Roles of Heterogeneous Habitat for Conservation of Nymphalidae in Sarawak (East Malaysia)

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Abstract— Species diversity characterises an area or a targeted habitat and provides information on the species assemblages, which is a primary reflection of habitat diversity. It incorporates both species richness and abundance and may rely on factors, such as host-plant availability and food resources. Kubah National Park is a lowland mixed dipterocarp forest, and uniquely offers various vegetation types, which includes heath and submontane forests. In the present study, four contrasting forest habitats were selected along forest trails, namely, primary forests, secondary forests, heath forests and forest edges. Forty baited traps were used within a six-months of sampling period. The highest abundance was recorded at the heath forest while the least was at the secondary forest. However, there was no significant difference in terms of species abundance between forest habitats for subfamilies, as well as for the 15 most abundant nymphalid species sampled, except for *Mycalesis mnasicles*. This satyrine was regarded as being able to differentiate habitat, apart from sensitive to canopy openings. Secondary forest provides a heterogeneous habitat for nymphalids, and thus highest diversity was observed here. This study implies that habitat association of the family is crucial, as it will provide information for both species inventory as well as the fluctuation patterns of the nymphalids diversity. Similar study is suggested to be carried out in the future, which incorporates more than one habitat types and in a more extensive period.

Keywords—Borneo, diversity, fruit-feeding butterflies, habitat, Kubah, Sarawak

I. INTRODUCTION

BIODIVERSITY is represented as the variability of living organisms in a particular area, from all kind of sources [1], [2]. In moist tropical regions, forests harbour the most species-rich habitat where it is home for a vast assemblage of flora and fauna. The terrestrial diversity on Earth is dominated by arthropods in tropical rainforests, mostly supported by the various functional niches offer in this habitat [3]. Comparatively, little is known however, regarding the factors that impacts the spatial distribution of species. Quantifying spatial distribution of arthropods in tropical rainforests may serves as the initial step in studying more on the global distribution of biodiversity on Earth [3]. So as to conduct a proper study on biodiversity, suitable taxa need to be selected. The taxon should be sufficiently diverse in that area, yet the diversity should not be too high, and efficiently sampled [4].

Butterflies are commonly used especially in studying how logging impacts species diversity [5]. They act as a biological indicator for forest disturbance or a flagship species for biological conservation [5], [6]. Being host-plant specific, the butterflies respond almost immediately to certain even minute changes in their environment [6], [7]. Among this group, the nymphalids or the fruit-feeding butterflies are widely studied as bioindicators mainly due to their sensitivity to environmental modifications [8].

In tropical rainforest, spatial factors such as branch height, light levels and tree species are unique and varied. Any form of disturbances whether it is natural or manmade, may influence the spatial pattern of the nymphalids assemblages. Certain nymphalid species may be affected by the humidity at the lower stratum of a closed-canopy forest, and others may strive here because of the plentiful food resources [8], [9]. The vast forest heterogeneity offered in the tropical rainforest provides habitat to the nymphalids, and indirectly play an important role in the conservation of both the flora and fauna. The objectives for this study were to assess the species diversity and abundance of the nymphalids in contrasting forest habitats in the Kubah lowland rainforest, and to observe the distribution of singletons and Bornean endemic species. Habitat preference of these nymphalids was also observed and analysed on the 15 most abundant nymphalid species sampled.

II. MATERIALS AND METHODS

A. Study site

Field sampling was conducted in Kubah National Park (N1°36'48.43", E110°11'51.59"), located in Kuching Division, Sarawak, 22 km west from Kuching city (Fig. 1). This 22 km^2 of conservation area consisted of mixed-dipterocarp forest, alluvial forest, submontane forest, heath forest as well as secondary forest [10]. Baited traps were installed in four different trails which represented different types of forest habitats, namely Waterfall Trail (primary forest), Belian Trail (secondary forest), Summit Trail (forest edge), and Rayu Trail (heath forest) (Table I; Fig. 2). Swamps and small jungle streams were observed in Waterfall and Summit Trail, whereas secondary growth in Belian Trail which are gradually growing back after the establishment of the park. Rainfall during the study ranged from 133 mm per month in September 2009 to 625 mm per month in October 2009, with the driest period in July 2009 (78.5% monthly mean relative humidity). Rainfall data were obtained from the Meteorological Department in Kuching, based in Kuching International Airport (N 1°29', E 110°20' in South Sarawak, 21.7 m a.s.l).

