DIVERSITY OF MACROMOTHS (LEPIDOPTERA: HETEROCERA) IN PERLIS STATE PARK, KEDAWI REGION, MALAYSIA: NEW DISTRIBUTIONAL RECORD OF NOCTUID

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ABSTRACT

This study aimed to determine the macromoths species diversity in Perlis State Park, Kedawi Region, Malaysia. Two sampling series were conducted on 17th - 21st April 2015 and 12th - 16th November 2015. Modified Pennsylvanian light trap with 160 W mercury vapor bulb was used to attract the macromoths in ground (≤ 2m) and lower canopy (≥ 20m) levels. A total of 386 individuals comprising 182 species from 13 families were recorded in 10 nights of sampling. The macromoths diversity was considerably high with Fisher's alpha diversity index of α= 134.5 and Shannon's diversity index, H' = 4.777. Noctuidae was the highest family recorded in terms of species number, while family Arctiidae was the highest for the number of individuals collected.

Keywords: Diversity, macromoths, ground level, lower canopy level, Perlis State Park

ABSTRAK

Kajian ini bertujuan untuk menentukan kepelbagaian spesies rama-rama makro di Taman Negeri Perlis, Rantau Kedawi, Malaysia. Dua siri persampelan telah dijalankan pada 17 - 21 April 2015 dan 12 - 16 November 2015. Perangkap cahaya Pennsylvanian yang diubahsuai dengan mentol wap raksa 160 W telah digunakan untuk menarik rama-rama makro pada dua ketinggian iaitu aras tanah (≤ 2m) dan kanopi rendah (≥ 20m). Sebanyak 386 individu yang terdiri daripada 182 spesies daripada 13 famili telah direkodkan selama 10 malam persampelan. Kepelbagaian rama-rama makro adalah cukup tinggi dengan indeks kepelbagaian alpha Fisher ialah α = 134.5 dan indeks kepelbagaian Shannon, H' = 4.777. Noctuidae adalah famili yang tertinggi dicatatkan dari segi bilangan spesies, manakala famili Arctiidae adalah jumlah individu yang tertinggi dikumpulkan.

Kata kunci: Kepelbagaian, rama-rama makro, paras tanah, paras kanopi rendah, Taman Negeri Perlis

INTRODUCTION

Moths are mostly known as nocturnal insects. They belong in the order Lepidoptera and suborder Heterocera. Moths play a significant role in the ecosystems as plant pollinators and become a food sources for other animals such as bats and birds. Typically, bats and birds will feed on the moth larvae (Butterfly Conservation 2012). Besides, moths also can be parasites, defoliators and pests, which made them important economically as well as the indicators for biodiversity (Aslam 2013; Chey 2010; Truxa 2012).

Perlis State Park is in Kedawi region, which is defined as the specialized area in the north of Peninsular Malaysia comprising the Langkawi Islands, Perlis and a part of Kedah north of Kedah River (Corbet & Pendlebury 1992). It differs remarkably from the remainder of the Peninsular Malaysia for its number of Burmese species being proportionally larger, species occurring in races distinct from other Malaysia's part, natural vegetation of White-Meranti Gerutu seasonal forest and its climate that is similar to Southern Thailand, which is seasonal semi-deciduous forest (Corbet & Pendlebury 1992; Forestry Department/DANIDA 2005; WWFM 1998). Studies that were conducted in Kedawi region previously recorded new distributional record of moths' species in Peninsular Malaysia (Idris & Abang 2011a, 2011b). As supported by Cerny and Pinratana (2009), Idris and Abang (2011a, 2011b) who discovered several new distributional records for moth species, there is a possibility to have similar macromoths species between Perlis State Park and Indo-Chinese or Burmese elements from the north.

This study was conducted as knowledge on moth zoogeographical distribution and biodiversity patterns in Malaysia are sparse. Moreover, the species composition and diversity of moths at different forest strata may be significant, especially the canopy-fliers. This study was also meant to contribute some information and resourceful data for long-term conservation management strategies by local authorities.

MATERIAL AND METHODS

Study Site

The study site was located at northwestern Perlis (N 6° 41' 51.7'' E 100° 11' 29.3''), in the northernmost part of Peninsular Malaysia (Figure 1). This park is mostly covered by seasonal semi-deciduous forest with natural vegetation of White-Meranti Gerutu seasonal forest, which is different from red 'meranti' forest found in most of forested areas in Peninsular Malaysia. Two main types of vegetations found here are limestone forest and lowland dipterocarp forest.

