et al., 2017). The effects of the antioxidant compound on the DPPH radical scavenging is due to the hydrogen donating ability and this is shown when DPPH solution is mixed with a substrate as a hydrogen atom donor and a stable non-radical form of DPPH will be obtained with a simultaneous change of the DPPH solution from purple to yellow colour (Kedare & Singh, 2011; Araújo, 2017). The equation below shows the correlation between the decreasing intensity of the purplish colour of the DPPH and the antioxidant activity (Li et al., 2017):

$$DPPH^{*} \quad + \quad AH \quad \rightarrow \quad \text{DPPH-H} \quad + \quad A^{*}$$

Free Radical Purplish Colour	Antioxidant	Neutral Yellow Colour	New Radical

A study used the DPPH method to test the antioxidant activities among 20 types of seaweed extracts that included 7 Chlorophyta (green algae), 9 Phaeophyte (brown algae) and 4 Rhodophyta (red algae). The results showed that *Padina australis* (Phaeophyta) as having the highest antioxidant activity of 53.3% among the other 19 seaweed extracts (El Gamal, 2010). Besides that, there is presence of antioxidant activity in *Padina australis* as there is reaction shown by its antioxidant compounds in scavenging the free radicals of the DPPH solution (Kedare & Singh, 2011).

Padina australis is shown to have potent antioxidant activities playing a role in delaying or preventing the oxidations of cellular oxidizable substrates and selectively inhibiting the ROS cascade events (Kedare & Singh, 2011). Apart from that, it can also help prevent degenerative diseases such as cancer and tumour or aging (Farasat et al., 2013).

Anti-inflammatory

Inflammation response can be triggered by infection, tissue damage or disruption of immune response and this process is usually followed by the release of inflammatory mediators (Guzmán-Álvarez et al., 2012; Thomas & Kim, 2013). Prostaglandin and leukotriene are potent mediators of inflammation that cause pain, oedema and vasodilation and all these conditions are derived from the arachidonic acid metabolism by cyclooxygenases (COXs) and lipoxidases (LOXs) respectively. Both COXs and LOXs play a significant role in modulating the inflammatory and allergic immune response by catalysing the oxygenation of n-6 polyunsaturated fatty

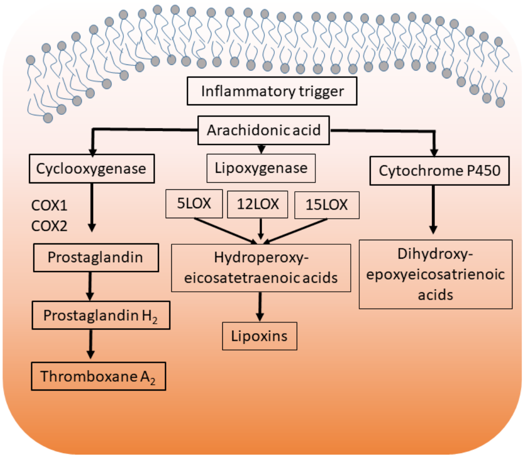

Figure 3. Inflammatory pathways in biological tissues

acid to form the biologically active prostaglandin and leukotriene metabolites (Tilley, Coffman & Koller, 2001). In order to relieve the swelling and pain caused by the inflammation, non-steroidal anti-inflammatory drugs (NSAIDs) are used nowadays. However, NSAIDs have been reported to cause some side effects such as the formation of stomach ulcer if NSAIDs is used frequently. Thus, it is imperative to target naturally renewable sources to relieve the inflammation or inflammation-induced oxidative stress so that it can reduce NSAIDs usage and hence decrease the adverse effects caused by the usage of NSAIDs (Mhadhebi, Mhadhebi & Robert, 2014).

Arachidonic acid (AA) exists in the cell membrane in the form of phospholipids. When the cell membrane is subjected to stimuli, especially the inflammatory reaction, the phospholipids are released from the cell membrane (Figure 3). Through the hydrolysis of phospholipids by Phospholipase A2(PLA2) and Phospholipase C(PLC) AA is released and then transformed into a bioactive metabolite with the help of different enzymes, thus promoting inflammatory cascades. Abundant resources of bioactive substances such as polyunsaturated fatty acids and fucoxanthin in *Padina australis* act as a competitive inhibitor of COXs or LOXs in the inflammatory reaction and lead to a decrease in the production of prostaglandins and leukotriene.

Among the natural renewable resources, seaweed extracts are reported as a potent inhibitor of COXs and LOXs in which a decreased effect in the production of inflammatory prostaglandins and leukotrienes are shown (Mhadhebi, Mhadhebi & Robert, 2014). There are also several studies showing that brown seaweeds have anti-inflammatory effects in the presence of sulfate polysaccharides, polyunsaturated fatty acids (PUFA) and fucoxanthin (Barbosa, Valentão & Andrade, 2014). These compounds found in the seaweed extracts may act as a competitive inhibitor of COXs or LOXs in an inflammatory reaction and later lead to a decrease in the production of prostaglandins and leukotrienes (James, Gibson, & Cleland, 2000; Kang, Khan & Park, 2008).

A study reported the testing of the anti-inflammatory effect of *Padina* species and *Sargassum* species through the increase in volume of the mice feet after the injection of brown algae extracts and inflammation inducer (Thomas & Kim, 2013). The results showed a significant increase in the percentage of inflammation from the 1st to 4th hour after the injection of inflammation inducer and both the test groups, *Padina* species and *Sargassum* species. Among the two species of brown algae, *Padina* sp. shows a higher anti-inflammatory effect as compared to the *Sargassum* species because the inflammatory inhibition effect of the *Padina* sp. lasted for three hours while the *Sargassum* species only lasted for two hours. This indicates that the *Padina* species is a better anti-inflammatory agent with a longer half-life than *Sargassum* species (Thomas & Kim, 2013). There is also a high negative correlation shown between total phenolic content and COX_{μ} and LOX_{γ} inhibition value and this means that all compounds except the phenolic-like polysaccharides present in *Padina* species are considered as a good inflammatory agent (Mhadhebi, Mhadhebi & Robert, 2014).

Padina species has the potential to be used as a remedy in treating the inflammation-related symptoms and is a green natural alternative that is free from the adverse effect of NSAIDs (Kang, Khan & Park, 2008; Mhadhebi, Mhadhebi & Robert, 2014).

Larvicidal

Mosquito plays a vital role in the transmission of pathogen and parasites such as dengue, yellow fever, malaria, filariasis and other diseases which can be fatal to humans (Ali, Ravikumar & Beula, 2013). According to WHO, the cases of mosquito-borne diseases have gradually increased from year to year with statistics showing there were more than 1 million people who had died from mosquito-borne diseases (Yu, Wong & Ahmad, 2015). Dengue is one of the widespread mosquito-borne viral infection in the tropical and subtropical regions all around the world (Roni et al., 2015). In Malaysia, the numbers of dengue deaths had increased up to 56% in 2015 as compared to 2014 (Yu, Wong & Ahmad, 2015). There are four types of serotype in dengue, and these are DENV-1, DENV-2, DENV-3 and DENV-4, but there is still no vaccine developed for the prevention of dengue (Yung, Lee & Thein, 2015).

Aedes aegypti and *Aedes albopictus* mosquitoes are the main vectors in spreading viral diseases such as dengue fever, yellow fever and chikungunya. Humans get infected after getting bitten by an infected female Aedes mosquito (Yu, Wong & Ahmad, 2015; Yung, Lee & Thein, 2015). It is essential to control the breeding of mosquitoes using organochlorine, organophosphate and carbamate larvicide or insecticides to kill mosquito (Salvador-Neto, Gomes & Soares, 2016). However, the excessive use of synthetic insecticides can cause toxicity to the environment, humans and other living organisms. The mosquitoes will also become resistant to the insecticides due to repeated use (Murray, Quam & Wilder-Smith, 2013). Many researchers found that marine halophytes such as seagrass, seaweed and mangrove are a group of plants that can adopt high saline conditions and they have been used in many therapeutic applications (Ali, Ravikumar & Beula, 2013; Ishwarya et al., 2018). According to Yu et al., 42 extracts and 13 bioactive compounds of the seaweeds have been found to act as an effective larvicide which can be used to replace chemical insecticides (Yu et al., 2015).

A separate study showed that the methanol extract of *Padina australis* possesses larvicidal activity with LC_{50} values between 200 to 500 µg/ml on the swimming behaviour of *Aedes aegypti* and *Aedes albopictus*. The mosquito larvae will undergo three phases after treated with *Padina australis* extracts. The larvae showed abnormal restlessness, wiggle flying movement, sudden sinking and floating movement in phase 1. In phase 2, the larvae turn into inactive mode with random tremor movement at the bottom of the container and followed by the paralysis and death of the larvae in phase 3 (Yu et al., 2015)

Padina australis also showed to have adulticidal effect against mosquitoes. It showed a lethal effect with LC_{50} values 30.80 and 36.21 mg/cm^2 against female adults of *Aedes aegypti* and *Aedes albopictus* respectively. Two phases of intoxication can be observed for the female adults after treating by the seaweed extracts. The female adults showed sluggish movement and were incapable to stand still on the surface of holding the tube in phase 1. While at phase 2, the female adults were paralyzed and fell at the bottom of holding the tube and died (Ghosh, Chowdhury & Chandra, 2012). This indicates that *Padina australis* has weak adulticidal activity. It is also reported that a combination of seaweed extracts together with other commercial insecticides which is known as binary insecticide mixtures will be more effective against adult mosquitoes (Ghosh, Chowdhury & Chandra, 2012; Vaikundamoorthy et al., 2018).

Therefore, *Padina australis* has proved its larvicidal activity against *Aedes aegypti* and *Aedes albopictus*.

Anti-hypertensive

In Malaysia, a wide variation of brown seaweeds can be found distributed along the Malaysian shores. Some of the brown seaweeds such as *Padina australis, Turbinaria ornata*, *Sargassum* species and *Padina tetrastromatica* are edible. In the past, brown seaweeds had already been used as a traditional Chinese medicine for cases of hypertension as it was believed that the brown seaweeds had the ability to lower down blood pressure (Lyu et al., 2017).

Hypertension is a disease of having abnormally high blood pressure within the arteries and the blood pressure reading will be based on both systolic blood pressure (SBP) and diastolic blood pressure (DBP) (Guyton, 1991). Based on the World Health Organisation (WHO) Guidelines, Joint National Committee on Prevention, Detection, Evaluation and Treatment on High Blood Pressure recommends, one will be hypertensive if their blood pressure reading exceeds 140/90 mmHg (Chobanian et al., 2003).