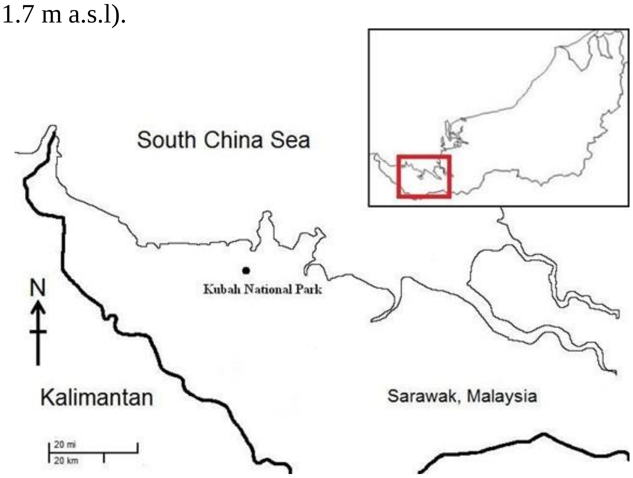

Figure 1. Study area which is in Kubah National Park, Kuching, Sarawak, in southern part of Malaysian Borneo (Source: Modified after Google Map 2011).

B. Butterfly sampling

Five replicate sampling units (tree) were selected in every forest habitat, and each would consist of one ground level baited trap hung between 1 – 1.5 m above ground, and another one at the canopy adjusted to 21 – 27 m above ground. Overall, there were 40 baited traps in all forest habitats; 20 traps were installed at the lower stratum and another 20 at the upper stratum. All traps were established by utilising the Single Rope Technique and suspended from thin nylon ropes run over the branches which are adjusted to considerable height. Fresh pineapples were used as bait and replenished on subsequent trapping days.

Survey was done for 84 days of sampling: 14 continuous days a month from 17 May 2009 to 17 November 2009. After 14 days of sampling, all traps were collected and re-installed in the next sampling occasion. Butterfly specimens were preserved properly and identified to species level, following [11] and [12]. All specimens were deposited at the UNIMAS FRST Museum, Kota Samarahan.

C. Statistical analyses

The number of species as well as individuals sampled were recorded and analysed for conventional biodiversity indices namely Shannon's diversity index (H'), Simpson's diversity index (1-D) and Fisher's-Alpha diversity index (α), with the EstimateS program version 8.2. Diversity *t*-test was used to compare the diversity between the four forest habitats. Next, the comparisons in terms of nymphalids' abundance between these four forest habitats were tested with Kruskal-Wallis test, both for species with 20 and more individuals and for all subfamilies. This analysis was tested against null hypothesis of equal abundance of these nymphalids in all forest habitats.

III. RESULTS

A total of 665 nymphalids representing 49 species have been sampled in 3360 trap-days with 153, 133, 189 and 190 individuals in primary, secondary, edge and heath forest, respectively (Table II). Lowest total abundance was recorded at SF2 with 20 individuals, while the highest was 57 individuals, sampled at FE5. Similarly, the highest species richness was also listed at FE5 with 21 species, whereas the lowest which were 12 species were recorded at SF1, SF2 and PF5 (Table II). Highest species richness which was observed at the forest edge sustained 76% of the total nymphalid species listed in the present study.

Diversity indices indicated the highest index for secondary forest (H': 3.033, 1-D: 0.933, α: 13.370) and the lowest at the primary forest (H': 2.799, 1-D: 0.921, α: 8.993) (Table III), even though there was no significant difference in between those four forest habitats (Diversity *t*-test: $p > 0.07$ in all comparisons). Species accumulation curves for nymphalids assemblages in all four forest habitats were not reaching the asymptote in their respective habitats (Fig. 3). This indicated that the guilds were not completely sampled, yet a few could be representative. Meanwhile, the rarefaction curve for those four assemblages revealed that the observed species richness was within the confidence limit of the curves for all respective habitats (Fig. 3).