Figure 1. Perlis State Park location

Insect Sampling

Four modified-Pennsylvanian light traps and 10 baited traps were used, with half of each trap types were set at ground level (≤ 2 m of height from the ground) and the other half at lower canopy level (standardized at ≥ 20 m from the ground) two locations per site. Light trap and baited-trap were set at different locations. A laser range finder was used to determine the canopy height. Single-rope technique was applied to hoist the trap to the lower canopy level. Light trapping was carried out from 1830 to 0600 each day. Ethyl acetate was used in the light trap as the killing agent. As for baited-trap, rotten bananas and ripe pineapples were used as the baits.

Species Identification

The identification of macromoth was done up to species level using stereomicroscope based on Barlow (1982) and Holloway (1983, 1985-1989, 1993-1999, 2001, 2003, 2005, 2008-2009, 2011), and voucher specimens were deposited at the UNIMAS Insect Reference Collection (UIRC), Faculty of Resource Science and Technology, Universiti Malaysia Sarawak.

Data Analyses

All the data were analysed by using the programs of Paleontological Statistics Software Package for Education and Data Analysis (PAST) version 3.11 (Hammer 2016) and *Estimate*S version 9.1.0 (Collwell 2013) to compute the diversity indices, which were Fisher's alpha diversity index (α) and Shannon's diversity index (H') for overall collection and the two strata. *EstimateS* was used to compute species similarity indices, which were Morisita-Horn and Bray-Curtis to examine overall compositional similarity between ground level and lower canopy level.

RESULTS AND DISCUSSION

A total of 386 individuals comprising of 182 species from 13 families (Table 1) across the vertical distribution from the ground level to the lower canopy level have been identified. Noctuidae was the most diverse family recorded with 47 species (25.82%), while Arctiidae was found to be the most macromoths collected with 143 individuals (37.05%) (Figure 2). Comparison of macromoths diversity index value between strata level showed that ground level has relatively more diversity compared to the lower canopy level (Table 2). According to Sulaiman et al. (2014), factors such as vegetation structure, terrain and microclimatic conditions also influence the diversity and distribution of moths. The diversity of macromoth is considered high in comparison to similar studies done at Tasik Chini, Pahang, Malaysia by Sulaiman et al. (2011). Another similar diversity study was done by Ismail & Sulaiman (2016) in respective to different altitudes. Given the lowest altitude for moth diversity from that study, the diversity in Perlis State Park is still higher. Therefore, the relatively high diversity of macromoths sampled in Perlis State Park might be correlated with the high biodiversity present in the undisturbed natural forest of the park, as it is protected area under the forestry law.

Table 1. Species checklist of moths sampled at Perlis State Park

Family	Subfamily	Species	No. of Individuals
Arctiidae	Arctiinae	*Creatonotos transiens*	2
		Spilosoma procedra	4
		Spilosoma sp. 1	1
		Spilosoma sp. 2	1
	Ctenuchinae	*Eressa annosa*	3
	Lithosiinae	*Adites pseudolyclene*	1
		Asura peloa	2
		Asura strigipennis	1
		Barsine exclusa	16
		Barsine sp. 1	1
		Barsine sp. 2	2
		Barsine sp. 3	1
		Brunia antica	14
		Cyana determinata	3
		Cyana horsfieldi	2
		Cyana indonesia	2
		Cyana malayensis	1
		Cyana pudens	1
		Cyana ridleyi	3
		Eilema apicalis	4
		Eilema griseadisca	3
		Eilema nebulosa	8
		Eilema flavicosta	6
		Eugoa bipuncta	7
		Garudinia pseudolatana	1
		Lyclene cuneifera	1
		Lyclene cuneigera	6