It is believed that seaweeds have the ability to absorb the ionic elements of the seawater which include potassium and sodium ions due to their growing environment in the sea (Sithranga Boopathy & Kathiresan, 2010). Van Leer et al., (1995) and Chobanian et al., (2003) both reported that diets that are rich in sodium and potassium can cause reduction of blood pressure in adults because the potassium ions may counteract with the effects of the sodium ions in the human body and reduce blood pressure (Van Leer, Seidell & Kromhout, 1995; Sithranga Boopathy & Kathiresan, 2010; Gotama, Husni & Ustadi, 2018; Gómez-Guzmán et al., 2018).

A study was conducted to test the antihypertensive effect of the edible brown seaweeds found in Malaysia using spontaneously hypertensive (SHR) rats and normotensive Wistar-Kyoto (WKY) rats and treated with different types of seaweeds such as *Turbinaria ornata*, *Sargassum* species, *Padina australis* and

Padina tetrastromatica. The results show a significant blood pressure reduction ($P < 0.05$) for all the three seaweeds in the spontaneously hypertensive (SHR) rats and normotensive Wistar-Kyoto (WKY) rats. The *Sargassum* sp. shows the effect of blood pressure reduction in SHR and WKY rats while the *Turbinaria ornata* and *Padina tetrastromatica* only shows the blood reduction effect in the SHR. In contrast to the effect on blood pressure, the brown seaweeds tested did not affect the heart rate with equal degrees of potency and only Turbinaria ornata was able to produce bradycardia effect in SHR. From this study, it suggests that only *Turbinaria ornate* contains negative chronotropic effect substance while *Sargassum* sp., *Padina australis* and *Padina tetrastromatica* will directly act on the blood vessels and it may cause vasorelaxation, and then followed by the reduction in TPR and blood pressure (Gotama, Husni & Ustadi, 2018).

Thus, further studies on the antihypertensive effect of *Padina australis* should be conducted, so that it can be used as a folk medicine in managing hypertension (Gotama, Husni & Ustadi, 2018).

Antidiabetic

Diabetes is a hyperglycemia condition caused by the decreasing of insulin secretion and action of insulin (Akbarzadeh et al., 2018). There are more than 20 million people worldwide suffering from type-1 diabetes mellitus and this was associated with an increase of 2% to 5% each year (Groop & Pociot, 2014; Lauritano & Ianora, 2016). There are insulin injections and oral anti-diabetic agents such as thiazolidinedione, biguanide and sulfonylurea available in the market that are used to control the blood sugar level in diabetic patients (Akbarzadeh et al., 2018). However, patients are found to suffer from unwanted side effects such as toxicity, gastrointestinal symptoms and cardiovascular disease for the prolonged consumption of antidiabetic drugs. Diabetes is divided into two types, which are type 1 diabetes mellitus and type 2 diabetes mellitus. 90 to 95% of diabetes patients are suffering from type 2 diabetes (Rekha & Sharma, 2013).

Enzyme α-glucosidase and α-amylase play a vital role in the intestinal absorption and breakdown of starch respectively. The inhibition of these enzymes can reduce the postprandial increase of blood glucose level which is important for the management of hyperglycaemia (Lordan et al., 2013). Enzyme α-glucosidase which located in the brush border surface membrane of the intestinal cell is important for the breakdown of maltose into glucose. The inhibition of α-glucosidase can prevent further hyperglycaemic level in blood.

Thus, the α-amylase is important for the breakdown of starch and glycogen (Lordan et al., 2013). The antidiabetic drugs used for type 2 diabetes normally inhibit the enzyme α-glucosidase by inhibiting the digestion of carbohydrates such as starch and sugar (Akbarzadeh et al., 2018).

According to another study, the inhibitory activity of brown seaweed *Padina, Sargassum* and Tubinaria against α-glucosidase enzyme are highest in laminaran and fucoidan fraction. It can be concluded that the laminaran and fucoidan fraction are able to lower the blood sugar level in blood and can be used for type 2 diabetes. Other than that, the IC_{50} value of laminaran fraction of *Sargassum duplicatum* showed the highest inhibiting activity against α-glucoside, which is 36.13 ppm. It is then followed by the laminaran of *Turbinaria decurens* (44.48 ppm), fucoidan of *Tubinaria decurens* (63.39 ppm), fucoidan of *Sargassum duplicatum* (75.10 ppm) and alginate of *Sargassum* (115.50 ppm) and *Turbinaria* (166.45 ppm). The lower the IC_{50} value, the greater the inhibitory activity of the α-glucosidase enzyme (Akbarzadeh et al., 2018).

Moreover, the ethanol extracts of other brown algae such as *Fucus vesiculosus, Padina australis* and *Palvetia canaliculata* have shown their efficacy in inhibiting the enzymes α-amylase and α-glucosidase (Lordan et al., 2013). According to Kang et al., (2010) another brown algae *Ecklonia cava* has been proved to have antidiabetic potential by using streptozotocin-induced type 1 diabetes mellitus rats and C2C122 myoblasts. The methanolic extracts from *Ecklonia cava* can decrease the plasma glucose level significantly and increase the insulin concentration in type 1 diabetes mellitus (Kang et al., 2010). The polyphenolic compound of *Ecklonia cava* has shown its antidiabetic effect by having an insulin-like action through AMP-activated protein kinase (Lauritano & Ianora, 2016).

However, the antidiabetic uses of *Padina australis* are still to be explored in detail and there is an urgent need to find a more natural product with potential therapeutic application which can be used in the treatment of various diseases or used as adjuvant therapy.

Conclusion

Marine seaweeds have become an alternative which can be used in the medical field in many ways. *Padina australis*, which is an example of edible brown seaweed has been used in the treatment of various medical conditions.

Padina australis may be used as an antibiotic in inhibiting the growth of bacteria or killing bacteria. Studies showed that its efficacy as an antibacterial agent against *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa* and *Bacillus cereus* while it only exhibits a narrow spectrum of antibacterial activity towards *Bacillus cereus*. Besides, the bioactive compound and extracts from *Padina australis* also exhibit an antioxidant effect by selectively inhibiting the ROS cascade events. In this case, DPPH assay is used to test the antioxidant activity of *Padina australis* extract which a colour change of the DPPH solution from purple to pale yellow colour observed. The usage of NSAIDs in treating inflammation has been gradually replaced by the usage of *Padina* species due to its greater anti-inflammatory effect when compared to *Sargassum* species. Moreover, *Padina australis* has been proved to possess larvicidal effect against *Aedes aegypti* and *Aedes abloppictus* by effectively killing the female adults and larvae of these mosquitoes. Although some studies conducted have shown *Padina australis* have the ability to lower down blood pressure and blood glucose level, however, the results are still counteracted due to limited research data. We hope that more research can be done on *Padina australis* to find out more of its functions and offer new medical knowledge in treating different diseases in the future. This, in turn, can replenish the shortage of some medicines in the treatment of diseases by replacing these with renewable seaweeds.

Data Availability and Ethical Statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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List of abbreviations

1. DPPH: 1,1-diphenyl-2-picrylhydrazyl radical
2. CAT: Catalase
3. COXs: Cyclooxygenases
4. GPX: Glutathione peroxidase
5. LOXs: Lipoxidases
6. MBC: Minimum bactericidal concentration
7. MIC: Minimum inhibitory concentration
8. NSAIDs: Non-steroidal anti-inflammatory drugs
9. ROS: Reactive Oxygen Species
10. SOD: Superoxide dismutase

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Research Article

The occurence of *Croton bonplandianus* in Java and a new record of *Caperonia palustris* for Malesia Region

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Abstract
Two noteworthy species belongs to the Euphorbiaceae, namely *Caperonia palustris* and *Croton bonplandianus*, have been recently collected from Java Island, West Malesia. The discovery of *C. palustris* is a new record for Malesia region, while *C. bonplandianus* is considered as a newly recorded alien species to the Flora of Java. *Caperonia palustris* is characterized by the glandular and non-glandular hairs on its stem and petiole, triangular to lanceolate or subulate stipules, and leaves in ovate-oblong or elliptic-oblong to lanceolate shape. *Croton bonplandianus* differs from the previously reported species in Java, *C. hirtus*, by its non-irritating hairs on the stem, sessile basal leaf glands, leaf margin with simple serration, and ellipsoid fruit. Descriptions and a brief discussion are given.

Keywords: *Caperonia*, *Croton*, Euphorbiaceae, Java, Malesia

Introduction
According to the classification system proposed by the Angiosperm Phylogeny Group, Euphorbiaceae *s.l.* has been separated into Euphorbiaceae *s.s.*, Phyllanthaceae, Peraceae, Picrodendraceae, Pandaceae and Putranjivaceae (APG IV, 2016). Euphorbiaceae *s.s.* is the largest segregate family and mainly distributed in the tropics. The family comprises 225 genera and more than 6,300 species in the world (Challen, 2015).

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Morphologically, the family has a superior ovary, then usually 3-locular with a single ovule per locule, and the fruit usually a dehiscent schizocarp with persistent central columella (Byng, 2014; Challen, 2015).

The information on the Euphorbiaceae *s.l.* in Malesia have been proposed by P.C. van Welzen (van Welzen, 2020). Euphorbiaceae *s.s.* consists of 81 genera to the Flora Malesiana treatment (van Welzen, 2020). Some of them are introduced genera, such as *Hevea* Aubl., *Jatropha* L., *Manihot* Mill., and *Ricinus* L. (van Welzen et al. 1997; van Welzen, 1998; Sam & van Welzen, 2004; van Welzen et al., 2017). Van Welzen & Fernández-Casas (2017) reported a genus new to Malesia, namely *Cnidoscolus* Pohl, from the Philippines. Moreover, a new genus, namely *Weda* Welzen, was recently discovered in Halmahera, North Maluku, Indonesia (van Welzen et al., 2020). Some novelties on species-level also have been made by some authors, including new species discovery (Setiawan et al. 2020) or new record (Mustaqim et al. 2019). On the other hand, the taxonomic studies also have shown the presence of new novelties for the non-native species such as Van Welzen & Fernández-Casas (2017), who reported the occurrence of *Cnidoscolus* Pohl in the Philippines and Irsyam et al. (2019) who reported two species of *Euphorbia* from Java. Other genera have not been reported in that treatment, especially the introduced plants.