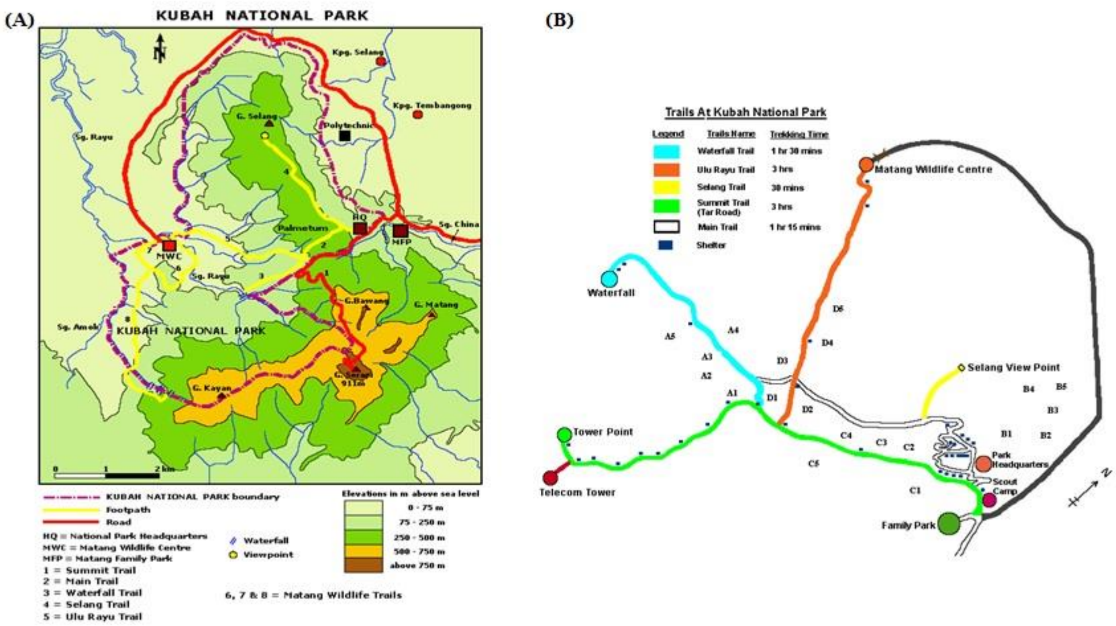

Figure 2. (A) Study site in Kubah National Park, Sarawak with four sampling areas; A. Primary Forest, B. Secondary Forest, C. Forest edge, D. Heath Forest**; (**B) Numbers designate individual replicate sampling units which represents one canopy and one ground level trap (Note: Map not to scale) (Source: [10]).

Table I. Habitat descriptions for study area in Kubah National Park, Sarawak, based on Hazebroek and Abang (2000) and personal observations.

Forest Trail	Forest Habitat	Elevation (a.s.l in m)	Plant Community
Waterfall	Primary forest	305	*Pandanus* spp., Strangling fig tree, *Alocasia robusta* (Giant Aroid) Large tree crowns which permit only little light penetration and less dense woody undergrowth (seedlings and sapling trees, shrubs, and climbers)
Belian	Secondary forest	120	Farmland over 30 years ago yet replanted mostly with 'Engkabang', and local fruits such as *Artocarpus* spp., *Durio* spp. and *Musa* spp.
Summit	Forest edge	120 – 270	Along the road to the summit of Mt. Serapi, at the ridge of a transition from primary to heath forest
Rayu	Heath forest	274	Bintangor, *Dryobalanops becarii* (Kapur Bukit), *Shorea inappendiculata* (Tekam)
			Dense herbaceous undergrowth, scarce of buttresses and climbers, and single-dominant communities of trees

Among all 49 nymphalid species sampled, 18 of them were only sampled at certain forest habitat, including a few nymphalid species were confined only to the forest edge: *Chersonesia intermedia*, *Cirrochroa emalea*, *Euthalia iapis*, *Mycalesis orseis*, *Tanaecia pelea*, and two singletons which were *Faunis stomphax* and *Mycalesis horsefieldii*. Lastly, *Mycalesis mineus* and *Polyura athamas*, both singletons, as well as *Coelitis euptychioides* and *Lexias pardalis borneensis* were listed only at the heath forest.

The equal abundance of the 15 most abundant nymphalid species between the four forest habitats was noted. Only *Mycalesis mnasicles*, a satyrine, was statistically proven to be more abundant, which was at the secondary forest (Table IV). The abundance of the rest of the nymphalid species was distributed randomly in all forest habitats, yet none was significantly restricted in any habitat. This is illustrated with the Venn diagram which shows that 14 of the 15 most nymphalid species were cosmopolitan, and only *M. mnasicles* was sampled in both secondary forest and forest edge (Fig. 4). Similarly, the abundance of the sampled nymphalids was also homogeneous between forest habitats when the data were pooled by subfamily (Table IV).

