SEPILOK BULLETIN

Volumes 21 & 22 June 2015 ISSN 1823-0067

SEPILOK BULLETIN

A journal of tropical forestry and related subjects.

Published by the Forest Research Centre, Sabah Forestry Department, Sandakan, Sabah, Malaysia.

SEPILOK BULLETIN
Vols. 21 & 22 June 2015

CONTENTS

Front cover: The moss *Leucobryum javense*, along the Mannan Trail of Trusmadi
(Photo: Andi Maryani A. Mustapeng)

Sepilok Bulletin 21 & 22: 1-16 (2015)

Butterflies and moths attracted to banana and prawn baits in a regenerated forest area formerly planted with rubber

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Abstract. Comparison of butterflies and moths was made between traps baited with banana and prawn at a regenerated lowland forest area formerly planted with rubber in Sabah, Malaysia. There was clear partitioning of groups shown in the annual samples. Lycaenid and hesperiid butterflies, micromoths were largely absent from banana baits, while satyrine butterflies, erebine and herminiine moths were comparatively scarce from prawn baits though other moth groups, geometrids in particular, were far more abundant in the prawn samples.

Keywords: baits, banana, biodiversity, Borneo, butterflies, forest, moths, plantation, prawn, rubber

INTRODUCTION

Research on fruit-feeding butterflies in the tropical rain forests of Borneo has been done by Beck & Schulze (2000), Hill *et al.* (2001), Hamer *et al.* (2003), Tangah *et al.* (2004), Dumbrell & Hill (2005), Benedick *et al.* (2006, 2009), and recently by Chey *et al.* (2014) on both butterflies and moths (Order: Lepidoptera) where a regenerated forest area formerly planted with rubber was shown to yield as high a lepidopteran diversity as a natural forest.

Using both banana and prawn baits at secondary vegetation in Genting, Peninsular Malaysia, Holloway *et al.* (2013) presented striking results of an annual sample with over twice as many species at higher taxonomic levels in the prawn traps. They also examined the method of bait-trapping for diversity of tropical Lepidoptera, with discussion on adult feeding behaviour.

The present exercise was conducted as a follow-up to the Genting samples, using rather similar sampling protocol, to examine the similarity and disparity of samples between the Malay Peninsula and Borneo.

MATERIALS & METHODS

Study site

A partially regenerated forest area previously planted with rubber, at the fringe of the Kawang Forest Reserve, about 30 km by road from the city of Kota Kinabalu, was the location for the study (see Chey *et al.* 2014). The area was planted with rubber prior to 1957 when the Kawang Forest Reserve was gazetted (Sabah Forestry Department 2005). Total area of the Kawang Forest Reserve was 1551 ha, of which secondary forest made up about 80%. No precise information on the size of the rubber plantation exists, but the present study area of forest with rubber remnants and wildings was estimated to be about 20 ha (Felix Vun Apin, pers. comm.). Rubber made up about 20% of the vegetation. Other than that, the area was dominated by pioneer species, with some *Eusideroxylon melagangai*, durian, and young dipterocarps (such as *Dryobalanops lanceolata*). Altitude for the study area ranged from 60 to 100 m.

Sampling using baited traps

There were three pairs of baited trap. Three traps were baited with rotting bananas and the other three with prawn heads. Each trap was about 100 cm in height and 30 cm in diameter, made of a nylon cylinder with a plastic plate on top and another plate at the bottom where the bait was placed (see Chey *et al.* 2014).

The three pairs of baited-traps, each pair consisting of a banana-baited trap and a prawn-baited trap, were placed in the study site. Each trap was suspended from a tree branch at about breast height. For each pair, the banana trap was about 10 m away from the prawn trap, providing the butterflies and moths choice. Each pair of traps was placed about 100 m away from the next pair.

The traps were checked the following day, and all the butterflies and moths within the traps were collected. The traps were run for three consecutive days per month, from July 2013 to June 2014. All the butterflies and moths were subsequently brought back to the insect museum of the Forest Research Centre in Sepilok for identification.

Identification

Butterflies sampled were identified using Otsuka (1988), Seki *et al.* (1991), Maruyama (1991), and Corbet & Pendlebury (1992), while moths were identified using Barlow (1982), Holloway (1985, 1988, 1993, 1996, 1997, 1998, 2003, 2005, 2008, 2009, 2011), Robinson *et al.* (1994), Inoue *et al.* (1982a,b), and Whitaker *et al.* (2014).

Analysis of data

The diversity of butterflies and moths in the annual samples was measured using the index Fisher's Alpha (α), and Preston's coefficient of faunal resemblance between banana and prawn samples was obtained. Fisher's α (Fisher *et al.* 1943) is independent of sample size where sampling completeness is low, and is under these conditions generally regarded as the best unitary measure of sample diversity (Taylor *et al.* 1976, Wolda 1981, Beck & Schwanghart 2010). Higher value of the index means higher diversity. Preston's coefficient of faunal resemblance (Preston 1962) based on presence/absence data gives species more equal weight and appears to be relatively robust when comparing samples of different sizes (Intachat *et al.* 1999). The coefficient ranges from 0 at total similarity to 1 at total dissimilarity.

RESULTS & DISCUSSION

Partitioning of groups

Appendix 1 shows the complete list of butterflies and moths sampled using the banana and prawn baits in Kawang. It can be seen from the matrix of figures that there is a clear partitioning of groups attracted to banana or prawn. Butterflies were generally more abundant in the banana-baited traps, but lycaenids and hesperiids were comparatively scarce. Moths on the other hand were higher in species and individuals in the prawn-baited traps except for the erebines and herminiines. Many adult erebines are known to feed on fruit in nature, some being pests in this respect (Holloway *et al.* 2013), and their larvae are defoliators, mostly of trees, with some preference shown for the families Fabaceae, Euphorbiaceae, Combretaceae and Sapindaceae. However, the herminiines probably only feed on fallen or rotting fruit and are not known as pests; their larvae are mostly general feeders on leaf litter and other vegetable detritus. Broadly speaking, the results here more or less concur with those of Genting (Holloway *et al.* 2013), though there are differences which will be discussed later.

Principal groups

The more common groups in terms of species attracted to banana and prawn are shown in Table 1.

For moths, the most common group attracted to banana was Herminiinae, and *Bocana manifestalis* Walker from the group was the most abundant species sampled with 203 individuals (Appendix 1). Erebinae, consisting many larger moths such as *Erebus ephesperis* Hubner and *Ischyja inferna* Swinhoe, was also highly attracted to banana. Scoliopteryginae appeared to be even for both banana and prawn. Most of the other moth groups were mainly attracted to prawn, with Ennominae alone yielding 46 species, followed by the micromoths of Pyraloidea with 23 species. The most abundant moth recorded was an endemic thyridid *Dysodia pennitarsis* Hampson (Robinson *et al.* 1994) with 260 individuals from the prawn traps (Appendix 1).

As for butterflies, it is obvious from Appendix 1 that with the exception of Lycaenidae and Hesperiidae, as well as Charaxinae, many were attracted to banana, the most abundant being the satyrine *Mycalesis orseis borneensis* Fruhstorfer with 47 individuals which was absent from the prawn samples. Satyrinae in particular and Morphinae were highly attracted to banana.

Table 1. Groups of butterflies and moths from banana and prawn traps with four species and above. Number of species in brackets.

Banana	**Prawn**
Herminiinae (28)	Ennominae (46)
Erebinae (27)	Pyraloidea (23)
Ennominae (13)	Lycaenidae (13)
Nymphalinae (7), Satyrinae (7)	Erebinae (9)
Morphinae (6)	Nymphalinae (8)
Scoliopteryginae (4)	Scoliopteryginae (5)
	Charaxinae (4), Desmobathrinae (4), Herminiinae (4), Hesperiidae (4), Thyrididae (4)

Diversity

The diversity values of Fisher's α based on the numbers of species and individuals are in Table 2.

The α value, numbers of species and individuals of the banana traps were similar to a previous sampling of 27 months at the same location in Kawang (Chey *et al.* 2014) with $\alpha = 39.57 \pm 5.08$, 114 species, 666 individuals. The observed similarity in α attests to its usefulness in assessing diversity. The numbers of species and individuals in the previous exercise were relatively low which could be caused by variability in natural factors.

Table 2. Fisher's α diversity values based on numbers of species and individuals sampled.

	Banana	Prawn	Total
Number of species (S)	111	141	223
Number of individuals (N)	598	809	1407
α (95% confidence range)	40.12 ± 5.37	49.37 ± 5.73	74.61 ± 6.67

The prawn bait yielded higher numbers of species and individuals and α value, mainly boosted by its ennomine and pyraloid moths (Appendix 1).

Altogether 223 species with 1407 individuals were recorded, yielding an α value of 74.61 ± 6.67. The total number of species was lower than that of Genting (Holloway *et al.* 2013) with 519 species, as the sampling was more intensive in the latter. Also, some of the more significant families recorded in Genting such as Tortricidae, Immidae, were not sampled in Kawang. *Melanitis* butterflies, *Amblychia* and *Sypnoides* moths were far more abundant in Genting. The numbers of Satyrinae and Morphinae were, however, relatively much higher from banana than prawn in Kawang compared to Genting. There were also relatively more ennomines in Kawang. The disparity could be due to difference in habitat and altitude as Genting at about 700 m is much higher than Kawang at about 100 m. Generally, the similarity of both banana and prawn samples between Kawang and Genting is evident, as shown in Table 3 with the numbers of shared genera in the major groups.

Table 3. Numbers of shared identified genera between Kawang and Genting for the major groups, followed by the numbers in Kawang (shared,Kawang).

Banana	Prawn
Herminiinae (7,8)	Ennominae (19,26)
Erebinae (13,15)	Pyraloidea (8,11)
Ennominae (0,9)	Lycaenidae (4,8)
Nymphalinae (4,6), Satyrinae (5,5)	Erebinae (3,7)
Morphinae (4,5)	Nymphalinae (2,5)
Scoliopteryginae (3,4)	Scoliopteryginae (2,4)
	Charaxinae (3,3), Desmobathrinae (1,1), Herminiinae (0,3), Hesperiidae (0,2), Thyrididae (4,4)

There were altogether only 29 shared species between the banana and prawn traps in Kawang (Appendix 1), yielding a Preston's coefficient of 0.822, meaning more than 80% of the species sampled were dissimilar, hence the clear partitioning of groups as noted earlier, and the considerable increase in the α value when the samples from the two baits are combined.

ACKNOWLEDGEMENTS

The authors would like to thank the staff of the Entomology Section of the Forest Research Centre, Sepilok, particularly Mr Momin Binti for help in fieldwork and identification, and also Mr Willibrord Jimin, Mr John Lee Yukang and Mr Saudi Bintang. The District Forest Officer of Kota Kinabalu, Mr Roslan Abdillah and his staff also provided support for the project.

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Appendix 1. List of butterflies and moths sampled using banana- and prawn-baited traps in Kawang, from July 2013 to June 2014. +Shared species between banana and prawn baits. *Endemic to Borneo.