Based on the Flora of Java vol. I, there are 43 genera and 114 species of Euphorbiaceae *s.s.* in Java (Backer & Bakhuizen van den Brink, 1963). Djarwaningsih (2012; 2013) has reported several newly recorded species from the island, namely *Balakata baccata* (Roxb.) Esser., *Endospermum diadenum* (Miq.) Airy Shaw, and *Suregada glomerulata* (Blume) Baill. Irsyam et al. (2019) reported two newly naturalized *Euphorbia* species from Bogor (West Java), namely *E. graminea* Jacq. and *E. hyssopifolia* L. In this paper, we formally report the occurrence of two non-native species from Java Island named *Caperonia palustris* (L.) A.St.-Hil., represents the first record of the genus for Malesia, and *Croton bonplandianus* Baill.

Materials and Methods

In this study, the specimens were collected during field explorations to Bogor, Bekasi, and Indramayu in West Java as well as Rembang in Central Java from April to December 2019. Plants were collected according to the guideline in van Balgooy (1987) and preserved as dried herbarium specimens. The descriptions and botanical illustrations were made based on the dried material and field notes on living characters. A further examination was conducted in order to confirm the identity of specimens in Herbarium Bogoriense (BO), Herbarium Bandungense (FIPIA), and Herbarium of Department of Silviculture, The Faculty of Forestry, IPB University. Moreover, the examination was also supplemented by images from L (bioportal.naturalis.nl), G (ville-ge.ch/musinfo/bd/cjb/chg/), and P (science.mnhn.fr/institution/mnhn/collection/p/list) (acronym follow Thiers 2020-continuously updated) as well as JSTOR Global Plants (plants.jstor.org).

Result and Discussion

Caperonia palustris (L.) A. St.-Hil., Hist. Pl. Remarq. Bresil 3/4: 245. 1825; Grisebach, Fl. Brit. West Ind. 43-44. 1864; Brown, Hutchinson & Prain, Fl. Trop. Africa VI: 832. 1913; Standley & Dahlgren, Fl. Costa Rica 18, 2: 601-602. 1937; Standley & Steyermark, Fl. Guatemala 24, VI: 56-57. 1949; Macbride, Fl. Peru 13, 3A: 1. 97. 1951, Webster & Burch, Ann. Missouri Bot. Gard. 54(3): 268. 1967; Burger & Huft, Fl. Costaricensis 36: 70. 1995; De Egea et al., PhytoKeys 9: 79. 2012; *Argythamnia palustris* (L.) Kuntze, Revis. Gen. Pl. 2: 594. 1891. – Basionym: *Croton palustris* L., Sp. Pl. 2: 1004. 1753 (‘*palustre*’). – Type: Cristina, Izabal, *S.F. Blake 7475* (neotype ?).

Herb to sub-shrub, woody at base, monoecious, erect, up to 60 cm tall, with milky latex. **Stem** erect, cylindrical, ridged, green; indumentum consisting of glandular and non-glandular hairs, c. 1 mm long. **Leaves** simple, alternate; petiole slender, 4–20 mm long, green, glandular hairs present; lamina ovate-oblong, elliptic-oblong to lanceolate, 5–12 × 2–5 cm, base rounded to acute, margin serrate, apex acute, acuminate or obtuse, secondary venation pinnate, regularly spaced, forming acute angle of c. 25˚ with midrib, 8–12 pairs, trinerved at base, marginal glands on leaf teeth and adaxial basal glands absent. **Stipules** triangular to lanceolate or subulate, 2-5 × c. 1 mm, caducous. **Inflorescence** racemose thyrse, axillary, 6–8 cm long, flowers unisexual, 1–4 proximal pistillate flowers, several distal staminate flowers; peduncle 2.3–4.3 cm long, hispid; bracteole ovate, c. 1 mm long. **Staminate flowers**: c. 1.5 mm wide; pedicels c. 1 mm long; sepals 5, united at base, ovate-elliptic, c. 1 × 0.5 mm, glabrous, green; petals 5, free, obovate-oblong, c. 1 × 0.5 mm long, white, glabrous, clawed, disc absent; stamens 10, unequal in size; filaments united near the base into a column, free distally, filiform, white; anthers oblong, yellowish; pistillode present, minute, cylindrical. **Pistillate flowers**: c. 1.5–2 mm wide; sub-sessile to sessile; sepals 5–6, united at base, ovate, unequal, in two rows, 3 inner larger, c. 3–5 × 1 mm, 3 outer smaller, c. 1.5–2 × 0.7 mm, persistent in fruit; petals 5,

free, oblong-lanceolate, white; staminodes and disc absent; ovary superior, trilocular with 1 ovule per locule, green, glandular hairs present; style short; stigma bifurcate, white, greenish at base, stigmatic papillae absent. **Fruits** trilocular capsule, deltoid at shape, 3–5 mm diameter; subsessile; persistent sepals 5–6, ovate to deltoid, c. 5 × 3 mm. **Seeds** globose, brown, diameter c. 2 mm, with narrow transverse scale-like processes, ecarunculate (Figure 1).
Distribution: Mexico and West Indies to Argentina. The species was also distributed to Africa and Madagascar (Brown et al., 1913; Macbride, 1951). It is here reported from Bogor (West Java) and Rembang (Central Java).

Specimens examined: **Indonesia. West Java:** the roadside from Duta Berlian Hotel to Babakan Lio, near ricefield area, Dramaga Sub-district, Bogor Regency, ± 201 m alt, 6°33'22.20"S 106°43'47.30"E, 16 July 2019, *MR Hariri 47* (FIPIA); Rice Field Observation of Agronomy & Horticultural Department, Agricultural Faculty, IPB University, Dramaga, Bogor Regency, 6°33'47.9"S 106°44'10.0"E, 04 December 2019, Z Al Anshori, *DRG12119-001* (FIPIA). **Central Java**: ricefield, Kedungdowo, Sidorejo Village, Sedan Sub-district, Rembang Regency, 6°45'54.8"S 111°34'34.3"E, August 2019, Z Al Anshori, *RBG0819-001* (FIPIA). **Puerto Rico**, Arecibo, 3/5/1847, *Krebs s.n.* (BO). Other specimens from Java were not found at BO.
Habitat and ecology: The species can be found in roadside, ditches, swamps, and other wet habitats (Webster & Burch, 1967).
Note: *Caperonia* A.St.-Hil. is a genus new for Malesia and it has been found in Java, Indonesia. The genus consists of monoecious herb or shrub having indumentum in the form of simple hairs, non-pulvinate petiole, the absence of both marginal glands on leaf teeth and adaxial basal glands, flowers with free petals, the absence of disc on the staminate flowers, psitillate flowers with non-papillate stigma, muricate ovary, and seed without caruncle (van Welzen, 1999). The specimens from Java were identified as *Caperonia palustris,* due to its glandular hairs on the stem and petiole, triangular to lanceolate or subulate stipules, and leaves in ovate-oblong, elliptic-oblong to lanceolate shape. The species may have been accidentally introduced to Java as soil contaminants. But, the time and vector of introduction are uncertain. The species has been described as an invasive alien species in the southern United States since 2007 (Miller et al., 2010; Godara et al., 2011). Thus, its occurence in Java needs to be noticed. In Bogor and Rembang, the species grows as a weed along ricefields and according to our observation, the seeds are dispersed by water. The previous study showed that the seeds have a capability to survive under flooded conditions (Koger et al., 2004).

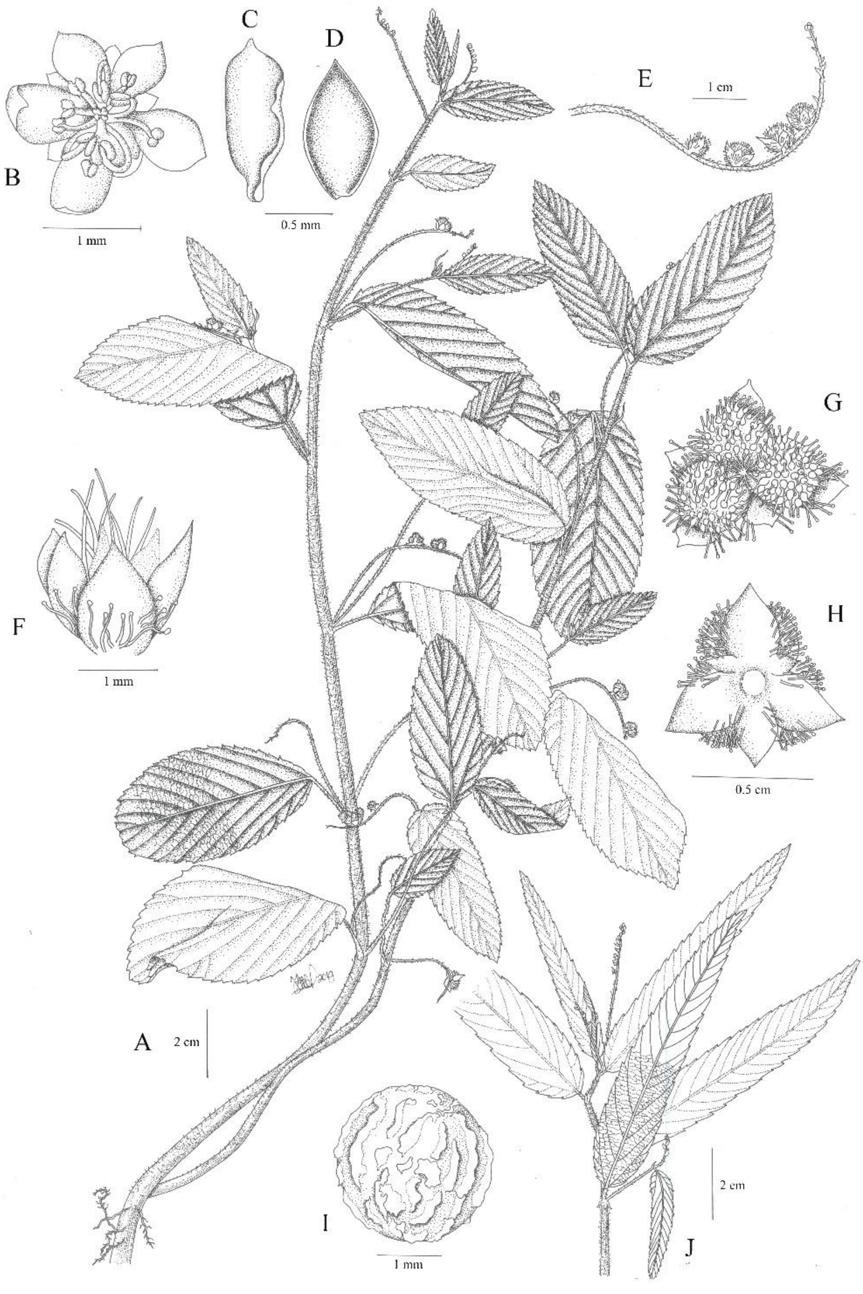

Figure 1. *Caperonia palustris* (L.) A.St.-Hil. a) habit; b) staminate flower; c) petal; d) sepal; e) infructescence, f) pistillate flower; g) adaxial surface of fruit, h) abaxial surface of fruit, i) ecarunculate seed, j) the leafy twig with linear-lanceolate leaves (Drawn by Z.A. Anshori)