		Lyclene obsoleta	1
		Lyclene pudibunda	1
		Lyclene sp. 1	1
		Lyclene sp. 2	1
		Lyclene sp. 3	1
		Lyclene sp. 4	2
		Macotasa nubeculoides	2
		Miltochrista cornicornutata	1
		Miltochrista lineata	12
		Miltochrista roseororatus	1
		Padenia duplicana	2
		Poliosia marginata	4
		Schistophleps sp.	5
		Teulisna uniplaga	4
		Torticosia excisa	5
		Tortricosia blanda	2
		Trichalis stomata	1
Bombycidae		*Ernolatia lida*	1
		Gunda subnotata	1
		Ocinara albicollis	1
		Penicillifera apicalis	1
Drepanidae	Drepaninae	*Paralbara perhamata*	1
		Strepsigonia affinis	1
		Tridrepana flava	1
Eupterotidae		*Ganisa plana*	2
		Tagora pallida	2
Geometridae	Ennominae	*Abaciscus shaneae*	1
		Abraxas sp.	5
		Amraica solivagaria	1
		Auzeodes coctata	2
		Boarmia costaria	1
		Boarmia uoptilaria	2
		Buzura insularis	1
		Buzura pustulata	7
		Calletaera subexpressa	1
		Celenna festivaria	1
		Cleora tenebrata	1
		Fascellina castanea	1
		Heterostegane urbica guichardi	1
		Hypochrosis lycoraria	8
		Hypomecis separata	1
		Hypomecis sommereri	1
		Lassaba acribomena	1
		Maidania tetragonata	1
		Ourapteryx picticaudata	1
		Petelia medardaria	1

		Plutodes cyclaria	1
		Plutodes malaysiana	12
		Tasta micaceata	5
		Tasta sectinota	1
	Geometrinae	*Agathia quinaria*	1
		Archaeobalbis subtepens	1
		Argyrocosma inductaria	1
		Comostola cedilla	1
		Metallolophia subradiata	1
		Oenospila sp.	1
		Ornithospila succincta	1
		Thalassodes hypocrites	1
Lasiocampidae		*Alompra roepkei sarotes*	1
		Hallicarnia albipectus	3
		Kunugia austroplacida	1
		Kunugia sp.	1
		Metanastria gamella	1
		Micropacha roepkei	1
		Trabala indra	1
Limacodidae		*Cania bandura*	2
		Contheyla lola	1
		Labeda cognata	1
		Narosa velutina	3
		Parasa darma	2
		Saccurosa calcicola	1
		Scopelodes anthela	2
		Setora nitens	1
		Thosea asigna	1
Lymantriidae		*Arctornis contrarcuatus*	1
		Arctornis phasmatodes	2
		Arctornis secula	1
		Arctornis sp.	2
		Artaxa ormea	1
		Bembina albinotata	1
		Calliteara cerigoides	1
		Calliteara zelotica	3
		Cispia punctifascia	2
		Euproctis fumosa	1
		Ilema vaneeckei	1
		Lymantria sublunata	1
		Micromorphe hemibathoides	2
		Orvasca ashleyi	1
		Orvasca sp.	2
		Somena similis	9
Noctuidae	Acontiinae	*Metamaene atrigutta*	2
		Palura niveicosta	1

Acronictinae	*Pachylepis dilectissima*	3
Aganainae	*Asota egens*	1
	Euplocia membliaria	5
	Peridrome orbicularis	3
Agaristinae	*Sarbanissa transiens*	13
Catocalinae	*Anisoneura aluco*	1
	Anisoneura salebrosa	1
	Armana nigraericta	1
	Egnasia overdijkinki	1
	Egnasia sp.	1
	Ercheia pulchrivenula	1
	Erebus caprimulgus	12
	Erebus ephesperis ephesperis	2
	Erebus sp. 1	1
	Erebus sp. 2	1
	Fodina sumatrensis	2
	Gracillina prosthenia	2
	Hepatica orbicularis	1
	Homodes perilitha	1
	Hypospila bolinoides	1
	Ischyja anna	1
	Ischyja hagenii	1
	Ischyja inferna	1
	Metaphoenia rectifascia	1
	Oglasa pachycnemis	1
	Ommatophora luminosa	7
	Oxyodes scrobiculata	1
	Pericyma cruegeri	1
	Phyllodes verhuelli	1
	Plecoptera nebulilinea	1
	Tamba sp.	2
	Thynas honesta	1
	Ugia viridior	1
	Xanthanomis xanthina	1
Chloephorinae	*Ptyonota formosa*	1
Euteliinae	*Anuga* sp.	1
	Caedesa angulifera	1
	Kobestelia obliquata	1
Ophiderinae	*Amphigonia motisigna*	1
	Bocula xanthostola	1
	Crithote horridipes	2
	Tamba lala	1
Sarrothripinae	*Tathothripa continua*	1
Stictopterinae	*Lophoptera acuda*	1
	Lophoptera illucida	1
Nolidae	*Calymera* sp.	1