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
NYMPHALIDAE																								
Satyrinae																								
Coelites euptychioides euptychioides C & R Felder											1													
Elymnias nesaea hypereides Fruhstorfer																		1						
Melanitis leda leda Linnaeus					1		1																	
Mycalesis anapita fucentia Fruhstorfer		2		2	1	4	2	1	2	3	2													
Mycalesis fusca adustata Fruhstorfer									1															
Mycalesis orseis borneensis Fruhstorfer	3	1	3	1	3	6	8		2	10	6	4												
Neorina lowii lowii Doubleday					1		1	1																
Xanthotaenia busiris burra Stichel									1		1													
Morphinae																								
Amathusia phidippus phidippus Linnaeus+					1		2	2	2	1		3					1	1			1			
Amathuxidia amythaon ottomana Butler		1		1																				
Discophora necho cheops C & R Felder+		1	1	1	1																2			
Discophora sondaica symphronia Fruhstorfer																				1		1	1	
Thaumantis klugius lucipor Westwood							1																	
Zeuxidia aurelius euthycrite Fruhstorfer				1	1		2		2		1	1												
Zeuxidia doubledayi horsfieldii C & R Felder	1							1			3	1												
Nymphalinae																								
Athyma kanwa kanwa Moore																							1	
Chersonesia rahria rahria Moore																						3	1	
Chersonesia risa cyanee De Niceville																						1		
Dophla evelina magama Fruhstorfer											1	1												
Euthalia iapis ambalika Moore										1														
Lexias dirtea chalcenoides Fruhstorfer	1								1			1												
Lexias pardalis dirteana Corbet+		2					1		1		2	1								1				
Stibochiona schoenbergi Honrath*											1	1												
Tanaecia orphne Butler*												1												
Terinos atlita fulminans Butler+								1														1	1	
Terinos terpander terpander Hewitson																					1			
Vindula dejone dejone Erichson														1				2	1		1	1		1
Vindula erota montana Fruhstorfer																							1	

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
Charaxinae																								
Charaxes bernardus repititus Butler															1			2	1	1	3	1		
Polyura athamas uraeus Rothschild & Jordan																	2		1			2		
Polyura moori saida Preyer & Cator																							1	
Prothoe franck borneensis Fruhstorfer+												1											1	
Danainae																								
Ideopsis vulgaris interposita Fruhstorfer																					1			
Parantica aspasia aspasia Fabricius													1								2			
LYCAENIDAE																								
Curetinae																								
Curetis felderi Distant			1																					
Curetis santana malayica C & R Felder																							1	
Lycaeninae																								
?*Arhopala pseudocentaurus nakula* C & R Felder															1									
Cheritra freja pallida H.H. Druce																						1		
Eooxylides etias Distant & Pryer*																							1	
Hypolycaena amasa maximinianus Fruhstorfer																						2		
Hypolycaena erylus teatus Fruhstorfer																	1							
Jacoona anasuja jusana H.H. Druce*																		1						
Jamides aratus adana H. Druce																						1		
Jamides pura tenus Fruhstorfer														1										
Nacaduba solta Eliot																		1						
Nacaduba sp.																								1
?*Prosotas* sp.																1								
Sinthusa makikoae H. Hayashi & Otsuka*																	1							
HESPERIIDAE																								
Hesperiinae																								
Burara harisa consobrina Plotz																					2			
Burara oedipodea oedipodea Swainson																							2	
Burara tuckeri Elwes & Edwards																							2	
Matapa cresta Evans																				1				
EREBIDAE																								
Erebinae																								
Anisoneura salebrosa Guenee																		1						
Avatha discolor Fabricius																							1	
Bastilla fulvotaenia Guenee						1																		

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
Ercheia cyllaria Cramer	1																							
Ercheia kebea Bethune-Baker									6															
Erebus caprimulgus Fabricius+					1	1													1					
Erebus ephesperis Hubner		2	4	1	9	14		1			2													
Ericeia korintjiensis Prout																		1						
Heterospila fulgurea Guenee+				1							1					1								
Hulodes caranea Cramer+		1	1			2						1							1					
Hypopyra lactipex Hampson				1																				
Hypopyra pallidigera Holloway				1																				
Hypopyra pudens Walker+				1	1	2	1	1	6		1		2											
Ischyja anna Swinhoe		1				2				1														
Ischyja hemiphaea Hampson											1	1												
Ischyja inferna Swinhoe		2	2		1		3	2	3	1	5	1												
Ischyja manlia Cramer	1	1									2													
Ischyja marapok Holloway	2	2					1		2		4	2												
Ischyja paraplesius Rothschild							1																	
Ischyja subreducta Holloway*									1	1	1													
Ischyja sp.									1															
Mocis undata Fabricius						1																		
Ommatophora luminosa Cramer		1										1												
Pindara illibata Fabricius									1															
Pterocyclophora ridleyi Hampson					1																			
Sypna albilinea Walker									1															
Sypna coelisparsa Walker																					1			
Sypna martina Felder																1								
Sypna sp.					1																			
Sypnoides infernalis Berio							3				1													
Thyas coronata Fabricius	1					1																		
Ugia viridior Holloway	1																							
Calpinae																								
Eudocima phalonia Linnaeus			3							1														
Eudocima srivijayana Banziger									2															
Phyllodes verhuelli Vollenhoven				1																				
Boletobiinae																								
Drepanorhina shelfordi Swinhoe*												2												
Maguda sp.+												6												1

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
Toanopsis homala Prout																						1		
Scoliopteryginae																								
Anomis scitipennis Walker+				1													1							
Dinumma combusta Walker		1				1						2												
Falana sordida Moore+						1			1												2			
Gonitis sumatrana Swinhoe																1								
Savara anomioides Walker+												1									1			
Savara pallidapex Holloway																		1						
Pangraptinae																								
Pangrapta holophaea Hampson		1					1																	
Pangrapta sp.																								1
Herminiinae																								
Adrapsa alsusalis Walker							1																	
Adrapsa angulilinea Prout							1																	
Adrapsa editha Swinhoe*							1																	
Adrapsa ereboides Walker						3			1															
Adrapsa terroides Holloway*					1																			
Bertula crucialis Felder & Rogenhofer						2																		
Bertula delosticha Swinhoe						1																		
Bertula inconspicua Swinhoe*										2	1	1												
Bertula insignifica Rothschild											1													
Bertula pallidicosta Holloway*+					1						1		1											
Bertula sphaerula Swinhoe*												1												
Bertula subnigripuncta Holloway*											2													
Bertula wallacea Holloway									1															
Bocana longicornis Holloway*							1	2	4															
Bocana manifestalis Walker+	5	6	5	21	32	92	19	1	15	1	6							2						
Bocana silenusalis Walker		1				10																		
Hepsidera ferruginea Holloway	1		1						1			1												
Herminiinae 1							1																	
Hipoepa fractalis Guenee																1								
Hipoepa sp.																1								
Hywoolla adda Swinhoe									1															
Hywoolla albapex Hampson						1	1		1															
Idia substigmata Holloway											1													
?*Naarda* sp.					1																			

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
?*Oxaenanus* sp.				2																				
Polypogon radula Holloway*							1																	
Simplicia anoecta Prout*					3						3													
Simplicia butesalis Walker			1																					
Simplicia concisalis Walker							1																	
Simplicia discosticta Hampson							1																	
Aganainae																								
Asota heliconia Linnaeus						1			1															
Mecodina poaphiloides Walker					2	4																		
Subfamily uncertain																								
Avittonia albidentata Hampson		1																						
NOCTUIDAE																								
Dyopsinae																								
Arcte modesta Hoeven																					2			
Cyclodes omma Hoeven																			1		2			
Acontiinae																								
Acontiinae 1					1																			
EUTELIIDAE																								
Euteliinae																								
Penicillaria plusioides Walker																							1	
NOLIDAE																								
Nolidae 1					1																			
GEOMETRIDAE																								
Ennominae																								
Amblychia angeronaria Guenee																		1			1		1	
Amblychia hymenaria Guenee																		1					1	
Amblychia infoveata Prout																				1				
Borbacha bipardaria Holloway+			1											2									1	
Borbacha punctipardaria Holloway+						2									1							1		
Catoria sublavaria Guenee																					2			
Chiasmia avitusaria Walker															2			1			3		4	2
Chiasmia fluidata Warren*																						1		
Chiasmia hygies Prout*																		2						
Chiasmia nora Walker															1									
Chiasmia ozararia Walker+								1							1						1	1	1	
Chiasmia translineata Walker																	1	1	3		2			

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
Chiasmia sp.																			1					
Cleora cucullata Fletcher																					1	1		
Cleora inoffensa Swinhoe+												1									2	1		
Cleora ?inoffensa Swinhoe																						1		
Coremecis incursaria Walker																							1	
Fascellina castanea Moore+			1		1	1							1					2	1		5			
Fascellina clausaria Walker								1																
Fascellina inconspicua Warren																					3			
Fascellina quadrata Holloway																							1	
Heterostegane warreni Prout																							1	
Hypomecis separata Walker																			1					
Lomographa luciferata Walker													4						2		2		3	5
Lomographa sectinota Hampson														1				2	2		3	1	1	
Luxiaria acutaria Snellen																						1		
Ophthalmitis clararia Walker															1		1						2	
Ophthalmitis rufilauta Prout*																					1	2		
Ophthalmitis satoi Holloway*															1									
Ourapteryx podaliriata Guenee																	1	3	3		6		1	
Parasynegia lineata Warren+				1		1																		1
Parasynegia sundastriaria Holloway																						1		
Pareumelea eugeniata Guenee														1									1	
Petelia delostigma Prout																					20		2	
Petelia distracta Walker													1											
Petelia medardaria Herrich-Schaffer+				1					1					1	1	5	2			1	13		1	2
Petelia paroobathra Prout+			1						1									1			15	1	3	1
Petelia sp.					1																			
Probithia exclusa Walker													1				1				2		1	
Probithia imprimata Walker+									1												5	1	1	1
Pseudalcis cinerascens Warren																				2				
Racotis boarmiaria Guenee																				1		1		
Ruttellerona pseudocessaria Holloway																						2		
Stalagmia guttaria Gray													1					1					1	
Sundagrapha lepidata Prout*																		1						
Tasta micaceata Walker+											1			1								1		
Thinopteryx crocopterata Kollar														2					2		2		1	
Xerodes ?ypsaria Guenee								1																

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
Xeropteryx columbicola Walker																	1	1		1			1	
Desmobathrinae																								
Eumelea ?djingga Sommerer																							1	
Eumelea florinata Guenee													1		1		1		1					1
Eumelea ludovicata Guenee																						1		
Eumelea rosalia Stoll																					1			
Sterrhinae																								
Antitrygodes divisaria Walker															1			1					1	1
Zythos strigata Warren													7											
Zythos turbata Warren+			1	1									23	8	8	2	1	5	14		20	2	9	1
URANIIDAE																								
Uraniinae																								
Urapteroides astheniata Guenee+											13	1	1	1			2						42	
CALLIDULIDAE																								
Tetragonus catamitus Geyer																						1		
DREPANIDAE																								
Drepaninae																								
Drapetodes fraterculа Moore									3															
THYRIDIDAE																								
Siculodinae																								
Collinsa sp.																			1		1		1	
Rhodoneura pudicula Guenee														1	1	2		2		2	4	2		
Thyridinae																								
Dysodia pennitarsis Hampson*+				3									6	15	3	5	8	26	47	17	52	46	27	8
Subfamily uncertain																								
Mellea sp.																		1						1
PYRALOIDEA																								
CRAMBIDAE																								
Spilomelinae																								
?Bradina sp.													1											
Conogethes sp.																			1					
?Conogethes sp.																1	1				1			3
Gadessa sp.																		1						
Glyphodes bivitralis Guenee														1		1	1	1	1	1	1			
Glyphodes sp.				1																				
Herpetogramma sp.																			4					

	Banana												Prawn											
	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	i	ii	iii	iv	v	vi
Hymenia sp.																					1	2		
?*Hymenia* sp.													1											
?*Nacoleia* sp.																1							2	2
Nevrina procopia Cramer														1										
?*Nevrina* sp.																								1
Notaspis sp.																						1		
Omiodes sp.																			1					
Pleuroptya sp.																			1					
Rhimphalea astrigalis Hampson																							4	
Rhimphalea sp.													1									1		
Spilomelinae 1															1									
Spilomelinae 2+												1												1
Spilomelinae 3																								1
Spilomelinae 4																							2	3
Syllepte sp.																							1	
PYRALIDAE																								
Epipaschiinae																								
?*Salma* sp.																1								
Pyralinae																								
?*Pyralis* sp.																				1				

Sepilok Bulletin 21 & 22: 17-26 (2015)

Diversity of praying mantis (Mantodea) in different habitat types in Sabah, Malaysia

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Abstract. A total of 818 individuals consisting of 38 species of praying mantis, belonging to seven families, was recorded from three study sites in Sabah. Most of the species and individuals were recorded from Danum Valley Conservation Area, a pristine Class I Protected Forest Area, with significant higher diversity indices (H', $1/D$, D_{Mg}) than Gomantong Virgin Jungle Reserve, a Class VI Protected Area, and Sukau Village, a residential area. Mantidae was the most dominant family with 16 species recorded accounting for 42% of total species collected. The most dominant species was *Hierodula* sp.1, making up 17% of total individuals.

Keywords: Borneo, Danum, diversity, forest, Gomantong, habitat, Mantodea, praying mantis, Sukau

INTRODUCTION

Praying mantis (Order: Mantodea) are fascinating insects because of their spectacular body shape, colour and behaviour. Being predatory insects, they play an important role by preying on other insects and may be useful for biological control of insect pests.

Approximately 2400 species have been described worldwide (Ehrmann 2002) and praying mantis exhibit extensive variations in morphological adaptation in relation to their habitat. Tropical regions are believed to harbour a diverse array of mantis species but have received little attention (Rivera & Svenson 2014). Schwarz & Konopik (2014) reported that Borneo is recognized as the island with the highest mantodean diversity known to date (118 species).

Mantis are highly cryptic, often resembling their surroundings by body structure in the shape of sticks, barks, dead leaves, flowers and many other types of camouflage. Therefore, vegetation types and structures are important for mantis to ambush prey and avoid predators.

Some information of habitat preference for praying mantis has been documented (Hill *et al* 2004) but very few studies have been conducted in Borneo looking into this aspect. This study was conducted to investigate the diversity and composition of praying mantis from different habitat types in Sabah, Borneo, and some findings were published earlier (Ling *et al.* 2013). This present paper is an update.