The additional species of *Croton* from Java

A key to the genus *Croton* in Java, modified from Backer & Bakhuizen van den Brink (1963) and Esser (2005)

1	A.	Herbs to sub-shrubs	2
	B.	Shrubs or treelet, climber, with distinctly woody stem	3
2	A.	Indumentum hispid, irritating hairs present, basal leaf glands stalked, leaf margin with coarse double-serration, fruit globose	*C. hirtus*
	B.	Indumentum flat, irritating hairs absent, basal leaf glands sessile, leaf margin with simple serration, fruit ellipsoid	*C. bonplandianus*
3	A.	Adult leaves on the lower surface are densely covered by scales, no epidermis visible, filaments hairy	*C. argyratus*
	B.	Adult leaves on the lower surface are covered by lepidote or stellate hairs, epidermis visible, filaments glabrous	4
4	A.	Leaves entirely pinnately nerved, lateral nerves 7–11, stalked glands along the margins absent	5
	B.	Leaves 5–7-nerved at base, lateral nerves 3–5, stalked glands along the margins present	6
5	A.	Calyx-lobes in the pistillate flowers with a hair-tuft at the apex, outside nearly glabrous, fruits rather densely lepidote outside	*C. oblongus*
	B.	Calyx-lobes in the pistillate flowers thinly scaly, fruits sparsely lepidote outside	*C. glabrescens*
6	A.	Shrubs to treelet, leaf base broadly rounded or slightly deccurent, axis of inflorescence glabrous	*C. tiglium*
	B.	Climber, leaf base cordate, not deccurent, stellate-hairy above, axis of inflorescence densely pubescent	*C. caudatus*

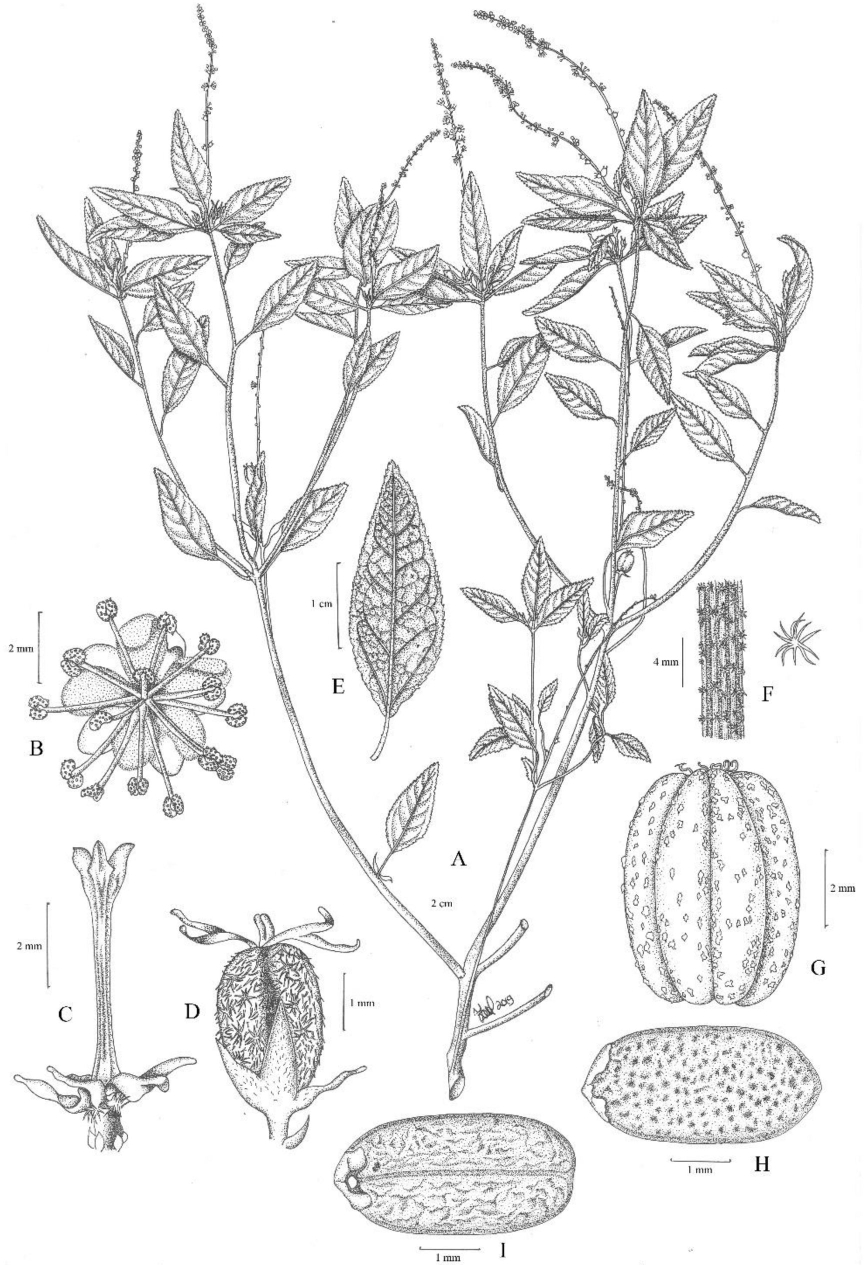

Figure 2. *Croton bonplandianus* Baill. A) habit; B) staminate flowers; C) pistillate flower; D) young fruit; E) adaxial leaf surface; F) young twig with stellate hairs; G) mature fruit, H) adaxial surface of seed, I) abaxial surface of seed. (All from *PJBIND0419-001* (FIPIA). (Drawn by Z.A. Anshori).

Croton bonplandianus Baill., Adansonia 4: 339. 1864, Whitmore, Tree Fl. Malaya 2: 84. 1973; Keng, Conc. Fl. Sing. 109. 1990; Turner, Gard. Bull. Sing. 45(1): 82. 1993; Esser in Chayam. & Welzen, Fl. Thai. 8(1): 195, plate X: 3. 2005; De Egea, Peña-Chocarro, Espada & Knapp, PhytoKeys 9: 80. 2012; *Oxydectes bonplandiana* (Baill.) Kuntze, Revis. Gen. Pl. 2: 610. 1891. − Type: Argentina: Province de Corrientes: ca. 600 m, 1833, *Bonpland s.n.* (syntype P!-image seen [P00623060, P00623061, P00623062, P00623063]).
Croton pauperulus Müll.Arg., Flora 47: 485. 1864. – Synonym: *Oxydectes pauperula* (Müll.Arg.) Kuntze, Revis. Gen. Pl. 2: 612. 1891. − Type: *Tweedie 1215* (holotype K).
Croton sparsiflorus Morong, Ann. New York Acad. Sci. 7: 221. 1893. – Synonym: *Oxydectes sparsiflora* (Morong) Kuntze, Revis. Gen. Pl. 3(3): 289. 1898. − Type: Paraguay, Distrito Capital, Asunción, 1888/11/01, *Morong 43* (syntype NY!-image seen [NY00262959], BM!-image seen [BM000504228]; isosyntype NY!-image seen [NY00262957], GH!-image seen [GH00047430], US!-image seen [US00109758]).
Croton rivinoides Chodat, Bull. Herb. Boissier, sér. 2, 1: 395 1901. − Type: In campo prope Cerrito, Paraguay, 1885, *Hassler 1004* (isotype P!-image seen [P00623064, P00623065], NY!-image seen [NY00262944]).
Sub-shrub up to 50 cm high, monoecious, with clear sap, branching near base; indumentum consisting of stellate, whitish hairs, not irritating. **Leaves** simple, sub-opposite to spiral; petiole filiform, 0.5–1.5 cm long, reddish green; lamina ovate-lanceolate to rhomboid, 2.5–4 × 1–1.5 cm, base cuneate, margin serrulate, apex acute to acuminate or obtuse, adaxial surface shiny green, abaxial surface pale green, with sparse whitish stellate hairs, trinerved at base; basal glands 2 at junction petiole and lamina, oblong, c. 1 mm, brown, basal leaf glands sessile. **Stipules** subulate, c. 1 mm, whitish. **Inflorescence** unbranched thyrse, 9–9.5 cm long, flowers unisexual, peduncle 0.5 cm long; bracteoles subulate, ± 0.5 mm long. **Staminate flowers**: c. 4 mm wide; pedicels c. 2 mm long; sepals 5, united at base, ovate, 0.5–1 mm long, greenish; petals 5, free, curved, oblong, c. 2 mm long, white; disc present, lobed; stamens inflexed in bud, free, 15–16, filaments filiform, c. 1.5 mm long, white; anthers reniform, yellowish-white. **Pistillate flowers**: c. 2.5 mm wide; subsessile; sepals 5, united at base, triangular-ovate, c.1.5 mm long, green; petals absent; ovary superior, trilocular with 1 ovule per locule, ovoid, c. 1 × 1 mm, green, whitish stellate hairs present; stigmas bifid, c. 1.5 mm wide, spreading, glabrous, creamy, persistent. **Fruits** capsules, ellipsoid, trigonous, c. 5 × 4 mm, green with purple-reddish tinged. **Seeds** ellipsoid, c. 5 × 3 mm, creamy white, carunculate (Figure 2).
Distribution: Southern Bolivia, Paraguay, South Western Brazil, and Northern Argentina (Radcliffe-Smith, 1986). The species was also occured in Thailand and

Malesia (Malay Peninsula, Singapore, Borneo and Sulawesi). Recently, the species has been collected from Bekasi and Indramayu, West Java.
Specimen examined: **Indonesia. West Java:** Sumuradem, Sukra Sub-district, Indramayu Regency, 6°16'28.9"S 107°57'57.7"E, 24 April 2019, Zakaria Al Anshori *PJBIND0419-001* (FIPIA); PT PJB UP Muara Tawar, Segarajaya, Tarumajaya Sub-district, Bekasi, 6°05'20.3"S 106°59'58.3"E, 29 September 2019, Zakaria Al Anshori *MTW0919-001* (FIPIA). Other specimens were not found in BO.
Habitat and ecology: In Java, the species grows in open disturbed areas, roadsides, and abandoned lands. It can also be found near upper tidal areas and dry fishponds and associated with salt-resistant species like *Sesuvium portulacastrum* (L.) L. (Aizoaceae). *Croton bonplandianus* grows as weeds in Bekasi and Indramayu.
Note: In Java, the specimens were identified as *Croton bonplandianus*. The species was characterized by stellate hairs on its stem which are visible as white dots, leaves are 1–1.5 cm wide with dense simple serration, and sessile basal leaf glands. Similar to the previous species, *C. bonplandianus* might be introduced to Java as a soil contaminants. The information about when it was firstly introduced is unknown. Within Malesia and SE Asia, *C. bonplandianus* was recorded for Thailand, the Malay Peninsula, Singapore (Turner, 1993; Chong et al., 2009), Borneo and Sulawesi (Esser, 2005). Furthermore, the species has been considered as an invasive alien species in India and Bangladesh (Islam et al., 2003; Rao & Sagar, 2012).