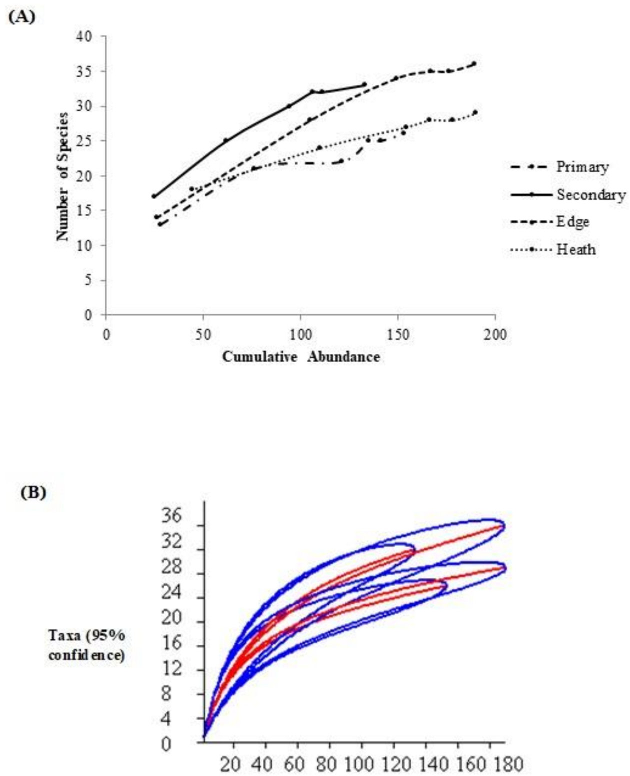

Figure 3. (A) Species accumulation curve for the total community of fruit-feeding butterflies (Lepidoptera: Nymphalidae) in four different forest habitats of Kubah National Park, Sarawak. (B) Individual rarefaction curve computed by PAST (version 1.96) with standard errors converted to 95% confidence interval (blue line).

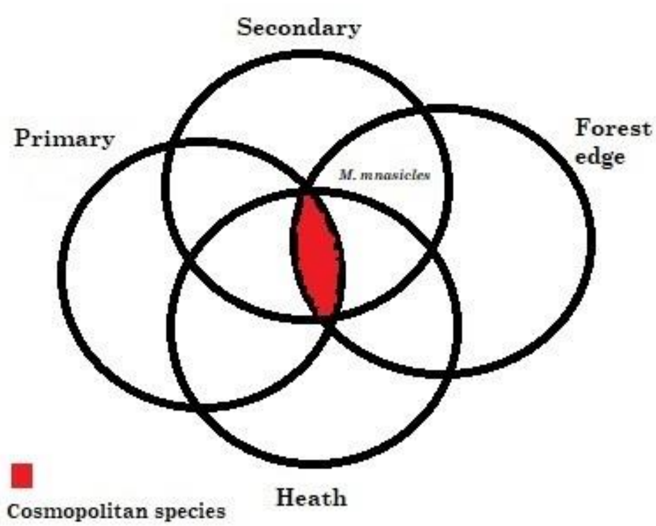

Figure 4. Venn diagram showing the 14 most abundant nymphalids species sampled as cosmopolitan species, which were present in all four forest habitats. Only *M. mnasicles* was present in both secondary forest and forest edge.

IV. DISCUSSION

Different forest types sustain distinctive community structures which are characterised by the unique abiotic and biotic factors [3], [13], [14]. At times, distances between the habitat area with another may also determine the species distribution [15]. Due to this habitat heterogeneity, unique assemblages of entomofauna are found to inhabit every different area of the forest. Most of the recorded nymphalids in this study was sampled from the forest edge (Table II), which also similar with the previous findings in Ecuadorian and Costa Rican forests [16], [17]. In this study, field sampling at the forest edge was carried out along the ridge of the forest, which was also sideways to the road. According to [18], edge effect is when the sampling was not conducted deep in the investigated habitat. Instead, the aim is to assess 'outer' area of the habitat, where the vegetation could still be similar as those in the middle of the habitat or slightly adapted with the different environmental conditions.