MATERIALS & METHODS

This study was conducted in August-December 2008, and May-June 2009, at three different habitat types.

Study sites

(1) Danum Valley Conservation Area (DVCA), Class I Protected Area (N 04°57'44", E 117°48'20")

DVCA is an intact, undisturbed lowland forest. The area is located within Lahad Datu district, eastern part of Sabah. It is situated within the Yayasan Sabah Concession Area covering about 43800 ha of primary rainforest. It is the largest remaining pristine rainforest in Sabah. Most of the area (91%) is covered with lowland evergreen dipterocarp forest (Reynolds *et al.* 2011). Species of the family Dipterocarpaceae make up approximately 88% of the total volume of large trees in DVCA (Marsh & Greer 1992).

(2) Gomantong Virgin Jungle Reserve (VJR), Class VI Protected Area (N 05°32'15", E 118°04'74")

Gomantong VJR is considered as a less disturbed habitat. It is located in the Lower Kinabatangan floodplains, surrounded by Gomantong Forest Reserve (Class I Protected Area). The VJR comprises approximately 1816 ha of forested area. These protected areas are among the oldest existing reserves in Sabah. The famous Gomantong Caves are situated here. The bird's nests collection is conducted twice yearly from 18 caves managed by the Sabah Wildlife Department. Much of the VJR is primary forest, but there are areas with old-growth secondary mixed dipterocarp forest. Some slopes in the southeast were affected by fires (Sabah Forestry Department 2005).

(3) Sukau Village (N 05°30'58", E 118°17'40")

Sukau Village was selected as a disturbed habitat. It is a residential area, situated on the lower part of Kinabatangan River, second longest river in Malaysia. This area is adjacent to Kinabatangan Wildlife Sanctuary (KWS), a protected area which is important for conservation of primates, large mammals and other wetland wild animals such as otters and Storm's stork. Sukau Village is a well-known area for eco-tourism. There are several attractions such as the presence of flagship wildlife species including proboscis monkey, Asian pygmy elephant and orang-utan. Oil palm plantations have become an important income for the villagers. As a result, many of them have converted their land to plantation (Fletcher 2009).

Sampling methods

Mantis were sampled by using light-trap and direct searching. In addition, six baited traps were set up at DVCA for one week to test the efficiency of this method in attracting mantis. At each site, sampling was carried out twice consisting of 10 days per sampling. In total, 60 sampling days were carried out throughout the study.

For the light-trap method, mantis were sampled from 1800h to 2400h. Light-trap has been proven as an efficient way to attract mantis (Ehrmann 2002, Helmkampf *et al.* 2007). While conducting the trapping, mantis were also searched for manually within a 5 m radius around the light-trap. Surrounding vegetation was checked thoroughly.

Baited traps were set up randomly along 100 m line transect at West Trail of DVCA (West 9.5; N 04°57'43.8", E 117°48'20.9") for seven consecutive days. Different baits of shrimp paste (1 trap), ripped bananas (3 traps), corned beef (1 trap) and canned tuna (1 trap) were used. The idea was not to trap mantis directly. Baited traps were used based on the fact that aroma from different baits attracts different insects such as butterflies, flies, ants and bees to the traps, which indirectly attracts mantis to come and prey on these insects.

Data analyses

The Shannon-Wiener's Diversity Index (*H'*) was used to measure the species diversity of praying mantis from each site. This index combines richness and abundance into a single measure (Magurran 1988). Simpson's Reciprocal Index (*1/D*) was used to measure species equitability of each study site. Species richness of the mantis sampled in this study was measured by using Margalef's Index (D_{Mg}). Pairwise comparisons using randomization tests based on 10000 random samples (Solow 1993) were performed to compare all the diversity indices between the study sites. All the statistical analyses were performed by using the software 'Species diversity and richness' (Henderson & Seaby 1998).

RESULTS

A total of 818 individuals was recorded from the three different sites. They consisted of seven families and 38 species. The largest and dominant family was Mantidae with 426 individuals accounting for 52% of the total individuals recorded. This family was represented by 16 species accounting for 42% of total number of species recorded in this study. *Hierodula* sp.1 was the dominant species represented by 139 individuals or 17% of the total sampled.

Table 1. List of praying mantis species and individuals at the three different study sites.

Family/ Subfamily/ Species	Sukau Village	Gomantong VJR	DVCA
Amorphoscelidae			
Amorphoscelinae			
Amorphoscelis borneana	0	0	4
Amorphoscelis rufula	0	0	13
Hymenopodidae			
Acromantinae			
Acromantis moultoni	0	0	4
Acromantis sp.	0	2	69
Citharomantis falcata	0	0	1
Ephestiasula sp.	0	0	59
Hestiasula phyllopus	0	0	1
Psychomantis borneensis	0	11	45
Rhomantis moultoni	0	0	6
Hymenopodinae			
Creoboter sp.	0	0	4
Hymenopus coronatus	0	0	1
Theopropus borneensis	1	0	3
Oxypilinae			
Ceratomantis kimberlae	0	0	1
Iridopterygidae			
Iridopteryginae			
Hapalopeza tigrina	1	1	0
Tropidomantinae			
Tropidomantis tenera	0	1	37
Liturgusidae			
Liturgusinae			
Humbertiella ocularis	1	0	14
Majangella moultoni	0	0	7
Theopompa borneana	0	0	6
Theopompa tosta	0	1	23
Mantidae			
Amelinae			
Amantis reticulata	7	0	0
Gonypeta sp.	0	3	4
Angelinae			
Euchomenella matilei	20	8	49

Family/ Subfamily/ Species	Sukau Village	Gomantong VJR	DVCA
Deroplatyinae			
Deroplatys desiccata	0	1	7
Deroplatys moultoni	0	0	2
Deroplatys truncata	0	0	37
Mantinae			
Tenodera sp.1	9	2	1
Tenodera sp.2	7	39	0
Tenodera sp.3	20	28	0
Paramantinae			
Hierodula heteroptera	0	0	2
Hierodula sp.1	7	19	113
Hierodula sp.2	0	0	3
Rhombodera basalis	0	0	6
Statilia maculata	1	17	2
Phyllotheliinae			
Ceratocrania macra	0	4	8
Phyllothelys decipiens	0	0	1
Tarachodidae			
Caliridinae			
Gildella suavis	0	0	1
Leptomantella sumatrana	0	6	66
Thespidae			
Haaniinae			
Haania borneana	0	0	1
Total species	10	15	34
Total individuals	74	143	601

The family Hymenopodidae was well presented with 11 species (29%). The least number of species was recorded from the family Thespidae with only one species represented by a single individual in DVCA. Tarachodidae was represented by two species *Leptomantella sumatrana* (6 + 66 individuals) and *Gildella suavis* (one individual in DVCA). In this study, *G. suavis* was the only species sampled by the baited trap technique, and was not recorded from other methods. All the three sampling sites shared four families (Mantidae, Hymenopodidae, Liturgusidae and Iridopterygidae) and four species (*Euchomenella matilei*, *Tenodera* sp.1, *Hierodula* sp.1, *Statilia maculata*).

Most of the individuals were collected from DVCA (601 individuals) representing seven families and 34 species. The families Amorphoscelidae and Thespidae were only found in DVCA. Eight singleton species (represented by one individual) were recorded from this area. From this study 19 species (50%) were recorded only from DVCA. Gomantong VJR recorded 143 individuals from 5 families and 15 species, with four singletons sampled from this area. No species was recorded exclusively from Gomantong VJR. The least number of individuals and species was recorded from Sukau Village. Four families represented by 10 species and 74 individuals were recorded from this area, including four singletons. *Amantis reticulata* was recorded only from this study site.

The Shannon-Wiener's Diversity Index (H') was found higher in DVCA, followed by Gomantong VJR and Sukau Village. Similarly, Simpson's Reciprocal Index ($1/D$) and Margalef's Index (D_{Mg}) also showed the same pattern (Table 2).

Table 2. The diversity indices in the three study sites.

	DVCA	Gomantong VJR	Sukau Village
Shannon-Wiener (H')	2.70	2.13	1.87
Simpson ($1/D$)	10.86	6.61	5.64
Margalef (D_{Mg})	5.16	2.82	2.09

The pairwise comparison test showed that all of the diversity indices were significantly higher in DVCA compared to Gomantong VJR and Sukau Village ($P < 0.05$). However, the diversity indices in Gomantong VJR were not significantly different from Sukau Village ($P > 0.05$) (Table 3).

Table 3. Pairwise comparison of diversity indices between study sites.

	H'	$1/D$	D_{Mg}
DVCA vs Gomantong VJR	$\Delta = 0.57$ $P = 0.00$	$\Delta = 4.25$ $P = 0.01$	$\Delta = 2.33$ $P = 0.00$
DVCA vs Sukau Village	$\Delta = 0.83$ $P = 0.00$	$\Delta = 5.22$ $P = 0.01$	$\Delta = 3.07$ $P = 0.00$
Gomantong VJR vs Sukau Village	$\Delta = 0.26$ $P = 0.08$	$\Delta = 0.98$ $P = 0.42$	$\Delta = 0.73$ $P = 0.16$

DISCUSSION

Habitat loss has been identified as a major factor driving extinction (Gröning *et al.* 2007). Habitat requirements of many species, particularly invertebrates, are less known. Mantis are highly dependent on their surrounding vegetation for prey and to avoid predators. Therefore habitat structures are important for survival of mantis species (Hill *et al.* 2004).

Mantidae are mostly leaf, grass and stick mantis which have colours and shapes resembling grasses and twigs. They live in grasses, trees, shrubs, and long and thin vegetation. They stay in flattened resting position and show dash-then-freeze strategy when they are disturbed (Ghose *et al.* 2009), so they are hardly noticeable when dwelling on grass and stick. Most of the species in this family can be found in all the three study sites.

Most of the *Tenodera* species (grass mantis) were abundant in Sukau Village and Gomantong VJR, but not in DVCA. However, species of the genus *Deroplatys* (dry leaf mantis), and species from the families Liturgusidae and Amorphoscelidae (bark-mimics) (Svenson 2014) showed the opposite result. This could be explained by the vegetation type in DVCA, which mainly consists of Dipterocarpaceae-dominated forest. The forest floor is usually covered with dry leaves and has less understorey vegetation such as herbs and grasses. Therefore, DVCA provides a good habitat (tree trunks) for the bark-mimic mantis (Liturgusidae, Amorphoscelidae) and many species of *Deroplatys* which require habitat with dry leaves, but poor habitat for grass and stick mantis. Similar result was reported by Helmkampf *et al.* (2007). The family Liturgusidae has a single subfamily with 17 genera and 65 species worldwide. The Bornean mantis comprise three genera and four species (*Humbertiella ocularis*, *Majangella moultoni*, *Theopompa tosta* and *T. borneana*) (Bragg 2010) and all the species can be found in DVCA.

Humidity is important for moulting and colouration of some mantis species. In some genera such as *Miomantis* and *Sphodromantis*, high humidity produces green form individuals, while dry conditions tend to produce the brown form. The difference in colour forms probably has survival value in relation to the surroundings (Balderson 1991).

The species of the family Hymenopodidae (flower mantis) were also less commonly found in Gomantong VJR and Sukau Village. This family requires prefect conditions (humidity) for moulting. Their legs are petal-like in shape and they are usually present in areas with flowers such as orchids (Roy 1999). DVCA is a pristine area which can provide excellent moulting conditions for this family. There was a wide range of species from this family collected from DVCA, e.g. three species of the subfamily Hymenopodinae (*Creobroter* sp., *Hymenopus coronatus* and *Theopropus borneensis*).

In this study, many species were sampled as singletons which may indicate rare species. This result may reflect the importance of these species which may be endangered due to their low abundance. However, this result may also be due to under-sampling bias as documented in many other tropical arthropod studies (Coddington *et al.* 2009). In DVCA, seven singletons sampled were not present in the two other sites. This result may imply the importance of habitat conservation.

Mantodean diversity may be affected indirectly by habitat structure (Hill *et al.* 2004) and plant diversity. In contrast to this study, Helmkampf *et al.* (2007) found that the diversity of praying mantis was higher in disturbed habitat (farmland) compared to the secondary and primary forests, but their result might be confounded by influx of mantis from the less disturbed area in the vicinity into the farmland. As mantis are generalist predators that feed on wide variety of taxa, they are not dependent on specific prey species. Highly productive habitats which support various organisms would provide good conditions for high abundance and diversity of mantis.