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Research Article

Studying the Impacts of Land Use Changes on the Occurrence of Vector Mosquitoes in Sabah, Malaysia

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Abstract

Land use changes as a result of infrastructural and agricultural development such as construction of forest field centre, establishment of large-scale oil palm plantations, and logging activities are increasing in Malaysia. These activities lead to environmental disturbances and may affect the ecological balance of many organisms. Mosquitoes are very sensitive to environmental changes since their diversity, distribution and abundance are influenced by even small changes in environmental conditions such as availability of suitable breeding sites. Mosquitoes from three different sites of varying disturbance levels at the SAFE Project experimental areas in eastern Sabah i.e., old growth forest (OG), logged forest (LFE) and heavily logged forest (Block B) were collected and identified to species level. Shannon-Wiener index and Simpson index of diversity were calculated and the diversity value were highest in LFE (H'= 0.4434, 1/D= 1.3427) and the least in Block B (H'= 0.3260, 1/D= 1.1627). A similar trend was detected in terms of mosquito abundance with the highest abundance recorded in LFE and the least in Block B. Results of the present study generally suggest that land use changes do affect mosquito diversity and abundance by altering, creating or providing places for the adult mosquitoes to breed.

Keywords: Land use changes, forest disturbance, vector mosquitoes, SAFE Project, Sabah

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Introduction

The modification of habitats due to human related activities plays an important role in changing the ecological balance of many organisms, for example natural and artificial places where mosquitoes breed, develop and potentially, transmit diseases (Norris, 2004). Land use change by human activities such as logging, agriculture and urbanisation can influence mosquito diversity, distribution and abundance, as well as other aspects such as biting behaviour and vector competence (Patz et al., 2000). As an adaptation to the changed environmental conditions, such as increase in human population, some vectors have been known to convert their feeding habit from primarily zoophilic to primarily anthropophilic. Mosquitoes are more sensitive to environmental changes compared to other forest species that transmit diseases to humans, such as bats and snails because their survival, density and distribution are influenced by the small changes in the environmental conditions such as temperature, humidity and the availability of breeding sites (Yasuoka & Levins, 2007). The aim of this study was to investigate the effects of progressive land use changes in the form of logging and oil palm plantation development on the mosquito community. This paper reports the preliminary findings of the diversity, distribution and abundance of mosquitoes in several forest areas that have been subjected to different levels of disturbance due to logging activities.

Methodology

Study area

This study was conducted at the Stability of Altered Forest Ecosystem (SAFE) Project experimental areas. The SAFE Project is a forest fragmentation experiment which is aimed at understanding the impacts of forest disturbance and fragmentation, as well as conversion into oil palm plantations, on the biodiversity, ecosystem functioning and services (Ewers et al., 2011). The project area includes Kalabakan Forest Reserve and Maliau Basin Conservation Area (Figure 1).

Three different forest types were selected in this study i.e. logged forest (LFE) and heavily logged forest (Block B) in Kalabakan Forest Reserve, and old growth forest (OG) in Maliau Basin Conservation Area.

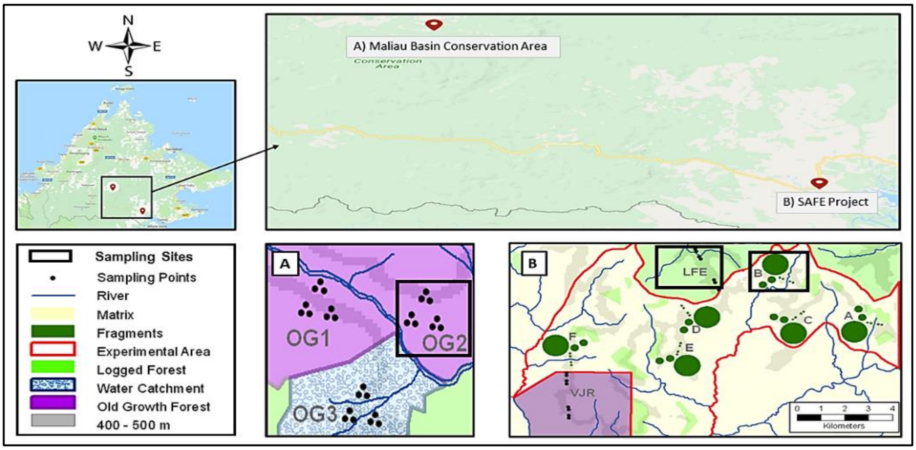

Figure 1. Map of Sabah showing the locations of study sites in Maliau Basin Conservation Area (OG2 (inset A)) and Kalabakan Forest Reserve (LFE and B (inset B)).

Adult Mosquito Sampling

Samplings of adult mosquito were conducted every alternate month from July 2017 to August 2018, for 12 nights at each study sites. A total of six survey points were selected, with two survey points (minimum separation of 500m) allocated for each sites (Table 1). Adult mosquitoes were collected by using human landing catches technique (HLC) conducted by two collectors simultaneously between 18:00 hr to 00:00 hr during every sampling occasion (Brant, 2015).

Table 1. Location of sampling points in the study sites.

Forest types	Coordinates	General habitat descriptions
Old growth forest (OG)	Survey point 1: N 04˚44' 09.8"; E 116˚58'40.1" Survey point 2: N 04˚44' 02.0"; E 116˚58'22.6"	Forest habitat which was lightly logged in 1970s and 1990s.
Logged forest (LFE)	Survey point 1: N 04°43' 24.6"; E 117°36' 11.0" Survey point 2: N 04°43' 28.8"; E 117°35'47.0"	Selectively logged in the 1970s and also from the late 1990s to the early 2000s, it has 71% forest cover.
Heavily logged forest (Block B)	Survey point 1: N 04°43' 03.4"; E 117°36' 33.5" Survey point 2: N 04°43' 39.4"; E 117°36' 51.9"	Selectively logged in the 1970s and also from the late 1990s to the early 2000s, re-logged three times, fragmented forest, it has 47% forest cover.

Source: Ewers et al. (2011); Struebig et al. (2013)

Immature Stages Sampling

Immature stages of mosquitoes were sampled at potential breeding sites such as streams, ground pools and tree holes at each study site. Collections of immature stages were conducted every month during the day between 06:00 hr to 18:00 hr and at night after 18:00 hrs. A 0.47 L standard dipper was used at the rate of 10 dips for ground pools and ditches, while 15 dips for streams and swamps (Chang et al., 1997). The samples in tree holes were collected using pipettes.

Mosquito Preservation and Identification

All collected samples of adult mosquitoes were pinned and morphologically identified to species level using compound microscope. Species identity was based on the identification key by Rattanarithikul et al., (2005a,b; 2006a,b), Reid (1968), Stojanovich & Scott (1966) and Sallum et al., (2005). The collected immature stages were preserved in 70% ethanol and identified up to genus level.

Data Analysis

Data analyses were carried using SPSS Version 20 and Microsoft Excel 2016. Shannon-Wiener's Diversity Index and Simpson's Diversity Index were used to obtain the diversity of mosquitoes collected in each site. The diversity indices were calculated by taking the number of each collected species and the proportion of the species from the total number of individuals in the samples. The variation in adult mosquito abundance between study sites was analysed using one-way ANOVA and the detailed comparisons between sampling sites was conducted using Tukey's HSD Post Hoc test. Data were first normalized to meet the normality assumptions before running the ANOVA test.

Results

Adult Mosquito Collections across Different Land Use Types

A total of 1,032 adult mosquitoes representing five different genera were collected over a cumulative total of 36 nights of sampling. They consisted of 533 anophelines and 499 culicines. Five species represented the culicines, i.e. *Aedes albopictus*, *Culex sitiens*, *Culex vishnui*, *Downsyiomia ganapathi* and *Heizmannia* sp., while the anophelines were represented by two species, i.e., *Anopheles balabacensis* and *Anopheles latens*. The results showed that *Anopheles balabacensis* was the most abundant species with 519 (or 50.29%) individuals collected and the least abundant was *Heizmannia* sp. with only one individual collected (0.19%). Out of these seven species, only those from the genus *Aedes*, *Anopheles* and *Culex* are known as vector mosquitoes and are medically important in Malaysia.

Mosquito abundance was the highest in logged forest area (LFE) with 552 individuals collected, followed by old growth forest (OG) with 302 individuals and heavily logged forest (Block B) 178 individuals (Table 2). Shannon-Wiener's index and Simpson's index were calculated and the diversity values were highest in LFE (H'= 0.4434, 1/D= 1.3427) and the least were in Block B with H'= 0.3260, 1/D= 1.1627. The variations in adult mosquito abundance between the old growth (OG), logged forest (LFE) and repeatedly logged forest (Block B) sites were significantly different (ANOVA, df= 17, F= 4.512, p= 0.029) (Figure 2).

Table 2. The abundance of mosquito species collected in different habitat types.