Light penetrability increased at the forest edge, and nymphalids are generally known to be drawn to sunlight [16], [19]–[22]. Some of the forest butterflies rely on the light availability in the forest for flight, as they require solar radiation to elevate their body temperature [20]. This could explain the presence of more nymphalids at the forest edge. Moreover, the forest edge in this study is exposed to human activities such as hiking and other recreational activities. This can be considered as intermediate disturbance, which could reflect a positive effect on butterflies' diversity [17]. [23] mentioned that highest diversity is maintained at intermediate scales of disturbance, and this also includes the forest butterflies.

In contrast, secondary forest listed the least total of species and individuals of nymphalids in this study (Table II). It is

Table II: Species richness and total abundance of the fruit-feeding butterflies (Lepidoptera: Nymphalidae) in Kubah National Park, Sarawak. (Each sampling unit consists of two: ground and canopy, functional baited traps).

Forest habitat	Sampling unit (Tree)	Species richness	Total abundance
Primary Forest	PF1	15	39
	PF2	15	25
	PF3	13	31
	PF4	15	32
	PF5	12	26
Secondary Forest	SF1	12	36
	SF2	12	20
	SF3	14	22
	SF4	14	32
	SF5	14	23
Forest Edge	FE1	18	37
	FE2	15	25
	FE3	13	30
	FE4	16	40
	FE5	21	57
Heath Forest	HF1	20	36
	HF2	18	40
	HF3	18	54
	HF4	15	35
	HF5	13	25
Primary Forest		26	153
Secondary Forest		32	189
Forest Edge		37	133
Heath Forest		29	190

Table III: Diversity indices for fruit-feeding butterflies (Lepidoptera: Nymphalidae), sampled in four different forest types in Kubah National Park, Sarawak.

	Primary	Secondary	Edge	Heath
Shannon (H’)	2.799	3.033	2.911	2.893
Simpson’s (1-D)	0.921	0.933	0.923	0.930
Fisher’s-Alpha (α)	8.993	13.370	13.190	9.537

Table IV: Abundance of fruit-feeding butterflies (Lepidoptera: Nymphalidae) in Kubah National Park, Sarawak; (a) species with ≥ 20 individuals; (b) subfamilies. The abundance of each species/ subfamily is tested against the null hypothesis of homogeneity of distribution between forest habitats. Species with asterisks (*) depart significantly ($p < 0.05$) between forest habitats (ns = not significant).

(a)

Species	Primary	Secondary	Edge	Heath	*p*-value
Charaxinae					
Prothoe franckii borneensis Fruh 1913	4	3	10	8	ns
Nymphalinae					
Bassarona dunya monara Fruh 1913	24	14	33	22	ns

Bassarona teuta bellata Distant 1886	10	17	27	18	ns
Lexias dirtea chalcenoides Fruh 1913	5	5	5	5	ns
Lexias pardalis dirteana Corbet 1941	8	6	6	7	ns
Tanaecia clathrata coerulescens Vollenhoeven 1862	3	3	7	13	ns
Morphinae					
Amathuxidia amythaon ottomana Butler 1869	13	4	18	14	ns
Zeuxidia amethystus wallacei C & R Felder 1867	12	3	7	23	ns
Zeuxidia aurelius euthycrite Fruh 1911	13	2	6	4	ns
Zeuxidia doubledayi horsefieldii C & R Felder 1867	7	3	5	16	ns
Satyrinae					
Melanitis leda leda Linnaeus 1758	4	2	3	13	ns
Mycalesis kina Staudinger 1892	2	1	4	13	ns
Mycalesis mnasicles mnasicles Hewitson 1864*	0	17	4	0	< 0.05
Neorina lowii lowii Doubleday 1849	1	9	9	2	ns
Ragadia makuta umbrata Fruh 1911	20	10	7	1	ns

(b)

	Primary	Secondary	Edge	Heath	*p*-value
Charaxinae	7	5	11	10	ns
Nymphalinae	57	55	96	79	ns
Morphinae	48	15	38	59	ns
Satyrinaae	41	58	44	42	ns

possible that the secondary growth in this forest habitat offers food resources and hostplants only to certain nymphalid species. Generalist species may strive well in this habitat, as the diverse secondary growth may provide resources sufficiently. Nevertheless, although the secondary forest habitat in this study recorded the lowest nymphalids, diversity index computed was otherwise. The most diverse group of nymphalids was recorded at the secondary forest (Table III). Similar with the forest edge, intermediate disturbance was also observed in the secondary forest. Belian Trail is comprised of secondary growth and local fruit trees, which may also offer more options of food resources to the nymphalids. The impacts of intermediate disturbance to the nymphalids are scale dependent: when a small-scale fragment was subjected to disturbance, the resulting diversity would be high [15], [21]. This was caused by the great turnover of species between patches which was differed according to the disturbance density [24]. However, this hypothesis does not applied to the overall insects in general as it also depends on the insects' dispersal capability [18], [24].