ACKNOWLEDGEMENTS

We are grateful to UMS (PRGS) and World Federation of Scientists (WFS) for financial support. We would like to thank all staff at Danum Valley Field Centre (DVFC) and Datuk Dr Glen Reynolds of the Royal Society (UK) for their kind assistance. We are also thankful to Dr Phil Bragg for identification of specimens and contribution of references. Dr Jan Beck of University of Basel, Switzerland, kindly commented on the manuscript.

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Sepilok Bulletin 21 & 22: 27-48 (2015)

Mosses of Sinua at eastern part of Trusmadi Forest Reserve, Sabah, Malaysia

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Abstract. A study on mosses was conducted at the eastern part of Trusmadi Forest Reserve (Trusmadi FR) during the Trusmadi-Sinua Scientific Expedition in 2011. A total of 151 specimens of mosses was collected comprising 24 families, 46 genera, and 83 species with two additional varieties. They represent 13.8% and 11.5% of the moss taxa found in Sabah and Borneo, respectively. The most common families were Leucobryaceae with nine species and a variety, followed by Sematophyllaceae, Pylaisiadelphaceae and Hypnaceae with eight species each. Among the species collected, 41 species are new records for Trusmadi FR, nine species new records for Sabah, and five species new additions to the moss flora of Borneo.

Keywords: Borneo, mosses, new records, Sinua, Trusmadi

INTRODUCTION

Trusmadi Forest Reserve (Trusmadi FR), Class I Protection Forest, is managed by Forest Management Unit No. 10 (FMU 10) under the Sabah Forestry Department, with an area of 74,736 ha (Sabah Forestry Department 2011). Mount Trus Madi (2,642 m), the second highest mountain in Malaysia, is located in the centre of the approximately 80 km Trusmadi range. This is partly located in Trusmadi FR (Figure 1).

There are three trails that lead to the summit of Mount Trus Madi: viz. Kaingaran Trail (Tambunan), Mannan Trail (Sinua, Keningau) and Mastan Trail (Apin-Apin, Keningau). The Trusmadi-Sinua Scientific Expedition was conducted from 24 October to 2 November 2011 along the Mannan Trail, at the eastern part of Trusmadi FR. The Mannan Trail is the longest trail among the three trails to the summit of Mount Trus Madi. It is 11.6 km from the expedition base-camp (5°30.219 N, 116°34.402 E) starting from 670 m a.s.l. near Kg. Sinua, Keningau (Figure 1).

Mannan Trail has three forest types, namely upland mixed dipterocarp forest, lower montane forest and upper montane forest. The climate is hot and humid in the base-camp with temperature at 26-32°C and becomes colder at 8-16°C near the cloud forest and summit zone (Sugau 2011). The soil of Trusmadi FR consists mainly of tertiary formation mudstone, shale and argillite with subordinate beds of quartzite, sandstone, siltstone, and limestone breccia (Acres 1972).

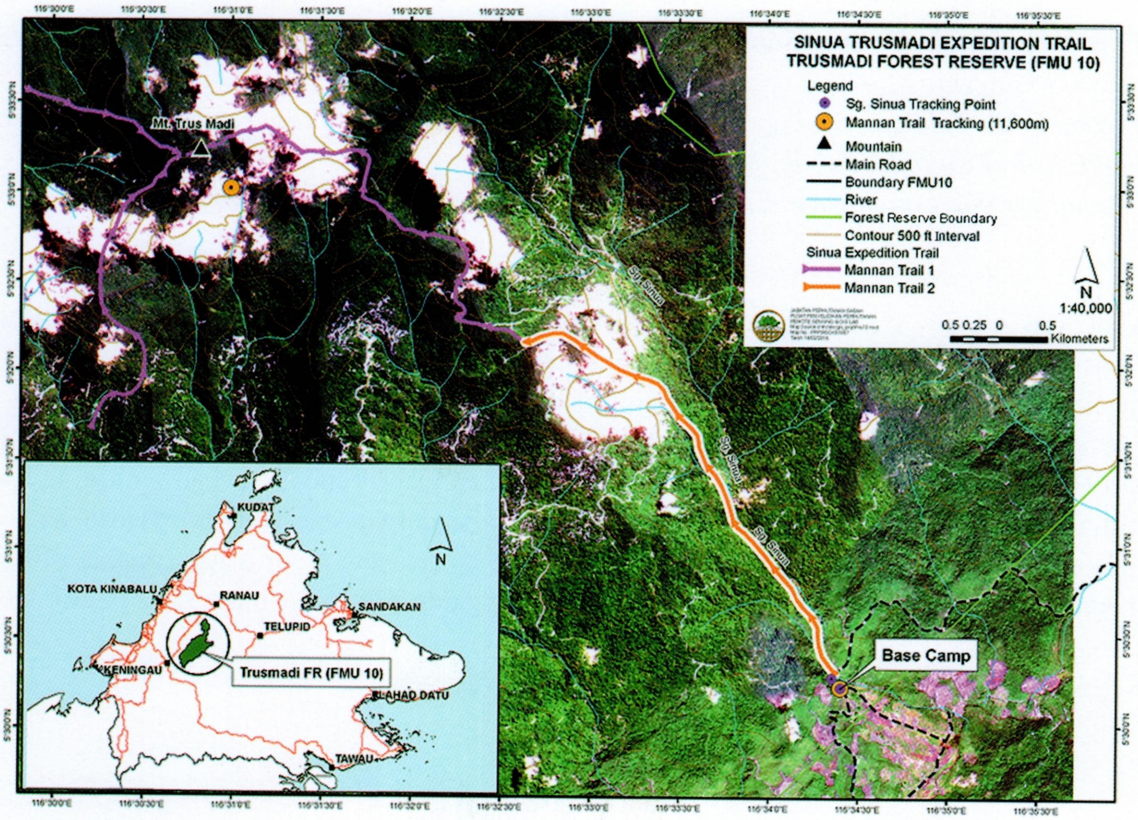

Figure 1. Map showing the location of Trusmadi-Sinua Scientific Expedition. Inset: Map of Sabah showing Trusmadi Forest Reserve.

The only documented survey on mosses in Sinua was by Suleiman & Edwards (2002). However, they only collected 48 taxa of mosses from lowland secondary forest during the survey in 1996. Thus, the objective of the present study was to prepare a complete checklist of mosses from Sinua and to determine new records of mosses from this area.

MATERIALS & METHODS

Moss specimens were collected along the Mannan Trail from the base-camp to the summit of Mount Trus Madi covering an altitudinal gradient from 670 m to 2,642 m. However, most of the specimens were collected within 670 m to 1,500 m. In addition to Mannan Trail, specimens were also collected in the riparian zone along a stream adjacent to the base-camp. Information on habitat and substrate was recorded for each specimen. Specimens were deposited at the SAN Herbarium, with duplicates at the BORNEENSIS Herbarium (BORH) of Universiti Malaysia Sabah. The sequence arrangement of families followed that of Goffinet *et al.* (2009). Species validity and distribution were according to the TROPICOS (www.tropicos.org) and The Plant List 1.1 (www.theplantlist.org) databases, with slight modifications based on available literature.

RESULTS & DISCUSSION

A total of 175 bryological specimens was collected of which 151 specimens were classified as mosses. The mosses were from 24 families, 46 genera, 83 species with two additional varieties (Table 1, Appendix 1). This number represents 13.8% of the 618 reported taxa of mosses in Sabah, and 11.5% of the 741 reported taxa of mosses in Borneo (Andi & Suleiman 2005, Ellis *et al.* 2010, Higuchi *et al.* 2008, Ho *et al.* 2010, Mohamed *et al.* 2010, Suleiman *et al.* 2006, Suleiman & Akiyama 2007, Suleiman *et al.* 2009, Suleiman *et al.* 2011). The highest number of species was from the Leucobryaceae with nine species and one variety. This is followed by the Sematophyllaceae, Pylaisiadelphaceae and Hypnaceae, each with eight species of mosses (Table 1). These three families are common in lowland areas in Borneo.

The number of montane species collected was low due to limited time spent in the summit zone during the expedition. Montane genera like the *Sphagnum* and *Dawsonia* were not collected on the Mannan Trail. In contrary, Suleiman & Edwards (2002) reported two species of *Sphagnum* and three species of *Dawsonia* from Kaingaran Trail, collected from 1,400 m to the summit region. Several taxa from their collection are common to montane areas, such as species of *Dicranoloma* and *Macromitrium*. Both of these genera are commonly found above 1,400 m a.s.l. but were not collected in the present study. Interestingly, the Kaingaran Trail was also dominated by lowland families such as Sematophyllaceae and Pylaisiadelphaceae. Pylaisiadelphaceae is a new family separated from Sematophyllaceae and Hypnaceae (Goffinet *et al.* 2009). The genera listed under this family that were found on Mannan Trail are *Isopterygium*, *Mastopoma*, *Taxithelium*, *Trismegistia* and *Wijkia*.

The present collection included five new records for Borneo, namely *Bryum rubens* Mitt., *Eurhynchium asperisetum* (Müll.Hal.) E.B.Bartram, *Hyophila javanica* (Nees & Blume) Brid., *Philonotis falcata* (Hook.) Mitt., and *Philonotis turneriana* (Schwägr.) Mitt. In addition, nine species are new records for Sabah, and 41 species are new records for Trusmadi FR

(Appendix 1). With these latest additions, Trusmadi FR has now 194 taxa of mosses recorded, which is ca. 26% of the mosses reported for Borneo and half of that of Mount Kinabalu. This shows that Trusmadi FR is an important habitat for mosses and more research is needed to further determine its richness.

Table 1. Summary of the mosses collected from Sinua, Trusmadi FR.

No.	Family	Genus	Species
1	Bartramiaceae	1	5
2	Brachytheciaceae	3	3
3	Bryaceae	1	3
4	Calymperaceae	4	7
5	Daltoniaceae	1	1
6	Dicranaceae	1	1
7	Fissidentaceae	1	5
8	Hypnaceae	2	8
9	Hypnodendraceae	1	3
10	Hypopterygiaceae	2	2
11	Leskeaceae	1	1
12	Leucobryaceae	4	9 + 1 var.
13	Meteoriaceae	2	3
14	Neckeraceae	2	3
15	Phyllodrepaniaceae	1	1
16	Pilotrichaceae	1	1 + 1 var.
17	Polytrichaceae	1	3
18	Pottiaceae	1	2
19	Pterobryaceae	1	1
20	Ptychomniaceae	1	1
21	Pylaisiadelphaceae	5	8
22	Rhizogoniaceae	1	1
23	Sematophyllaceae	6	8
24	Thuidiaceae	2	3
	Sum	**46**	**83 + 2 var.**

ACKNOWLEDGEMENTS

We would like to thank the FMU10 Trusmadi MPCT (Management Planning Core Team) and the Forest Research Centre (FRC) of the Sabah Forestry Department for jointly organising and funding the expedition. Special thanks to Mr Jameson Jumian, Mr Peter

Sumpit, Ms Juraidah Nasser (practical student) and Mr Markus Gumbilil for their assistance during the field surveys. We are also indebted to Mr Mohamad Jumri Abd. Hamid (GIS Unit of FRC) who provided the map.

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Some common and interesting moss species in Sinua, Trusmadi FR.
(All photos by Andi Maryani A. Mustapeng except where indicated)

Figure 2. *Leucobryum javense.*

Figure 3. *Leucobryum sanctum.*

Figure 4. *Calymperes porrectum.*

Figure 5. *Claopodium prionophyllum.*

Figure 6. *Pyrrhobryum spiniforme.*

Figure 7. *Pogonatum piliferum.*
(Photo: Monica Suleiman)

Appendix 1. Checklist of mosses from Sinua, Trusmadi Forest Reserve.

Presented below is a list of the mosses collected in the present study. Species reported for the first time for Trusmadi FR, Sabah and Borneo are marked with (*), (**), and (***), respectively.

POLYTRICHACEAE

Pogonatum cirratum subsp. *fuscatum* (Mitt.) Hyvönen

On clay-soil, along trails, in partially shaded area, 889-1137 m alt., TMS Andi 10, 64.

Pogonatum neesii (Müll.Hal.) Dozy

On stone-wall, sometimes moist, by a stream, in full shade, 643 m alt., TMS Andi 79, 84.

Pogonatum piliferum (Dozy & Molk.) A.Touw (Figure 7)

Growing on soil and small boulder, along trails, in partially shaded area, 1120-1150 m alt., TMS Andi 47, 68.

FISSIDENTACEAE

**Fissidens ceylonensis* Dozy & Molk.

On clay-soil along a trail, in partially shaded area, 1142 m alt., TMS Andi 52.

**Fissidens crenulatus* var. *elmeri* (Broth.) Z.Iwats. & Tad.Suzuki

On soil by a stream, close to base-camp area, in full shade, 643 m alt., TMS Andi 94.

**Fissidens crispulus* Brid.

On stone-wall, sometimes wet, by a stream, in full shade, 638.5-671 m alt., TMS Andi 77, 82(a), 83, 108, 138.