Genus	Species	Number of individuals (%)			No.
		OG	LFE	Block B	
Aedes	*albopictus*	7 (2.32)	474 (85.86)	3 (1.68)	484 (46.90)
Anopheles	*Balabacensis*	280 (92.72)	74 (13.41)	165 (92.69)	519 (50.29)
	latens	8 (2.65)	0 (0)	6 (3.37)	14 (1.36)
Culex	*Sitiens*	3 (0.99)	2 (0.35)	2 (1.12)	7 (0.68)
	vishnui	1 (0.33)	1 (0.19)	1 (0.56)	3 (0.29)
Downsyiomia	*ganapathi*	3 (0.99)	0 (0)	1 (0.56)	4 (0.39)
Heizmannia	sp.	0 (0)	1 (0.19)	0 (0)	1 (0.09)
Total		**302 (100)**	**552 (100)**	**178 (100)**	**1032 (100)**

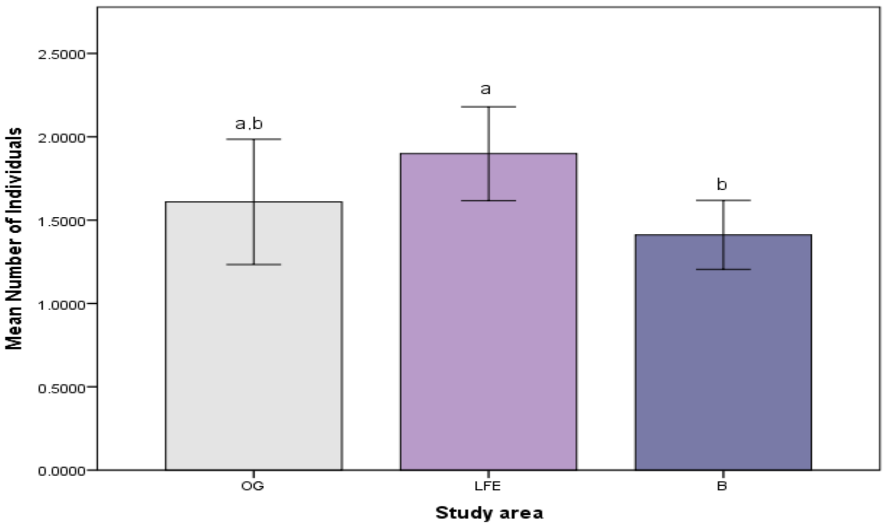

Figure 2. Adult mosquito abundance in OG, LFE and Block B. Note: Error bars indicate 95% Confidence Intervals and different letters above bars indicate significant differences derived from a Tukey-HSD post hoc test which described in the text

Post-Hoc Tests revealed that the adult mosquito abundance in LFE was significantly higher than in Block B (Tukey's HSD Post Hoc, p= 0.024), while no significant difference was detected in LFE compared to OG (Tukey's HSD Post Hoc, p= 0.212). Similarly, no significant difference was detected in OG compared to Block B (Tukey's HSD Post Hoc, p= 0.464).

Larva Collections

A total of 420 larvae from four different genera were collected from the breeding sites in this study. Five breeding sites were detected in LFE i.e., streams, ground pool, rock pool, laboratory construction site and water filled rubbish. Whereas, only two breeding sites were detected in OG and Block B i.e. streams and ground pools. Genus *Culex* recorded the highest abundance with 263 individuals collected, followed by *Aedes* with 138 individuals, *Anopheles* (10 individuals) and *Armigeres* 9 individuals. The most widespread genus was *Culex*, i.e. found in all three study sites. Genus *Aedes* was only found in OG and LFE, while *Anopheles* and *Armigeres* were found only in LFE (Table 3; Figure 3).

Table 3. Number of larvae collected from various breeding sites in the study areas.

Genus	Areas found	Breeding sites	No.	Percentage (%)
Aedes	OG, LFE	Laboratory construction site, ground pool, rock pool, empty can, water filled rubbish	138	32.86
Anopheles	LFE	Ground pool, rock pool	10	2.38
Armigeres	LFE	Laboratory construction site	9	2.14
Culex	OG, LFE, Block B	Laboratory construction site in LFE, ground pool, streams, rock pool, tree hole, empty can, water filled rubbish	263	62.62
Total			**420**	**100**

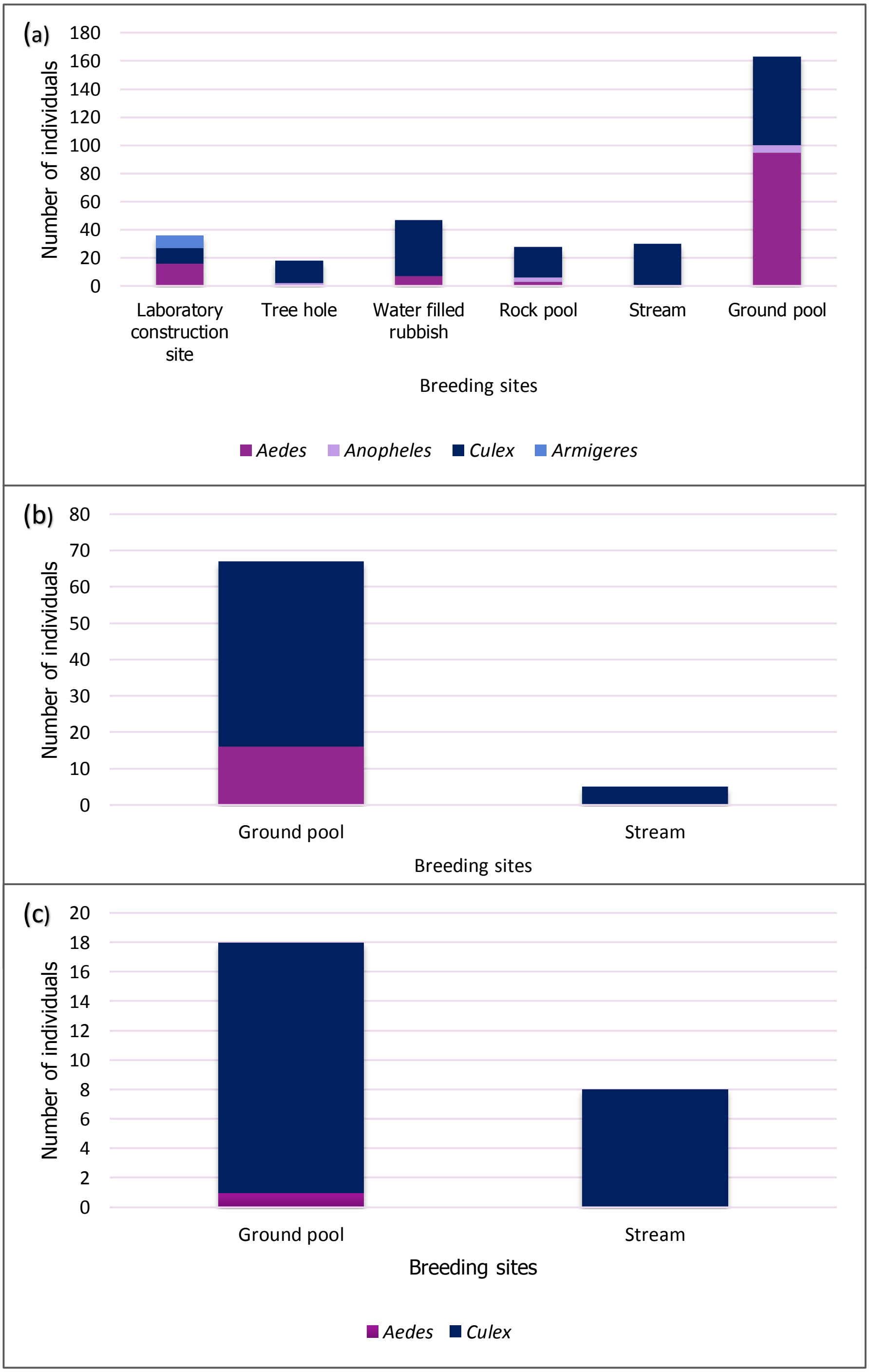

Figure 3. Number of mosquito larvae collected in (a) OG, (b) LFE and (c) Block B.

Discussion

Adult Mosquito Collections across Different Land Use Types

In this study, mosquitoes were more abundant in the logged forest area (LFE) than in old growth forest (OG). This finding is in agreement with the findings by Brant et al. (2016) and Ebrahim & Mahadimenakbar (2018). The higher abundance of mosquitoes may be attributed to the greater potential breeding sites in logged forest which were created as a result of human disturbance activities. Indeed, more breeding sites were found in LFE such as at the laboratory construction site, ground pools, tree holes, streams, empty cans and other water filled rubbish, compared to in OG and Block B, where only two breeding sites for mosquito were found i.e. ground pools and streams.

Anopheles balabacensis was found dominating two study sites; OG and Block B, while in LFE, the most frequently collected species was *Aedes albopictus*. Brant (2015) showed that *Aedes albopictus* only breeds in residential areas. LFE is a twice logged forest that is surrounded by human settlement areas and also a laboratory construction site. Since *Aedes albopictus* is anthropophilic or well known as a vector that prefers to take blood meals from humans rather than animals, this could explain why this species dominated the logged forest site (Li et al., 2014). According to Nazri et al. (2013), *Aedes albopictus* is more likely to breed in natural containers or outdoor man-made habitats containing organic debris. Based on the results of the present study, *Aedes* larvae was collected mostly from the ground pools. Wheel tracks on the ground made by 4WD vehicles used by staff and researchers residing nearby LFE sampling sites formed puddles or ground pools providing suitable breeding sites for mosquitoes, whereas in OG and Block B there were no wheel tracks present within this study area (Brant et al., 2016).

In terms of number of vector mosquito presence, all sites seemed to have the same vector species. *Aedes albopictus*, *Anopheles balabacensis*, *Anopheles latens*, *Culex sitiens* and *Culex vishnui* were found in OG and Block B. However, there was no *Anopheles latens* recorded in LFE. *Aedes albopictus* is known as a vector of dengue disease in Malaysia (Brant, 2011). The population of this species spreads widely because of its ability to live in all ecotypes in towns, villages and forest fringes (Ebrahim & Mahadimenakbar, 2018). *Anopheles balabacensis* is an exophagic and exophilic species, but could also be endophagic (Brant et al., 2016). In East Malaysia, females of this species are highly anthropophilic. Despite some of them being more anthropophilic, other subpopulation can be more zoophilic (Sallum et al., 2005). Miyagi (1973) found that this species is attracted to humans, monkeys and water buffaloes. These could be the reasons why this species was found in all study areas in the present study. In fact, they were dominant in the OG and Block B area.