		Didigua lilacina	1
		Erizada lichenaria	1
		Miaromima cornucopia	1
		Siglophora haematica	1
		Siglophora hayata	1
Notodontidae		*Eupydna testacea postrubra*	1
		Gargetta hampsoni	1
		Ginshachia bronacha	1
		Ginshachia sp.	2
		Parasinga cinerascens	1
		Phalera sundana	3
		Quadricalcarifera sp.	1
		Teleclita sundana	1
Saturniidae		*Antheraea helferi borneensis*	1
		Attacus atlas	1
Sphingidae	Macroglossinae	*Acosmeryx socrates*	1
		Angonyx testacea	2

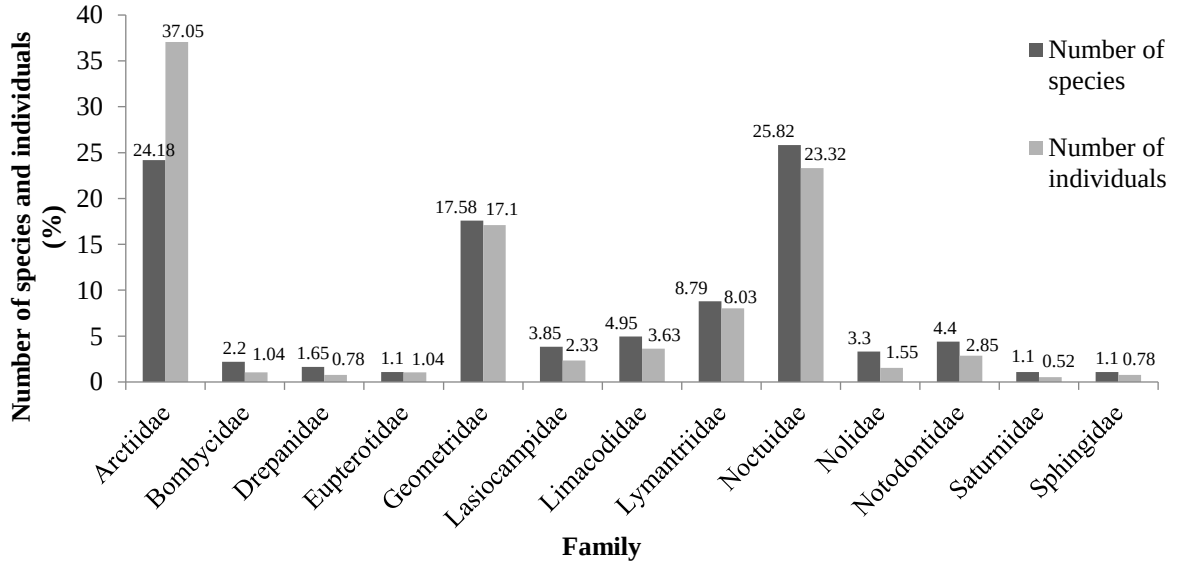

Figure 2. Percentage representative number of species and individuals caught at Perlis State Park

Table 2. Diversity indices of moth assemblages

Gradient Level	Fisher's alpha Diversity Index (α)	Shannon's Diversity Index (H')
Overall	134.5	4.777
Ground	100.5	4.375
Lower canopy	97.25	4.362

Noctuidae was found to be the most diverse family sampled with 47 species. According to Stojanović and Ćurčić (2011), Noctuidae is the enormous group among the order Lepidoptera. Furthermore, noctuid moths are abundant and widespread particularly in the tropical areas (Common 1990). They are also night-flying moths, and the adults prefer to gather around lights (Stojanović & Ćurčić 2011). These behaviours might be one of the major contributions of highly species occurrence of Noctuidae in this study. The abundant moths sampled in the family Noctuidae was *Sarbanissa transiens* (Noctuidae: Agaristinae) with 13 individuals. According to Kitching (1984), the genus *Sarbanissa* Walker favoured light at night and thus explains the high number of individuals collected from family Noctuidae throughout the 10 sampling nights. This could be due to the composition of vegetation that comprised the food sources and breeding sites for Noctuidae in general. However, the subfamily Catocalinae was the most species sampled in the family Noctuidae with 29 species in total. This might be related to the high propensity of Catocalinae in the open habitat (Holloway 1985). In addition, Barlow (1982) stated that numerous species from Catocalinae are correlated with secondary vegetation. Perlis State Park that comprises of secondary vegetation around the park headquarters might have high food resources available for noctuid moths from subfamily Catocalinae.