**Fissidens nobilis* Griff.

On moist stone-wall by a stream, in partially shaded area, 704 m alt., TMS Andi 117, 118.

Fissidens wichurae Broth. & M.Fleisch.

On stone-wall, with clay-soil along a trail, in partially shaded area, 1200 m alt., TMS Andi 33.

DICRANACEAE

**Leucoloma molle* (Müll.Hal.) Mitt.

On rotten log along a trail, in partially shaded area, 1051 m alt., TMS Andi 16.

LEUCOBRYACEAE

**Campylopus comosus* (Schwägr.) Bosch & Sande Lac.

On soil along a trail, in open area, 1000 m alt., TMS Andi 70.

Campylopus exasperatus (Nees & Blume) Brid.

On humus, on the summit of Mount Trus Madi, in open area, 2633 m alt., TMS J3.

Dicranodontium uncinatum (Harv.) A.Jaeger

On humus, with soil, on the summit of Mount Trus Madi, in open area, 1943-2642 m alt., TMS J1, J2, J4, J11, J25.

Leucobryum aduncum Dozy & Molk. var. *aduncum*

On decaying fallen log, by a stream, in partially shaded area, 980 m alt., TMS Andi 72.

Leucobryum aduncum var. *scalare* (Müll.Hal. *ex* M.Fleisch.) A.Eddy

Growing on decaying fallen logs, along a trail and by a stream, in partially shaded area, 843-903 m alt., TMS Andi 8, 12.

Leucobryum bowringii Mitt.

On rotten log by a stream, in partially shaded area, 730 m alt., TMS Andi 135(a).

Leucobryum chlorophyllosum Müll.Hal.

Growing on decaying, rotten and fallen logs, along trails, and by a stream close to base-camp area, from partial to full shade conditions, 704-1140 m alt., TMS Andi 9, 58, 63, 126, 133(b).

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

On decaying fallen log and soil, along trails and by a stream, in partially shaded area, 843-1100 m alt., TMS Andi 7, 69.

**Leucobryum sanctum* (Nees *ex* Schwägr.) Hampe (Figure 3)

On decaying and rotten logs, along trails and by a stream, from partial to full shade conditions, 706-901 m alt., TMS Andi 11, 129.

Schistomitrium apiculatum (Dozy & Molk.) Dozy & Molk.

On rotten log by a stream, close to base-camp area, in full shade, 730 m alt., TMS Andi 133(a).

CALYMPERACEAE

Arthrocormus schimperi (Dozy & Molk.) Dozy & Molk.

On moist rotten log by a stream, close to base-camp area, in partially shaded area, 710-730 m alt., TMS Andi 131, 132(b).

**Calymperes porrectum* Mitt. (Figure 4)

On fallen log by a stream, close to base-camp area, sometimes moist, from partially shaded to full shaded areas, 643 m alt., TMS Andi 89(a), 90(a), 91, 92.

**Leucophanes glaucum* (Schwägr.) Mitt.

On moist stone wall, by a stream, close to base-camp area, in full shade, 704 m alt., TMS Andi 120.

Leucophanes octoblepharioides Brid.

On treelet root by a stream, close to base-camp area, in full shade, 704 m alt., TMS Andi 122.

Syrrhopodon albo-vaginatus Schwägr.

On rotten log, by a stream, close to base-camp area, in partial shade, 730 m alt., TMS Andi 132(a).

**Syrrhopodon loreus* (Sande Lac.) W.D.Reese

On rotten log by a stream, in partially shaded area, 730 m alt., TMS Andi 135(b).

Syrrhopodon muelleri (Dozy & Molk.) Sande Lac.

On tree trunk, by a stream, in partially shaded area, 638 m alt., TMS Andi 139.

POTTIACEAE

**Hyophila involuta* (Hook.) A.Jaeger

On wet to dry boulders, and moist stone-walls, by a stream, close to base-camp area, from open to full shade conditions, 643-704 m alt., TMS Andi 73, 75, 102, 109, 123.

****Hyophila javanica* (Nees & Blume) Brid.

On moist stone-wall, by a stream, in full shade, 643 m alt., TMS Andi 82(b). This species is similar in habit to *H. involuta* but much smaller, the stems seldom exceeding 5 mm in height (Eddy 1990). Rather uncommon, growing on damp rocks and in shaded area. Eddy (1990) reported that this species was found in Java, Sumatra and adjacent islands. It is also recorded in China (Redfearn & Wu 1986).

BRYACEAE

Bryum coronatum Schwägr.

On moist stone-wall by a stream, close to base-camp area, in full shade, 643 m alt., TMS Andi 80(a), 81.

**Bryum mildeanum* Jur.

On wet boulder by a stream, in full shade, 692 m alt., TMS Andi 101.

****Bryum rubens* Mitt.

On moist soil by a stream, close to base-camp area, in full shade, 643 m alt., TMS Andi 95. This is a small and delicate species and shoots are usually not more than 1 cm tall. The bright red tubers (white when young) at the base of the lower leaves is the best character to recognise this moss in the field. It is common in the temperate northern hemisphere, India, and Japan; also reported in Sulawesi from disturbed ground in high-altitude forest (Eddy 1996). This species is also distributed in

United States, New Zealand and South Africa.

PHYLLODREPANIACEAE

**Mniomalia semilimbata* (Mitt.) Müll.Hal.

On fallen log by a stream, intermingled with other mosses, in partially shaded area, 643 m alt., TMS Andi 90(d).

BARTRAMIACEAE

Philonotis bartramioides (Griff.) D.G.Griffin & W.R.Buck

On decaying log by a stream, in partially shaded area, 643 m alt., TMS Andi 86.

****Philonotis falcata* (Hook.) Mitt.

On moist stone-wall and wet boulders, by a stream, in full shade, 643-692 m alt., TMS Andi 100, 104. This is one of the robust Malesian species of the genus, and can be recognized in the field by having strictly 5-ranked and triangular leaves, with short apices and plane upper margins. It is widespread in Asia and Malesia, from India and Burma to Malaya and most of the larger Malesian islands (Eddy 1996).

**Philonotis hastata* (Duby) Wijk & Margad.

On stone-wall by a stream, close to base-camp area, in partial shade, 643 m alt., TMS Andi 74.

****Philonotis turneriana* (Schwägr.) Mitt.

On soil along a trail, in partially shaded area, 1347 m alt., TMS Andi 19. This species is close to *P. falcata* but easily distinguished by the former's long excurrent costae. It is reported to be widespread in continental Asia, especially northern India, extending eastwards to China and Japan; rather local in Malesia, such as in Java, Sumatra and the Philippines (Eddy 1996). This species was also reported previously from Himalayas, Burma, Hong Kong, Korea, and Hawaii (http://moss.biota.biodiv.tw/pages/580).

Philonotis sp.1

On moist stone-wall, by a stream, in full shade, 643 m alt., TMS Andi 80(b). This species is small, has only 1.1 mm long leaves, and differs from other *Philonotis* species with percurrent costae, not vanishing below leaf apex. It is close to *P. hastata* but it is difficult to identify it to species level without the capsule.

RHIZOGONIACEAE

Pyrrhobryum spiniforme (Hedw.) Mitt. (Figure 6)

On tree trunk, fallen and rotten logs, by streams and trails, from partial to full shade conditions, 706-1290 m alt., TMS Andi 29, 53, 127.

HYPNODENDRACEAE

Hypnodendron dendroides (Brid.) A.Touw

On humus by a trail, slope area, partially shaded, 2315 m alt., TMS J23.

**Hypnodendron fuscomucronatum* (Müll.Hal.) A.Jaeger & Sauerb.

On moist stone-wall, by a stream, in full shade, 671 m alt., TMS Andi 111. This species is also found in the Philippines.

**Hypnodendron subspininervium* subsp. *arborescens* (Mitt.) A.Touw

On fallen log by a stream, in partially shaded area, 643 m alt., TMS Andi 90(b).

PTYCHOMNIACEAE

**Garovaglia plicata* (Brid.) Bosch & Sande Lac.

On decaying root, along a trail, in partially shaded area, 1138 m alt., TMS Andi 60.

HYPOPTERYGIACEAE

***Cyathophorum hookerianum* (Griff.) Mitt.

On fallen log by a stream, in partially shaded area, 643 m alt., TMS Andi 90(e). This species was reported in Sarawak by Kruijer (2002), and from Kalimantan Timur by Suleiman & Wiriadinata (2003). It is also distributed in mainland China, the Philippines, Laos, Sikkim, the Ryukyus and Japan.

**Hypopterygium tamarisci* (Sw.) Brid. *ex* Müll.Hal.

On small boulder along a trail, in partially shaded area, 1200 m alt., TMS Andi 31.

DALTONIACEAE

Distichophyllum malayense Damanhuri & Mohamed

On boulder along a trail, in partially shaded area, 1348 m alt., TMS Andi 26(b).

PILOTRICHACEAE

Callicostella papillata (Mont.) Mitt. var. *papillata*

Growing on fallen, and rotten logs, boulders, and stone-wall, along trails and by streams, in partially shaded area, 671-1156 m alt., TMS Andi 15, 42, 62, 66, 110, 121.

**Callicostella papillata* var. *prabaktiana* (Müll.Hal.) Streimann

On moist to wet stone-walls, by streams, in full shade, 643-704 m alt., TMS Andi 78, 106, 112, 113, 114, 115.

LESKEACEAE

**Claopodium prionophyllum* (Müll.Hal.) Broth. (Figure 5)

On small boulder along a trail, in partially shaded area, 1180 m alt., TMS Andi 34. Recorded only in Sabah within Borneo region by Iwatsuki & Noguchi (1975). It is widely distributed in China but considered as a rare species locally.

THUIDIACEAE

**Pelekium contortulum* (Mitt.) A.Touw

On rotten fallen log, along a trail, in partially shaded area, 1150 m alt., TMS Andi 46. This species is easily confused with *Pelekium investe* (Mitt.) A.Touw, but it can be separated from the latter by its recurved to squarrose stem leaves and broadly acute branch apices (Touw 2001). This is the second record of this species in Borneo. It could be overlooked due to its small size.

Thuidium cymbifolium (Dozy & Molk.) Dozy & Molk.

Growing on decaying log, boulder, soil and stone-walls, by streams and along trails, from partial to full shade conditions, 643-1301 m alt., TMS Andi 4(b), 27, 43(b), 97, 124, 125.

**Thuidium pristocalyx* (Müll.Hal.) A.Jaeger

Hanging from tree-root by a stream, and also growing on boulder and treelet trunk along a trail, in partially shaded area, 643-1347 m alt., TMS Andi 18, 65, 96. Identification of this species was based on Touw (2001).

BRACHYTHECIACEAE

*****Eurhynchium asperisetum* (Müll.Hal.) E.B.Bartram

On soil mixed with small rocks by a trail, in partially shaded area, 1347 m alt., TMS Andi 21. The plants are bright green in colour, soft in texture and the branches are densely leaved. This species is tolerant of bright sunlight and is almost a weedy species (So 1995). Previously recorded in Papua New Guinea, the Philippines, and Hong Kong. Ho *et al.* (2006) also reported this species in Sumatra.

**Oxyrrhynchium vagans* (A.Jaeger) Ignatov & Huttunen

On boulder, along a trail, in partially shaded area, 1348 m alt., TMS Andi 25. A second record for Sabah and Borneo, this species is synonymous with *Rhynchostegium vagans* A.Jaeger, which was reported previously from Tenom, Sabah by Dixon (1916).

Rhynchostegium celebicum (Sande Lac.) A.Jaeger

On root and sometimes found growing on boulders along trails, in partially shaded area, 1165-1301 m alt., TMS Andi 28, 35, 37.

METEORIACEAE

Aerobryopsis wallichii (Brid.) M.Fleisch.

On boulder along a trail to satellite camp 1, in partially shaded area, 827 m alt., TMS Andi 1(b).

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

Growing on leaf along a trail, in partially shaded area, 1071-1120 m alt., TMS Andi 17, 67.

Floribundaria pseudofloribunda M.Fleisch.

On fallen rotten log, along a trail, in partially shaded area, 1156 m alt., TMS Andi 41.

HYPNACEAE

**Ectropothecium ichnotocladum* (Müll.Hal.) A.Jaeger

On decaying root along a trail, in partially shaded area, 1138 m alt., TMS Andi 59.

**Ectropothecium intorquatum* (Dozy & Molk.) A.Jaeger

On boulder along a trail, in partially shaded area, 1347 m alt., TMS Andi 20. Reported 80 years ago in Sabah (Dixon 1935, Bartram 1936).

**Ectropothecium moritzii* A.Jaeger

On boulders along trails, in partially shaded area, 1146-1152 m alt., TMS Andi 43(a), 49.