Larva Collections

Habitat preference may be different among mosquito species (Haarlem & Vos, 2018). *Culex* mosquitoes could be found in natural and man-made breeding sites, but some of them are most likely to breed in stagnant polluted water (Low et al., 2012). The present study found that the most collected mosquito was from the genus *Culex* and the least was from genus *Armigeres*. The *Armigeres* larvae was collected from the laboratory construction site in LFE and was not present in OG and Block B. According to Pandian and Chandrashekaran (1980), this genus prefers to breed in foul smell and stagnant water. Clearly, more studies and greater number of sampling locations are needed to confirm the absence of this genus in the study area.

Conclusion

In general, there were differences in terms of diversity, distribution and abundance of vector mosquitoes among the different land-uses. In this study, logged forest area (LFE) showed higher mosquito abundance compared to old growth forest (OG) and heavily logged forest (Block B). The present study provided some evidence suggesting that land use changes do affect mosquito diversity and abundance and by altering, creating or providing places for the adult mosquitoes to breed. This study also found that *Anopheles balabacensis* was the dominant species collected in OG and Block B, whereas in LFE, the predominant species was *Aedes albopictus*. Since these species are important vectors for malaria and dengue, proper control methods such as removing mosquito habitat, controlling adult mosquito population by using EPA-registered pesticides and installing door or window screen need to be emphasized to the locals to prevent mosquito bites and spread of these diseases.

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Research Article

Utilization of "Benda" (*Artocarpus elasticus* Reinw. ex Blume) in Bogor, West Java, Indonesia: An Ethnobotanical Case Study

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Abstract
Family Moraceae consists of 60 genera, one of which is the genus of *Artocarpus*. One species of *Artocarpus* is *A. elasticus*, known as Benda by local people in Bogor. Its fruit is used as an alternative food but it is still less known. This study was carried out to evaluate the use of *A. elasticus* in Bogor as food and its surroundings by direct observations in the field and interviews with selected informants and proximate analysis. The results of the study revealed that the fruit and the seeds are eaten like other species of *Artocarpus*; i.e. *A. heterophyllus* (Jackfruit), *A. champeden*, the wood of Benda is used for cabinets and latex to catch birds. *A. elasticus* is quite rare now, and the seeds have a high carbohydrate content. So there is a need for intensive cultivation to maintain its sustainability.

Keywords: Ethnobotany, food, *Artocarpus*, proximate, Bogor, West Java.

Introduction
Plant biological resources play an important role to meet basic human needs as a source of food, energy, building materials, and medicines (Sastrapradja, 2006). In general, the Indonesian population relies on plants to meet their food needs, including vegetables, fruits, and a form of alternative carbohydrate. According to Widjaja et al. (2014), food reserves are dominated by fruits.

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Moraceae is a large family of a plant consisting 60 genera and nearly 1,400 species, including several important genera such as *Artocarpus, Morus,* and *Ficus*. Several species of *Artocarpus* have long been recognized for their exceptional medicinal value and their edible aggregate fruits in South East Asia, Indonesia, the Western part of Java and India.

The genera of *Artocarpus* comprises circa 45 species and ranges from Sri Lanka to South China and through Malesia to Solomon Islands and Australia; 32 of these species occur as wild trees in Malesia, *A. elasticus* is found in the Thai - Malay Peninsula, Indo Burma, Sumatra, Borneo and Palawan (Philippines), Java and the Lesser Sunda Islands (Berg et al., 2006, Williams et al., 2017). In Indonesia, Benda is known as bendho (Java), teureup (Sundanese, Java), mengko (Sumatra); in Malaysia: terap nasi (Peninsular), terap (Sarawak); in Thailand: oh, ka-oh, tuka (Peninsular) (Djarwaningsih et al., 1995).

The important species belong to the genus *Artocarpus* are *Artocarpus heterophyllus* (Jack fruit), *Artocarpus altilis* (Breadfruit), *Artocarpus hirsutus* (Wild jack), *Artocarpus lakoocha* and *Artocarpus camansi* (Breadnut) (Hari et al., 2014). The genus *Artocarpus* is known to possess potential phytochemicals such as new coumarin isolated from *A. altilis* leaves with antioxidant activity (Abbas et al., 2011). Flavonoid from the bark of Cempedak (*A. champeden*) has potential to be developed as a new antimalarial drug (Nindetu, 2009). Hafid et al. (2010), it was reported that extract from *A. champeden* exhibited potent antimalarial activities against *P. falciparum* in vitro and *P. berghei* in vivo. Several isolated compounds from *A. champeden* exhibited antimalarial activity. Chemical compounds isolated from *A. kemando* displayed inhibition effects to a very susceptible degree in cancer cell line tests (Ee et al., 2011). Phytochemical analysis of *A. lakoocha* revealed the presence of tannins and alkaloids (Kumar et al., 2010).

Carbohydrates play a major role in human diet, comprising about 4 - 85% of energy intake. Its most important nutritional property is its easy digestibility in the small intestine (Shakappa & Talari, 2016).

The genus *Artocarpus* consists of 45 species in which the fruits of 15 species of *Artocarpus* are widely used as table fruit or processed materials in Indonesia such as jackfruit, and its relatives include *A. elasticus* (Uji, 2004). However, research on *A. elasticus* is still rarely done, and neither is its use in the community. The objective of this study was to study ethnobotany and determine the nutrient content of Benda (*A. elasticus*). Therefore, it needs to be explored further in order to support the diversification programme.

Materials and Methods

The study was conducted in the city of Bogor and Bogor regency, West Java: 106°43’30’’ – 106°51’00’’E and 30’30’’ – 6°41’00’’S, with altitude ranging from 190 to maximum 350 m.a.s.l. (Figure 1). Data on *A. elasticus* was collected by interviewing local communities (Sundanese) comprising about 20 people, men and women, especially about Benda plant (*Artocarpus elasticus*) (Table 1). Interviews were conducted in open, free and purposive sampling as well as direct observation in the field by showing a picture of Benda (Walujo, 2004; Vogl et al., 2004; Nolan & Turner, 2011). In addition to the interviews, plant collections for herbarium samples, fruits and seeds were collected for proximate analysis.

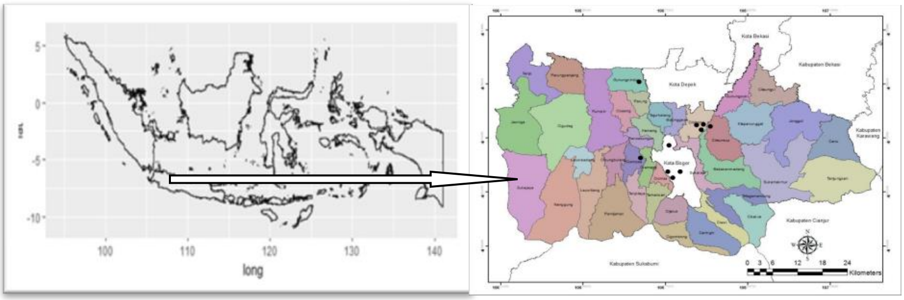

Figure 1. Maps of Indonesia (left), Bogor (right)

Table 1. Characteristic of respondents in Bogor, West Java

	Data	Total number	Percentage (%)
Gender	Male	13	59.09
	Female	9	40.91
Age	50 - 60	8	36.36
	40 - 49	7	31.82
	30 -39	7	31.82
Education	Primary school	10	45.45
	Junior high school	8	36.36
	Senior high school	4	18.19
Job	Employee	4	18.19
	Worker	13	59.09
	Housewife	3	13.63
	Fruit seller, bird seller	2	09.09

Proximate analysis was carried out in the Research Center for Bioresources and Biotechnology, IPB University. Proximate analysis was performed using the standard AOAC methods (1984). Ash content was determined through the gravimetric method. The Kjeldahl method was used to determine protein content. Fat content was determined using the Soxhlet method; while crude fibre content by gravimetric; carbohydrates by different method.

Results

Based on the results of interviews and field observations, it is known that Benda plant is scattered in several locations in the city of Bogor and Bogor regency (Cikaret, Pasir kuda, Semplak, Tanah baru, Salabenda), Botanical Garden and several districts of Ciampea (Cicadas 1 village); Cibinong: Sampora, Nanggewer, Nanggewer Mekar; Citeureup (Leuwinutug village); Sukaraja (Cijujung village), and Gunung Sindur (Pabuaran village) (Table 1) (Figure 1).

Table 2. Distribution of benda in Bogor city and Bogor regency

No	Location in Bogor city	Location in Bogor regency
1.	Cikaret (west of Bogor city)	Cicadas 1 Village (Ciampea district)
2.	Pasir kuda (west of Bogor city)	Sampora (Cibinong)
3.	Semplak (west of Bogor city)	Nanggewer (Cibinong)
4.	Tanah Baru (North of Bogor city)	Nanggewer Mekar (Cibinong)
5.	Salabenda (North of Bogor city)	Leuwinutug Village (Citeureup district)
6.	Botanical gardens (Centre of Bogor city)	Cijujung Village (Sukaraja district)
7.		Pabuaran Village (Gunung Sindur district)

Only a small number of Sundanese people in Bogor know about Benda , this is due to the decreasing population of Benda to the extent that it is rarely found and increasing human population causes a decrease in land for planting Benda. Benda is usually found on the banks of rivers, open areas next to housing estates and in the Bogor Botanical Garden. Benda plants are also known by the people of Cianjur regency.

A. elasticus is a tree (Benda) up to 40m in height. The leaves are spirally arranged; lamina coriaceous to chartaceous, entire, elliptic, size 20-95cm by 10-50cm, or when a juvenile is pinnately incised with 3 or 4 pairs of lobes; upper surface scabrous. Infructescences are ellipsoid to cylindrical or to subglobose, size up to 6-17cm by 5.5-12cm, covered with 3-4mm long cushion shaped to pyramidate to cylindrical apices of the perianths: skin covered with yellow-brown to bright orange; fruits are sweet, aromatic (but not as strong as

A. champeden), 4–207 seeds, and edible; fruiting in August-September and ripening in December–January (Figure 2 & 3); seeds are many and variation shaped, oval, globose, circa 1cm long. A tree has circa 200 fruits, their weight is 234-565 grams. It sometimes grows up to 1,500 m above sea level. This species is closely related to *A. sericicarpus*.