Meanwhile, family Arctiidae has the highest number of macromoths collected with 143 individuals. Also, it was the second diverse family collected in this study with 44 species. According to Hill and Abang (2005), occurrence of arctiid moths throughout the forests of South East Asia are frequent and highly distributed. *Brunia antica* (Arctiidae: Lithosiinae) was the most arctiid moths encountered in the family Arctiidae with 14 individuals collected. The subfamily Lithosiinae was the most species encountered in the family Arctiidae with total of 39 species as Lithosiinae consists of massive number both genera and species and the larvae commonly feed on moss or lichen (Barlow 1982). During the second series of sampling, the forest floor was moist, and some mosses and lichens were found. As food sources were highly available, this explained the high species number collected from subfamily Lithosiinae.

Comparison of macromoths diversity between both strata indicated that there was no significant difference in species diversity of macromoths between ground level and lower canopy level with p-value > 0.05 (Table 3). The similarity of macromoths species between ground level and lower canopy level was obtained by using similarity indices of Morisita-Horn (0.456) and Bray-Curtis (0.332). The results showed lower similarity of macromoths species between ground level and lower canopy level. As Morisita-Horn was highly sensitive to the abundance of the most common species, therefore it showed the highest similarity index compared to Bray-Curtis. The lower similarity between strata might due to the specialization of food resources for each species encountered at each stratum are themselves stratum-limited (Ashton et al. 2016) and this indicate the occurrence of larval assemblages in that stratum. Furthermore, the difference of microclimate, microhabitat, availability of food sources, ability of flights and feeding behaviours might affect the abundant species of adult moths at certain forest strata. Also, the number of traps used across vertical transects influence the species caught with more restricted levels of flight across the forest strata (Intachat & Holloway 2000). Nevertheless, while ground level had slightly high diversity index than lower canopy level, both of them had no significant difference ($p > 0.05$) in species diversity of macromoths. This might be due to the small differences in height between ground level and lower canopy level as 20m was not enough to see the significant differences of moth distributions across the vertical stratification. In a study of Intachat and Holloway (2000), the traps were hoist in the height up to 30m to increase the probability of more species to be caught in the traps. There

are some moth species that have flight preference at canopy level due to the flowering season of some canopy tree species (Holloway 1996).

Table 3. Diversity *t*-test for both ground and lower canopy level

Gradient Level	**Ground**	**Lower canopy**
Number of species	106	108
Shannon Index	4.3753	4.3616
Variance of estimator	0.005182	0.005169
t-test statistic	0.13446	
df	385.71	
p-value	**0.89311 > 0.05 (No significant difference)**	

There were some species in this study that found to be rare to the particular type of habitats based on Holloway (1986-1987, 1993, 1996, 1998-1999, 2001, 2003, 2005). A total of 28 species with 65 individuals are considered rare (Table 4). All the species categorized as rare lowland forest species. One particular species which is happened to be rare lowland forest and limestone species which is *Cyana horsfieldi* (Arctiidae) was sampled.

Table 4. Sampled species categorized as rare for lowland forest and limestone habitat