**Ectropothecium zollingeri* (Müll.Hal.) A.Jaeger

On moist boulders (sometimes submerged), and stone-wall, along trails and by streams, from partial to full shade conditions, 643-1347 m alt., TMS Andi 22, 76, 98, 99.

Ectropothecium sp.1

On boulders along trails to satellite camp 1, in partially shaded area, 827-1348 m alt., TMS Andi 1(a), 24. This species has strong falcate leaves, with serrulate margins, ca. 2 mm long.

Ectropothecium sp.2

On rotten root along a trail, in partially shaded area, 1160 m alt., TMS Andi 39. This species has finely recurved margins of branch leaves, a character found in *Mastopoma*.

Ectropothecium sp.3

On tree branch, along a trail, in partially shaded area, 1290 m alt., TMS Andi 30. This species has sharply serrate margins to denticulate at base with prorate cells as in *E. moritzii* but the mid lamina cells are linear and much longer.

Vesicularia reticulata (Dozy & Molk.) Broth.

Growing on root of treelet and decorticated fallen log, along trails, in partially shaded area, 1140 m alt., TMS Andi 56.

PYLAISIADELPHACEAE

Isopterygium albescens (Hook.) A.Jaeger

On rotten log, root of treelet and trees, decaying root, and boulder, along trails and by streams, from partial to full shade conditions, 706-1348 m alt., TMS Andi 26(a), 38, 44, 45, 61, 128.

Isopterygium bancanum (Sande Lac.) A.Jaeger

On fallen and rotten tree trunk along a trail, and also found growing on a mushroom by a stream, in partially shaded area, 643-1170 m alt., TMS Andi 36, 87.

Isopterygium minutirameum (Müll.Hal.) A.Jaeger

On boulder by a stream, in partially shaded area, 1348 m alt., TMS Andi 23.

Mastopoma uncinifolium (Broth.) Broth.

On rotten logs along a trail, in partially shaded area, 1140-1142 m alt., TMS Andi 51, 57.

Taxithelium instratum (Brid.) Broth.

On moist boulder and rotten log by a stream, in partially shaded area, 730 m alt., TMS Andi 136, 137.

Taxithelium kerianum (Broth.) Broth.

On treelet trunk, along a trail, in partially shaded area, 1146 m alt., TMS Andi 50.

******Trismegistia lancifolia* (Harv.) Broth.

On decaying log along a trail, close to a stream, in partially shaded area, 827 m alt., TMS Andi 2, 3.

**Wijkia* cf. *surcularis* (Mitt.) H.A.Crum

On decaying log along a trail, in partially shaded area, 903 m alt., TMS Andi 13. This specimen has the characters of *W. surcularis* except for much longer laminal cells of stem leaves, reaching to ca. 110 µm (Tan & Jia 1999). It is distributed from India to China. This species is a second record for Borneo, after being reported recently in Maliau by Mohamed *et al.* (2010).

SEMATOPHYLLACEAE

Acanthorrhynchium papillatum (Harv.) M.Fleisch.

On moist rotten log, by a stream, in partially shaded area, 730 m alt., TMS Andi 134.

Acroporium convolutum (Sande Lac.) M.Fleisch.

On soil, along a trail of a ridge, in open area, 2585 m alt., TMS J21.

Acroporium diminutum (Brid.) M.Fleisch.

On tree trunk, along a trail, in partially shaded area, 1038 m alt., TMS Andi 14.

**Meiothecium microcarpum* (Harv.) Mitt.

On fallen log by a stream, in partially shaded area, 643 m alt., TMS Andi 90(c).

***Radulina hamata* var. *scaberula* (Mont.) B.C.Tan, T.J.Kop. & D.H.Norris

On rotten log, by a stream, in full shade, 706 m alt., TMS Andi 130. This variety is distinguished by having falcate to circinate leaves without the long and sharply acuminate apices commonly seen in the var. *hamata* and var. *elegantissima*. The cells are also rather consistently oblong-elliptic in the upper half of the leaf, rarely becoming linear apically as in the var. *hamata*. This species was reported for the first time in Bau limestone of Sarawak within Borneo as *Radulina hamata* var. *aequorea* (Tan *et al.* 2007). It is usually found growing on rotten logs and limited to the lowland rain forest, while the other varieties extend their ranges to montane forests and also grow epiphytically.

Trichosteleum boschii (Dozy & Molk.) A.Jaeger

On decaying rotten logs and moist boulder, along trails and by streams, in partially shaded area, 827-1146 m alt., TMS Andi 4(a), 48, 55.

***Warburgiella breviseta* (Broth.) Broth.

On rotten log, along a trail of a ridge, in partially shaded area, 2553 m alt., TMS J18. In Borneo, the species was reported from Sarawak (Dixon 1935) as *Clastobryella capillifolia*. However, it is also reported in other Asian countries like Seram (Indonesia), and the Philippines.

Warburgiella circinata Dixon

Growing on soil, and tree trunk, along trails, on a ridge, from partially shaded to open areas, 1943-2585 m alt., TMS J22, J24. This species is endemic to Borneo. Its type specimen was collected from Mount Dulit of Sarawak in 1804 (Dixon 1941). Thus far, the only record of this species in Sabah was from Mount Trus Madi (Suleiman & Edwards 2002).

PTEROBRYACEAE

***Calyptothecium recurvulum* (Broth.) Broth.

Hanging from tree branch, along a trail, in partially shaded area, 980 m alt., TMS Andi 71. This pendulous species was reported in Sarawak by Mohamed *et al.* (2004). World distribution: China, Japan, India, Sri Lanka, Myanmar, Indonesia, the Philippines, Fiji, New Guinea, Pacific Islands, and Australia.

NECKERACEAE

Himantocladium cyclophyllum (Müll.Hal.) M.Fleisch.

On boulder by a stream, in full shade, 704 m alt., TMS Andi 116.

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

On small boulder along a trail, in partially shaded area, 1200 m alt., TMS Andi 32.

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

On fallen log by a stream, from partial to full shade conditions, 643 m alt., TMS Andi 89(b), 93.

Sepilok Bulletin 21 & 22: 49-57 (2015)

Diversity of epiphytic mosses along an altitudinal gradient at Minduk Sirung Trail in Crocker Range Park, Sabah, Malaysia

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Abstract. This study aims to determine the effects of altitude on the diversity of epiphytic mosses along an altitudinal gradient at Minduk Sirung Trail in Crocker Range Park, Sabah, Malaysian Borneo. Three altitudes were selected, namely 1400 m, 1700 m and 2000 m, each with 20 m x 20 m size of sampling area. Five trees with DBH of more than 20 cm were randomly selected for each area. Samples of mosses were collected from five 20 cm x 30 cm plots, placed randomly from 0-2 m height for each tree; the total number of plots was 75. Kruskal-Wallis test was used to determine the effect of altitude on diversity of epiphytic mosses and Jaccard index was used to compare the species richness on different altitudes. A total of 38 species and three varieties from 17 genera and 11 families of epiphytic mosses was recorded including one new record to Sabah, *Himantocladium warburgii* (Broth.) M.Fleisch. Results of this study show that the diversity of mosses was influenced by altitude (P = 0.008). Sematophyllaceae had the highest species richness while Hookeriaceae, Hypnaceae, Meteoriaceae and Thuidiaceae had the lowest. *Syrrhopodon tristichus* Nees ex Schwägr. had the highest abundance and was present at each altitude. The highest species richness was at 1700 m with 31 taxa, followed by 1400 m with 16 taxa, whereas the lowest was at 2000 m with 12 taxa. The highest similarity of species occurrence was between 1400 m and 1700 m with 11 species.

Keywords: Altitude, Borneo, bryophytes, Crocker Range Park, epiphytes

INTRODUCTION

The changes on forest structure can be clearly seen when altitude increases to montane forest (Richards 1954). Tree trunks are packed and covered by epiphytic ferns, bryophytes and lichens that favour cloudy and misty environment. Tropical rainforest, especially montane forest, is rich with epiphytic plants (Richards 1984). Epiphytes are very sensitive to environmental changes, thus changes in chemical and physical properties of the atmosphere have direct impact to these plants (Farmer *et al.* 1992, Benzing 1998, Zotz & Bader 2008). Bryophytes are good biological indicator, and due to their sensitivity to environmental changes, the occurrence of bryophyte species has been related to microclimatic changes which relate to vegetation type (Vellak & Paal 1999, Holz & Gradstein 2005).

The richness and composition of bryophytes communities may indicate forest quality in terms of forest structure and resource availability (Frego 2007). Although mostly are small in size and inconspicuous, bryophytes are an important component in tropical rainforest and play an important role in nutrient cycle and water stability (Pócs 1980, Nadkarni 1984, Frahm 1990, Hofstede *et al.* 1994, Hölscher *et al.* 2004). They also provide habitats for other plants like orchids and ferns in mossy forests. The diversity of epiphytic bryophytes is controlled by several environmental factors, such as moisture availability, radiation, temperature and wind speed at different altitudes as these factors influence the growth of epiphytic mosses (Benavides *et al.* 2004). Frahm *et al.* (1990) showed that species richness and abundance of bryophytes increases from lowland to submontane and to montane forest on Mount Kinabalu.

Thus far, no studies on the ecology of bryophytes in Crocker Range Park (CRP), an important watershed area for the west coast and interior of Sabah, have been carried out. Thus, the specific objectives of this study are: (1) to determine the diversity of epiphytic mosses along the Minduk Sirung Trail, (2) to study the effect of altitude on the diversity of epiphytic mosses, and (3) to compare the species richness of the epiphytic mosses at different altitudes.

MATERIALS & METHODS

Study area

The study was conducted along the 12 km Minduk Sirung Trail in CRP, a newly established trail connecting Mount Alab sub-station and Mahua sub-station in Tambunan district. CRP is the largest terrestrial park and protected area in Sabah which covers an area of 139,919 ha; located between the west coast and interior plains of Sabah (latitude 5°07' to 5°56' N and longitude 115°50' to 116°28' E). The area is about 110 km long and 15 km wide from Mount Kinabalu in the north extending to Mount Lumaku in the south. The elevation ranges from 100 m in lowland areas, along the Padas River to Mount Minduk Sirung (2076 m), the highest peak of CRP (Suleiman & Akiyama 2007).

Sampling method

Sampling was carried out from 12 October to 16 December 2013, along an altitudinal gradient from 1400 m to 2000 m a.s.l. Three altitudes (1400 m, 1700 m, 2000 m) were selected; an area of 20 m x 20 m were randomly selected at each altitude. Five trees with trunk diameter at breast height (DBH) of more than 20 cm were randomly selected at each altitude. To evaluate the ecological distribution of epiphytic mosses at three altitudes, five plots of 20 cm x 30 cm were randomly set on trunk surface of each tree within 0 to 2 m height (Gradstein *et al.* 2003, Ariyanti *et al.* 2008, Gradstein & Culmsee 2010). Total number of plots was 75.

Data analysis

The effects of altitude on diversity of epiphytic mosses were tested with a non-parametric ANOVA (Kruskal-Wallis test). The species richness of epiphytic mosses was compared at each altitude based on presence and absence of species by using Jaccard index.

RESULTS

Diversity of epiphytic mosses

A total of 238 specimens of mosses from 75 plots was identified to 38 species and three varieties from 17 genera and 11 families (Table 1). The largest families were Sematophyllaceae and Dicranaceae with 10 and eight taxa, respectively. A total of 16 taxa was recorded at 1400 m, 31 taxa at 1700 m and 12 taxa at 2000 m (Table 2). The most common and abundant species in the study area were *Syrrhopodon tristichus* Nees ex Schwägr. and *Leucobryum javense* (Brid.) Mitt. var. *javense* with 35 and 23 individuals, respectively. Both species were found at the three altitudes.

Table 1. Summary of epiphytic mosses of Minduk Sirung Trail according to family.

Family	Number of genera	Genera (%)	Number of species & varieties	Species & varieties (%)
Sematophylaceae	3	17.6	10	24.4
Dicranaceae	4	23.5	8	19.5
Calymperaceae	1	5.9	6	14.6
Leucobryaceae	1	5.9	6	14.6
Rhizogoniaceae	2	11.7	3	7.3
Hypnodendraceae	1	5.9	2	5
Neckereceae	1	5.9	2	5
Hookeriaceae	1	5.9	1	2.4
Hypnaceae	1	5.9	1	2.4
Meteoriaceae	1	5.9	1	2.4
Thuidiaceae	1	5.9	1	2.4
Total	17	100	41	100

Table 2. List of species and varieties of epiphytic mosses from three altitudes along Minduk Sirung Trail.