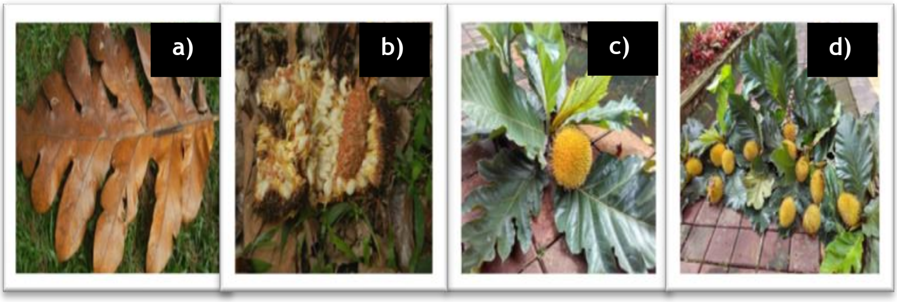

Figure 2. Leaves, Fruits of 'Benda' (a) Dry leaf), (b) Ripe fruit with seeds exposed, c) Single ripe fruit with leaves and (d) Many ripe fruits (*Artocarpus elasticus*)

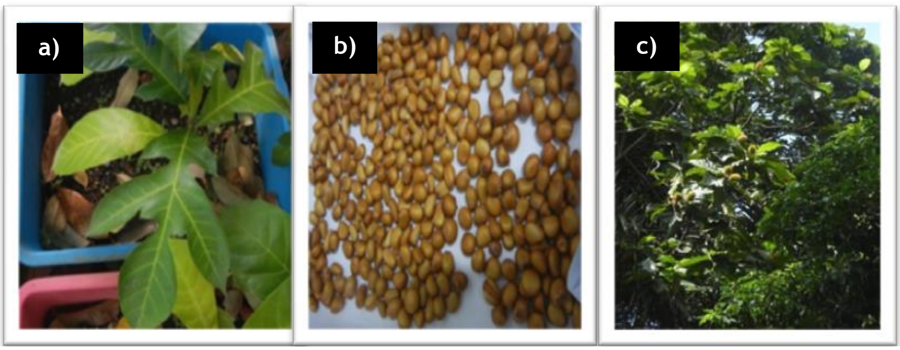

Figure 3. (a) Seedling, (b) seeds and (c) habit of Benda (*Artocarpus elasticus*)

Based on specimens of *A. elasticus* in Herbarium Bogoriense, Botany Division, Research Center for Biology, this species was found in the Thai - Malay Peninsula, Indo Burma, Sumatra, Borneo and Palawan (Philippines), Java and the Lesser Sunda Islands.

Benda (*A. elasticus*) and its utilization today is less known; however, it was popular around 25 years ago. The flesh of ripe fruits are eaten raw, while the seeds are cooked before being consumed, unripe fruits can also be eaten cooked. The seed resemble peanuts seed; it is consumed fried or roasted after washing. The stem's latex which is known as Pulut is used to snare birds/ birdlime which can ensnare little birds. Apart from latex of Benda, people also use latex from breadfruit, jackfruit and rubber to trap birds. The latex from Benda can be used without any latex mixture from other plants. Benda latex is more sticky compared to other latex. Latex from other species of *Artocarpus* such as *A. champeden*, is also used for birdlime (Heyne, 1987). The wood of Benda is usually used as a coffin board (Table 3).

Table 3. Utilization of Benda (*A. elasticus*)

No	Part of Plant	Utilization
1.	Fruit	Flesh of ripe fruits eaten raw and unripe fruits eaten cooked
2.	Seed	consumed fried or roasted after washing
3.	Latex	used to snare birds/ birdlime
4.	Wood	used as coffin board

The results of proximate analysis of seeds and flesh of Benda collected from Bogor show that Benda seeds contain 1.43% ash, 6.85% protein, 2.39% fat, 10.62% crude fiber, 49.03% carbohydrate (Table 4). Steamed Benda flesh contain 1.21% ash, 0.97% protein, 0.61% fat, 2.73% crude fiber, 11.72% carbohydrate (Table 5). Proximate composition is important in determining the quality of raw material and often the basis for establishing the nutritional value and overall acceptance of consumers (Kavitha & Parimalavalli, 2014).

Table 4. Proximate Composition of Benda, Tarap, Jackfruit and Pigeon pea

Samples	Benda seeds (*A. elasticus*)	Tarap seeds (*A. odoratissimus*)*1	Jackfruit seeds (*A. heterophyllus*)*2	Pigeon pea (*C. cajan*)*3
Ash %	1.43	1.17		3.80
Protein %	6.85	8.80		14 - 30
Fat %	2.39	15.60	5.40	1 - 9
Crude fiber %	10.62	12.30		5 – 9.4
Carbohydrate %	49.03	49.65	51.10	36 - 65.8

Note: *1 Masri et al. (2017); *2 Mahmud et al. (2009); *3 Van der Maesen & Somaatmadja (1989).

Table 5. Proximate Composition of Benda flesh, Tarap flesh

Samples	Benda flesh (*A. elasticus*)	Tarap flesh (*A. odoratissimus*) *1
Ash %	1.21	0.6 – 0.8
Protein %	0.97	1.2 – 1.5
Fat %	0.61	
Crude fiber %	2.73	0.8 - 1.3
Carbohydrate %	11.72	12.0 - 25.2

Note: *1 Tang *et al.* (2013)

Discussion

According to Uji (2004), there are many species of native fruits from Kalimantan, edible or genetic biodiversity source. These are mostly in the form of trees and Moraceae are among the top trees after Euphorbiaceae and Anacardiaceae. *A. elasticus*, one species of Moraceae.

For Bogor city, many regions come from the name of plants in Sunda language or Indonesian language commonly. Not many people realize that the name of their home comes from a plant name. Based on Hidayat (2009) about region names that still exist and those that do not any longer, in Bogor Regency there are names that come from the family of Moraceae, especially *Artocarpus*, like Bojong Nangka, Ciampea (*Artocarpus heterophyllus*), Bojong kulur (*Artocarpus altilis*), Cigudeg (*Artocarpus heterophyllus*)and Citeureup (*Artocarpus elasticus*). In this research, Citeureup and Ciampea are included.

According to Megawati et al. (2015), based on the diversity of native Kalimantan fruit trees in the Botanical Garden of Mulawarman University, Samarinda it is known from 235 Ha there are 18 species of trees, and the dominant one is the Moraceae family, and the most species is terap (*Artocarpus elasticus*) comprising 95 trees.

Places to grow Benda apart from the botanical garden are in areas where the tree is in poorly maintained condition, such as at cliffs or riverside prone to flooding, and trees that are not maintained grow wild. Sujarwo *et al*. (2016) stated that like in Bali, land use changes were observed and identified as causes of decline for *Artocarpus elasticus*, *Amorphophallus campanulatus*, *Arenga pinnata*, and *Borassus flabellifer*. The consumption of wild and semi-wild edible plants has been “a way of life” for many rural populations throughout the world. The wild edible plants are used as supplements to food but information on possible toxic effects are not known (Acharya & Acharya, 2010).

In three years, two out of seven Benda trees were lost because they were old and some were too close to rivers/cliffs causing them to die easily. Some were lost to make way for construction of buildings. One way to preserve this tree is through cultivation. Cultivation efforts are still needed, as from 226 species in 35 plant families of fruits native to Kalimantan, only 58 species were cultivated (Uji, 2004). There are 15 species of *Artocarpus* genera, and of these 11 species have been planted in local community gardens and 12 species grew wild in the forest in Kalimantan (Siregar, 2006).

Proximate analysis of Benda seeds is almost the same compared to that *A. odoratissimus* seeds i.e. 1.17% ash, 8.8% protein, 15.60% fat, 12.30% crude fiber, 49.65% carbohydrate (Masri et al., 2017). Carbohydrate and fat content of Benda seeds is lower compared to that of Jackfruit seeds i.e. 51.10% carbohydrate and 5.40% fat (Mahmud et al., 2009), and Sy Muhammad et al. (2019) reported, that the proximate analysis of Jackfruit seed powder i.e. 69.39 carbohydrate%, 13.67% protein, 10.78% moisture, 2.41% ash, 0.75% fat and 3.00% crude fiber.

Proximate analysis of *Cajanus cajan* i.e. 3.8% ash, 14-30% protein, 1–9% fat, 5-9.4% crude fiber, 36-65.8% carbohydrate (Van der Maesen & Somaatmadja, 1989) (Table 4). Proximate analysis of benda flesh is almost the same with *A. odoratissimus* flesh i.e. 0.6-0.8% ash, 1.2-1.5% protein, 0.8-1.3% crude fiber, 12.0-25.2% carbohydrate (Tang et al., 2013) (Table 5).

One such popular variation commonly found in Brunei Darussalam is its hybrid with *A. heterophyllus* (Jackfruit). The hybrid is locally called Tibadak-nangka or nanchem since the local name for Jackfruit is Nangka and *A. champeden* is known as Chempedak. Both *A. champeden* and its hybrid are popular edible fruits in Brunei Darussalam as well as in South East Asia due to their soft and firmly textured flesh. Ripened *A. champeden* (2.8 – 3.5%) and Nanchem (3.2 – 3.4%) have higher total carbohydrates and energy content than the unripe (1.8 – 2.5%) seed (Lim et al., 2011).

Aside from being used as food, latex of Benda is also used as an adhesive, to ensnare small birds. Pulut is an effective way to trap small birds wthout injuring or damaging bird feathers (Munandi, 2013; Miller, 2019). The study of Ridwan et al. (2015) showed that there is a relationship between bird population and the diversity of trees in Kentingan Campus Surakarta, i.e. Moraceae, Fabaceae and Myrtaceae inhabited by Cabai Jawa (*Dicaeum trochileum*), Pleci/Kacamata (*Zosterops palpebrosus*), Prenjak Jawa (*Prinia familiaris*).

In other locations there are 22 latex producing plants including those from the Moraceae family, namely *A. elasticus, Ficus* sp., *Parartocarpus* cf. *triandra* which is used by the Suku Anak Dalam in Jambi. The latex called Tungkal is used to catch birds (Andhika et al., 2015). *A. elasticus* is harvested from natural forests and indigenous agroforestry in Kalimantan (Uji, 2004).

Conclusion

Up to now the Sundanese community in Bogor consume the fruits and seeds of Benda (*A. Elasticus)* as an alternative food source, and use it as building material (wood). Benda contains a high carbohydrate content. This study can be an interesting insight for the community, breeders and policy makers.

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