Rare Species	**Notes**
Barsine exclusa (Arctiidae)	Rare species in lowland forest and secondary forest (Holloway 2001)
Cyana horsfieldi (Arctiidae)	Holloway (2001) taken only five Bornean specimens from both lowland and lower montane forest (to 1000m) as well as on limestone.
Cyana pudens (Arctiidae)	This species is infrequent in lowland dipterocarp forest (Holloway 2001)
Lyclene cuneigera (Arctiidae)	Single specimen collected by A.R. Wallace in Sarawak, possibly in the lowlands (Holloway 2001)
Tortricosia blanda (Arctiidae)	Holloway (2001) had sampled two specimens from an area of disturbed lowland forest at Poring (600m) on the eastern slopes of G. Kinabalu.
Ernolatia lida (Bombycidae)	Rare species in lowland forest (Holloway 1987)
Tridrepana flava (Drepanidae)	Rare species from the forest of lowlands to about 2000m (Holloway 1998)
Ganisa plana (Eupterotidae)	Holloway (1987) reported single material of lowland race sampled each at Labi in Brunei and lowland dipterocarp forest on G. Mulu.
Calletaera subexpressa (Geometridae)	Infrequently in the lowlands, most commonly sampled by Holloway (1993) in lower montane forest, predominantly on limestone, and also collected from upper montane.
Plutodes malaysiana (Geometridae)	Rare in lowland dipterocarp forest and alluvial forest (Holloway 1993)

Agathia quinaria (Geometridae)	Rare species in lowland forest, with one material taken by Holloway (1996) at 1000m on G. Mulu.
Argyrocosma inductaria (Geometridae)	Infrequent in lowland forest, but had collected by Holloway (1996) in secondary forest also.
Comostola cedilla (Geometridae)	Four specimens of this uncommon species taken by Holloway (1996) from primary forest in the lowlands.
Micropacha roepkei (Lasiocampidae)	This species is infrequent but it occurred in a widespread of lowland forest types (Holloway 1987)
Cania bandura (Limacodidae)	Described by Holloway (1987) as a rare species in a widespread of lowland forest types.
Arctornis phasmatodes (Lymantriidae)	Holloway (1999) recorded this rare species frequently in lowlands, but with singletons from 1000m on G. Mulu and 1618m on Bukit Retak, Brunei.
Bembina albinotata (Lymantriidae)	Rare species but found in most lowland forest types (Holloway 1999)
Ilema vaneeckei (Lymantriidae)	Rare in a range of lowland forest types and heath forest (Holloway 1999)
Anisoneura aluco (Noctuidae)	This species is infrequent, but Holloway (1999) had collected from the lowlands to 2600m.
Armana nigraericta (Noctuidae)	Infrequent species with only three Bornean specimens collected by Holloway (2005); two from 300m on G. Santubong and one from the coast of Brunei at Kampong Kapok.
Egnasia overdijkinki (Noctuidae)	Uncommon species which represented by old material from Sarawak and Pulo Laut (Holloway 2005)
Ercheia pulchrivenula (Noctuidae)	Normally is an infrequent species but had been collected by Holloway (2005) in Brunei, G. Mulu and G. Kinabalu.
Hypospila bolinoides (Noctuidae)	Infrequent recorded by Holloway (2005) from the lowlands up to 1930m.
Plecoptera nebulilinea (Noctuidae)	Rare in lowlands in forested and disturbed habitats (Holloway 2005)
Thynas honesta (Noctuidae)	Rare species but has been sampled by Holloway (2005) from the lowlands (300m) to 1620m.
Erizada lichenaria (Nolidae)	Rare species in lowland forest (Holloway 2003)
Siglophora hayata (Nolidae)	This species is infrequent in lowland forest, probably mostly alluvial and coastal forest (Holloway 2003)
Angonyx testacea (Sphingidae)	Rare species from lowlands to 2110m (Holloway 1987)

Two individuals of *Gracillina prosthenia* (Noctuidae: Catocalinae) were sampled and this marks as a new distributional record for Peninsular Malaysia (Figure 3). Prior to this, its geographical range was reported to be in South Thailand, Singapore, Sumatra and Borneo (Holloway 2005), all from lowland forest. This kind of finding is expected as supported by Idris & Abang (2011a, 2011b) because not much study has been done in this Kedawi region.

Figure 3. *Gracillina prosthenia* ♀ (Noctuidae: Catocalinae)

CONCLUSION

The results of the study indicate that the overall diversity of macromoths in Perlis State Park was considerably high. Assessing on the diversity and vertical distribution of macromoths is important as the information and resourceful data of the preferences and specializations of certain species at different strata. The data can be used for further study and management strategies for long-term conservation and ecological stability for authorities. A longer sampling period should be conducted to get more significant data and more traps should be set up to maximize the catch that would cover more species and information.

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