Species & variety	Family	1400 m	1700 m	2000 m	Total occurrence
Acroporium convolotum var. *convolotum*	Sematophylaceae	0	1	0	1
A. diminutum	Sematophyllaceae	1	6	3	10
A. joannis-winkleri	Sematophyllaceae	0	0	8	8
A. lamprophyllum	Sematophyllaceae	0	2	0	2
A. rufum	Sematophyllaceae	0	1	0	1
A. stramineum var. *hamulatum*	Sematophyllaceae	0	1	0	1
Cryptopapillaria fuscescens	Meteoriaceae	0	1	0	1
Dicranodontium fleischerianum	Dicranaceae	0	0	17	17
Dicranoloma assimile	Dicranaceae	1	1	0	2
D. blumii	Dicranaceae	0	0	2	2
D. braunii	Dicranaceae	5	1	0	6
D. brevisetum	Dicranaceae	0	4	0	4
D. leucophyllum	Dicranaceae	0	1	0	1
Ectropothecium sp.1	Hypnaceae	0	2	0	2
Exostratum blumii	Dicranaceae	1	0	0	1
*Himantocladium warburgii**	Neckereceae	1	1	0	2
H. flabellatum	Neckereceae	10	2	0	12
Hypnodendron beccarii	Hypnodendraceae	0	7	0	7
H. milnei subsp. *milnei*	Hypnodendraceae	0	1	0	1
Leucobryum aduncum var. *aduncum*	Leucobryaceae	1	0	0	1
L. chlorophyllosum	Leucobryaceae	6	0	0	6
L. javense var. *cyathifolium*	Leucobryaceae	0	0	4	4
L. javense var. *javense*	Leucobryaceae	7	7	9	23
L. juniperoideum	Leucobryaceae	2	0	0	2
L. scabrum	Leucobryaceae	0	0	1	1
Leucoloma molle	Dicranaceae	10	3	0	13
Lopidium struthiopteris	Hookeriaceae	3	0	0	3
Pyrrhobryum medium	Rhizogoniaceae	2	1	6	9
P. spiniforme	Rhizogoniaceae	0	2	0	2
Rhizogonium lamii	Rhizogoniaceae	0	5	0	5
Syrrhopodon sp.1	Calymperaceae	0	1	0	1
S. gardneri	Calymperaceae	0	1	3	4
S. japonicus	Calymperaceae	0	7	0	7
S. prolifer	Calymperaceae	0	2	14	16
S. trachyphyllus	Calymperaceae	0	2	0	2
S. tristichus	Calymperaceae	11	13	11	35

Species & variety	Family	1400 m	1700 m	2000 m	Total occurrence
Taxithelium vernieri	Sematophyllaceae	0	1	1	2
Thuidium glaucinum	Thuidiaceae	0	2	0	2
Trismegistia calderensis var. *calderensis*	Sematophyllaceae	0	2	0	2
T. calderensis var. *rigida*	Sematophyllaceae	3	4	0	7
T. calderensis var. *subintegrifolia*	Sematophyllaceae	5	5	0	10
Total individuals		69	90	79	238
Total species and varieties		16	31	12	41

*New record for Sabah

Effect of altitude on diversity of epiphytic mosses

The non-parametric ANOVA shows that the species diversity of epiphytic mosses was significantly influenced by altitude (Kruskal-Wallis, $X^2 = 9.777$, d.f. = 2, P = 0.008). A total number of 16 taxa was collected at 1400 m and increased to 31 taxa at 1700 m but decreased to 12 taxa at 2000 m.

Based on the Jaccard index, the number of species shared between each altitude ranged from four to 11. The highest similarity of species occurrence was found between 1400 m and 1700 m (30.5%) while the altitudinal range between 1400 m and 2000 m shows the lowest similarity (16.6%) (Table 3).

Table 3. Jaccard index and the number of shared taxa between three altitudes.

Altitude	1400 m	1700 m	2000 m
		Number of shared taxa	
1400 m	-	11	4
1700 m	0.305	-	7
2000 m	0.166	0.194	-
	Jaccard index		

DISCUSSION

The diversity of mosses along Minduk Sirung Trail was found to be considerably rich. The number of taxa of mosses recorded in the small study area represents 7% of the total number of mosses reported for Sabah. Sematophyllaceae, a large family with high number of genera (Tan & Buck 1989), exhibited the highest species richness (24%). Most of the species collected in this family were from the genus *Acroporium*; about 27% of the total number of species of *Acroporium* reported for Borneo (Tan 1994) was collected during the study. The second largest family was Dicranaceae, mostly from the genus

Dicranoloma. Dicranaceae is one of the largest families and has the highest number of genera for acrocarpus mosses in the highlands of Borneo. Meanwhile, Hookeriaceae, Hypnaceae, Meteoriaceae and Thuidiaceae gave the lowest species richness among all the species recorded.

Among the 41 taxa of epiphytic mosses collected, one species is a new record for Sabah which is *Himantocladium warburgii* (Broth.) M.Fleisch. This species is endemic to the Philippines and was only recorded from Mindanao. It was collected on Mount Kitanglad at 2200 m from tree trunks in a montane mossy forest (Enroth 1992). This species was first identified as *Neckera warburgii* Broth. by Brotherus in 1990 based on the Warburg collection from Mount Batangan in Mindanao island (Tan & Noguchi 1984). It was then renamed *Himantocladium cyclophyllum* (Müll. Hal.) M.Fleisch. by Fleischer but Tan & Noguchi (1984) confirmed it as a different species. Akiyama *et al*. (2001) illustrated a species of *Himantocladium* from Mount Kinabalu, collected at 3000 m, which was very similar to *H. warburgii*. Thus, this species may not be rare in Crocker Range.

The diversity of epiphytic mosses in the study area was significantly influenced by altitude. Along 1400 m to 1700 m, the species richness of epiphytic mosses increased drastically from 16 taxa to 31 taxa. It shows that epiphytic mosses reach their maximum species diversity at 1700 m where mossy forest starts to develop. This is similar to Mount Kinabalu, where species diversity and coverage of bryophytes reaches its maximum within the mossy forest (1900-2600 m). Mossy forest develops as a result of permanent clouds and stagnation of humid air masses that leads to daily misty weather (Frahm *et al*. 1990). This condition leads to optimal growth of bryophytes due to permanent availability of water within moderate air temperature. In higher mountains such as Mount Kinabalu, mossy forest is formed at higher altitude, which is from 1900 m. However, the formation of mossy forest depends on geographical factors, such as total elevation of the mountain, closeness to the sea and presence of humid air currents (Frahm *et al*. 1990). The altitudinal limits of vegetation zones tend to be lower than on extensive montane ranges. This is called the *'massenerhebung effect'*, for example, the compression of forest zone on a small mountain compared with a larger one (Richards 1996).

Species richness of epiphytic mosses at 2000 m was lower than 1700 m. The highest peak of CRP is Mount Minduk Sirung with the elevation of 2076 m. The highest ridge is exposed to strong wind, and has generally shorter and smaller crown trees. The abundance of epiphytic bryophytes on tree trunks was clearly seen in the mossy forest but the species richness was low. The most dominant epiphytic moss at this elevation was *Dicranodontium fleischerianum* W.Schultze-Motel. This species is also common above 2600 m on Mount Kinabalu, forming large cushions along the trail.

The difference in number of species was clearly seen among the three altitudes. The highest similarity of shared species was between 1400 m and 1700 m where 11 species were shared, while the lowest was between 1400 m and 2000 m where only four species were shared. Several species of epiphytic mosses were only found at certain altitude, such as *Dicranodontium fleischerianum*. Another prominent species at 2000 m was *Syrrhopodon prolifer* Schwägr. On the other hand, *Syrrhopodon tristichus* and *Leucobryum javense* var. *javense* were abundant in the study area and common at the three altitudes.

CONCLUSION

This study proves that the diversity of epiphytic mosses in CRP is affected by altitude. It shows that upper montane forests in tropical regions are important habitat for epiphytic mosses, providing the optimal environmental conditions for growth. This study provides baseline information on the biological diversity of epiphytic plants along the Minduk Sirung Trail.

ACKNOWLEDGEMENT

We would like to thank Sabah Parks for the permission to conduct the study in Crocker Range Park and for providing field guide from Mount Alab sub-station.

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Sepilok Bulletin 21 & 22: 59-63 (2015)

Vegetative propagation of *Eusideroxylon zwageri* (Belian)

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Eusideroxylon zwageri Teijsm. & Binn. or ironwood, locally known as Belian, is a hardwood that belongs to the family Lauraceae. It grows very slowly (approx. 0.5 cm in dbh per year) and may take 120 years to reach a height of 30 m. The species is distributed in Sumatra, Borneo, Sulu Archipelago and Palawan in the Philippines. It is generally found in lowland areas of primary forest up to 400 m above sea level, in flat or sloping terrain, and also in old secondary forest (Suselo 1987).

The wood of Belian is highly resistant to bacterial, fungal, insect and borer attack, strong and extremely durable; hence it is highly prized for many outdoor uses. The wood is usually used in heavy construction, marine work, boat-building, piling, printing blocks, specialty furniture, flooring, roofing shingles and tool handles (Suselo 1987). The major threats to ironwood are over-exploitation, shifting cultivation and illegal logging (Irawan & Gruber 2004, IUCN 2015), thus the IUCN (2015) has classified *E. zwageri* as a 'vulnerable species' as per the criteria A1cd+2cd. Recognising the rapidly declining population of the Belian and the need to conserve this near-extinct species, we have come up with this study with the main objective of producing planting materials via vegetative propagation by stem cutting.

The study was carried out in a mist propagation chamber at the Forest Research Centre (FRC) nursery from November 2014 to April 2015. Twenty stockplants aged over 2 years were selected and used in this study. Three single-node stem cuttings measuring 5 cm were taken from each stockplant and the attached leaf trimmed to half of its original size to minimise water loss through transpiration. Half of the cuttings were treated with Seradix 3 (a commercial rooting hormone containing approx. 0.8% IBA) while the other half were left untreated and labelled as Control (N=60). These cuttings were then set onto 2 different rooting media, i.e. sieved river sand and peat moss. The relative humidity and temperature data were taken daily. The temperature and relative humidity in the mist propagation chamber fluctuated during the day, ranging from 62% to 92% and 25°C to 32°C, respectively. The misting interval in the rooting chamber was set at 15 seconds burst every 10 minutes. Data recorded were the occurrence of rooting and the number and length of roots produced.

Plate 1. Peat moss as a rooting medium.

Plate 2. Sieved river sand as a rooting medium.

Rooting was first observed after 4 months and the number of successfully rooted cuttings was only 12 (Table 1); giving only 20% rooting success. The high mortality of cuttings might be due to the fluctuation in the temperature and relative humidity in the rooting chamber caused by the frequent electricity supply disruption throughout the study. Despite the poor rooting rate shown in this study, it is noteworthy to record that it is feasible to produce rooted cuttings of Belian. Our results concurred with the findings by Irawan (1999) and Irawan (2001). It appeared that Belian cuttings did not require rooting hormone to produce roots as the 20% rooted cuttings were mainly from the Control. Conversely, only one cutting applied with exogenous rooting hormone had rooted.

Table 1. The 12 successfully rooted cuttings of Belian (after 6 months of observation).

Nodal Position	Rooting Medium (Peat Moss/River Sand)	Treatment (Seradix/Control)	Number of Roots	Root Length (cm)
2	Peat Moss	Seradix	1	0.2
2	Peat Moss	Control	3	0.2
3	Peat Moss	Control	2	0.5
2	Peat Moss	Control	1	0.3
1	Peat Moss	Control	2	0.2
1	River Sand	Control	1	2
2	River Sand	Control	2	0.3
2	River Sand	Control	2	0.2
3	River Sand	Control	2	0.3
1	River Sand	Control	2	0.3
2	River Sand	Control	2	0.5
3	River Sand	Control	2	0.3

The preliminary findings indicate that planting materials of Belian could be produced by vegetative propagation through stem cutting. However, no conclusive recommendations could be drawn from this study due to the high mortality of cutting materials. We believe that the poor survival of cuttings was caused by the unfavourable conditions within the rooting chamber. It is possible that the erratic fluctuation of both factors, temperature and humidity, was not conducive to the adaptation of the cuttings to the given microclimate, thus resulting in their ultimate mortality. Creating a more constant environment may help to eliminate this as an influencing factor, thereby, also giving a more predictable result.

It is noteworthy that other factors may have also contributed to the poor rooting of Belian such as the rooting substrate, the physiological age of the stockplants from which cuttings were derived, or even the type of explant used. Further experimentation with a more rigorous design is warranted to ascertain the feasibility of mass production of Belian by vegetative propagation.

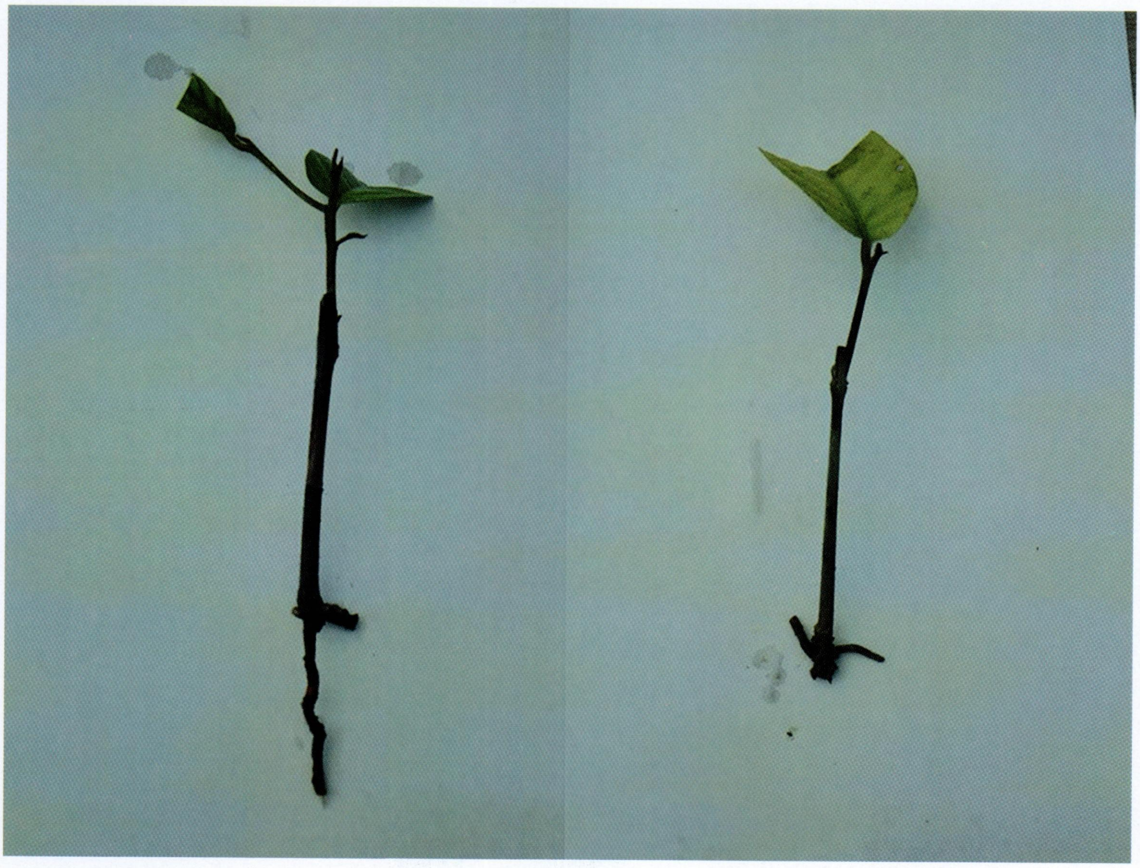

Plate 3. Rooted cuttings of Belian in river sand (L) and peat moss (R) media after 4 months.

ACKNOWLEDGEMENTS

We thank Mohd Khairul bin Mad Hansam, Kolej Komuniti Tambunan intern, for the assistance rendered in the experiment. We are also grateful to Dr Doreen K.S. Goh, the Managing Director of YSG Biotech, Sabah Foundation Group, for reviewing the earlier draft and for providing some important comments.

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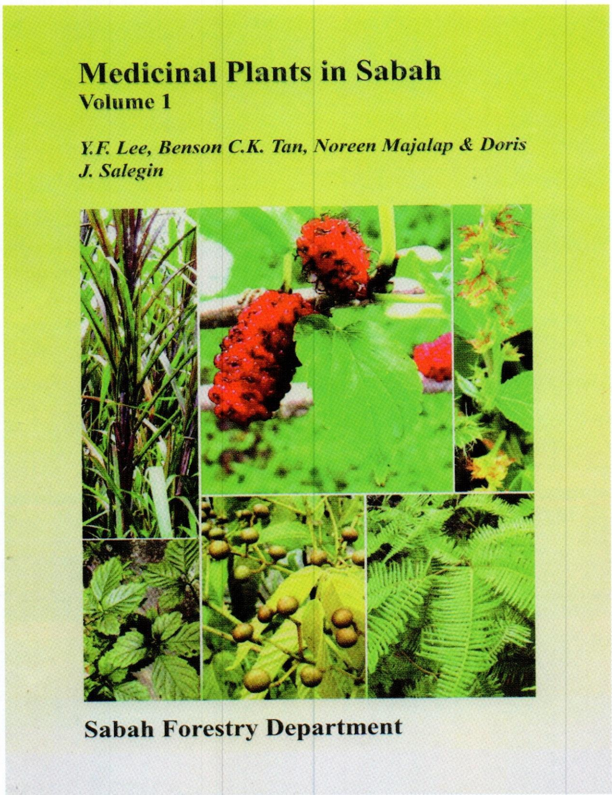
BOOK REVIEWS



Medicinal plants in Sabah. Volume 1 by Y.F. Lee, Benson C.K. Tan, Noreen Majalap & Doris J. Salegin. Published by Sabah Forestry Department, Sandakan, 2015. Pp. 149. ISBN 978-967-0180-13-7.

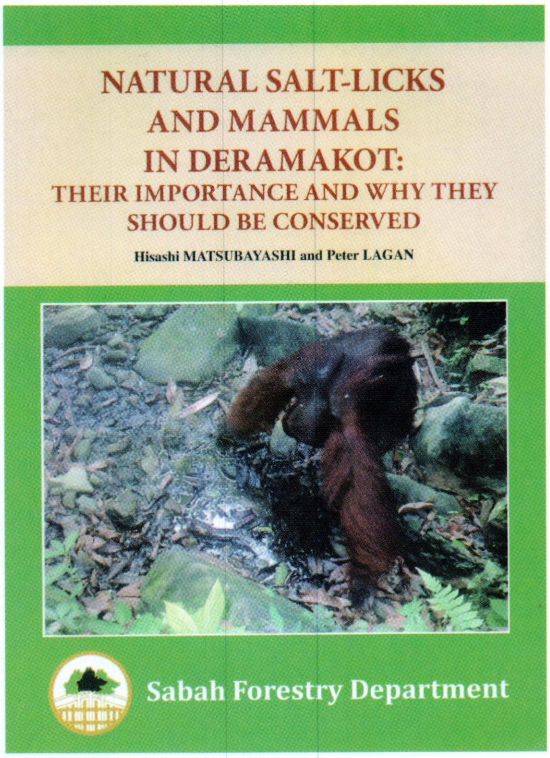
Reviewed by M. Ajik

In recent years, there is a marked acceleration in the use of, and search for, drugs and dietary supplements derived from plants. According to the World Health Organisation (WHO), approximately 25% of modern drugs used in the United States have been derived from plants.

Medicinal plants are indeed interesting and important. In Sabah, there are abundant plants with medicinal properties that have yet to be documented. This publication is an introductory volume that collates and describes about 100 species of medicinal plants in Sabah, and the first in a series.

Over 200 colour photographs help readers to recognize and differentiate the described medicinal plants. The properties and uses of the plants described in this book are based on the principles and concepts of traditional Chinese medicine involving the Six External Pathogens, the Four Energies of Herbs and the Five Flavours. A cautionary note and disclaimer on Page 6 reminds readers that the information provided is not meant to diagnose, treat and cure any disease. The objective of this series of manuals is strictly for documentation of the known medicinal plants in Sabah, and for reference purposes.

This handy book is a very useful and informative guide for herbalists, botanists, ethnobotanists, students and the general public who are keen on plants as alternative remedies for certain ailments.



Natural salt-licks and mammals in Deramakot: their importance and why they should be conserved by Hisashi Matsubayashi & Peter Lagan. Published by Sabah Forestry Department, Sandakan, 2014. Pp. 60. ISBN 978-967-0180-11-3.

Reviewed by V.K. Chey

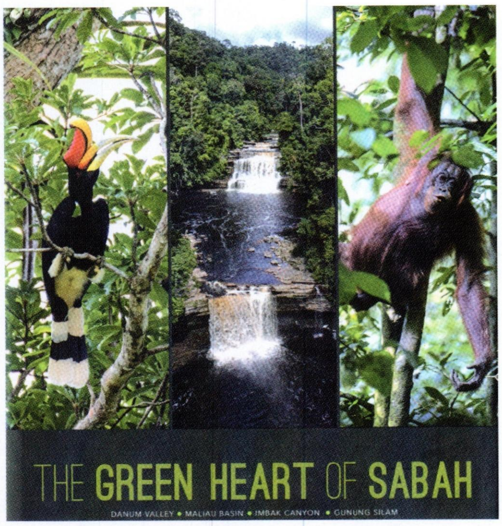
This booklet gives a fascinating account on mammals, many of them flagships, recorded at the natural salt-licks in Deramakot Forest Reserve. Orang-utan, elephant, banteng, sun bear, clouded leopard, and a plethora of other medium to large mammals are here, illustrated in full colour.

Many of these mammals are endangered or vulnerable under the IUCN Red List. This underlines the importance of Deramakot for biodiversity conservation, which at 55,507 hectares is the first tropical rainforest certified by the Forest Stewardship Council.

Mammals visit salt-licks to obtain minerals, particularly sodium which is deficient in plants. Research on the salt-licks in Deramakot revealed high concentration of minerals, particularly in the water of the salt-licks. Most intriguing is the presence of vast colonies of leeches in the Deramakot salt-licks, which have adapted to the salty conditions and readily attach themselves to unsuspecting victims.

Also, orang-utans are frequent visitors to the Deramakot salt-licks, though they were previously thought to be largely arboreal and seldom descend to the ground. This and other fascinating information is reported in detail in this wonderful booklet.

Deramakot, best known for its sustainable forest management project through reduced impact logging done in collaboration with Germany (GTZ), is shown here to be an invaluable refuge for mammals. The two authors, Hisashi Matsubayashi, a mammalogist from Tokyo University of Agriculture, and Peter Lagan, a senior forestry officer attached to Deramakot, have done a marvellous job in giving us this excellent publication.



The green heart of Sabah: Danum Valley, Maliau Basin, Imbak Canyon, Gunung Silam by Matt Oldfield. Photographers: Jason Isley, Ch'ien C. Lee, Christian Loader, Matt Oldfield & Gilbert Woolley. Published by Scubazoo Publications, Kota Kinabalu, in association with Sabah Forestry Department, Sandakan. 2014. Pp. 255. ISBN 978-967-10528-3-9.

Reviewed by M. Ajik

This stunning coffee-table book is produced by Scubazoo, a team of professional wildlife photographers and cameramen, to commemorate the 100th anniversary celebrations of the Sabah Forestry Department. The book offers a glimpse into some of the most spectacular habitats on our planet, the tropical forests of Sabah's 'Green Heart'. Covering the conservation areas of Danum Valley, Maliau Basin, Imbak Canyon and Gunung Silam, the book explores the different types of forest within these amazing landscapes, the many plant and animal species that are living in there and the complex ecosystems that have evolved over millions of years. Apart from providing vital ecosystem services, these conservation areas are home and vital refuges for rare and endangered species, e.g. Bornean orang-utan, Sumatran rhino (its status is now regarded as extinct in the wild) and Bornean pygmy elephant.

In the Introduction, Datuk Sam Mannan, the Director of Sabah Forestry Department, presents in length some interesting facts about the 'Green Heart' of Sabah emphasizing the commitment of Sabah Forestry Department as the custodian to soundly manage, protect and conserve Sabah's forests. Datuk Dr Glen Reynolds, the Director of Royal Society South East Asia Rainforest Research Programme (SEARRP), contributes important points pertaining to management history of the 'Green Heart' of Sabah, people in the forest, logging history, conservation and restoration, and forest connectivity and fragmentation.

Behind the Lens, a chapter penned by one of the photographers Jason Isley, shares a photographer's challenging yet rewarding experience capturing high-quality images in the forests. In fact all the photographs featured in this book are of superb quality. Highlighting both the beautiful landscapes and bountiful diversity of Sabah's natural wealth, this book will stand as a permanent reminder to all of us the importance of conservation and sustainable resource use, as mentioned by the Right Honourable Chief Minister of Sabah, Datuk Seri Panglima Musa Haji Aman in the Foreword. This book is a must-have for nature lovers and photographers.

GUIDE TO CONTRIBUTORS

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

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SEPILOK BULLETIN

Vols. 21 & 22 June 2015

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Front cover: The moss *Leucobryum javense*, along the Mannan Trail of Trusmadi (Photo: Andi Maryani A. Mustapeng)