High diversity of entomofauna in the disturbed area is always observed to be related with the heterogeneity of vegetations [17], [25]. Theory of intermediate disturbance suggests that this condition allows both climax and pioneer species to coexist together and thus increased the overall diversity [21]. With the enormous microhabitats found in the secondary forest, the nymphalids of Morphinae and Satyrinae were high in diversity in this habitat. According to [26] the fruit-feeding butterflies of genus *Amathuxidia* (Morphinae) are rarely observed in undisturbed areas and very much associated with their larval host-plant, Family: Palmae, which was abundant in this habitat.

Decreased diversity pattern in the primary forest was also observed in previous studies such as in Thailand and Sabah, Malaysia [16], [27], [28]. Theoretically, the virgin forest would possess less heterogenous vegetations when compared to the secondary forest, as pioneer trees such as *Macaranga* spp. would dominate the area and subsequently homogeneous vegetation is formed [27]. Therefore, low diversity of nymphalids is common in the primary forest and mostly are Charaxinae [21].

The diversity of the forest butterflies is largely influenced by the vegetation structure as well as taxonomic composition [17]. Therefore, as the response to habitat fragmentation is species-specific, it would be reflected in the species composition, because different butterfly species or subfamily would have different dispersal ability and behavior in response to host-plant distribution [29]. One of the factors that determine the distribution of nymphalid species is the resource availability for adult butterflies and possibly the larval host-plants [25], [28], [30]. Furthermore, the female butterflies spend most of the time in areas which are associated with plant resources that are important for larval stages [25].

Eighteen nymphalid species were recorded at only certain forest habitat, and this includes singletons and an endemic species. At the forest edge, more 'sun-lover' butterflies were recorded such as Nymphalinae and Satyrinae. Satyrine butterlies are known to be host-plant specific, and abundant in areas with increased disturbance [15]. Monocotyledonous annual plants which are their hostplant were abundant in this habitat. Similar finding of the abundance of these two subfamilies at the forest edge and along the road was observed in eastern Amazon, Brazil [31].

On the other hand, primary forest was also preferred by few nymphalid species including *R. makuta*, despite of sustaining the least diverse nymphalids assemblages in the present study. This satyrine was noted to inhabit undisturbed forest with large trees and greater canopy cover, as this nymphalid species is highly-dependent on closed-canopy forest [24]. Similar canopy layer was observed at the Waterfall Trail on top of a few small streams and damp areas along the trail. These characteristics provides a suitable habitat for this species, as *R. makuta* is also known for their mud-puddling behaviour [30], [32].

Nevertheless, most of the 18 nymphalid species were listed at the forest edge and secondary forest. This species distribution was possibly correlated with the environmental variables in these forest habitats. With the diversity and different successional stages of plants in the secondary forest, plentiful food resources for the adult nymphalids and host plants for the larval growth would support their survival [6], [28]. For instance, *R. polynice* is described as uncommon and exclusively rely on its host plant (Urticaceae: *Poikilospermum suaveolens*) [26]. This species was recorded as singleton in the secondary forest in the present study. Another singleton at the secondary forest was *F. stomphax*, which was possibly also due to the abundance of their host plants, *Musa* spp. and *Pandanus* spp., in this habitat [26].

Among all the 15 most abundant nymphalid species, only *M. mnasicles* was statistically proven to show habitat preference while the others were equally distributed in all forest habitats (Table IV; Fig. 4). This satyrine butterfly was described to be sensitive to canopy opening and light, apart from being able to differentiate habitat types [15], [28]. Similarly, this small-sized satyrines was able to co-exist abundantly in even fragmented habitats [29].

V. Conclusion

The allocation of total species abundance of these frugivorous butterflies was not significantly observed between the contrasting forest habitats. Despite of the highest nymphalids abundance at the heath forest and highest species number at the forest edge, no significant preference was observed for all subfamilies. Similar finding was recorded for the 15 most abundant nymphalid species except for *M. mnasicles*, as being able to differentiate habitat types. Most of the singletons were listed at the secondary forest, probably correlated with the presence of their hostplants there. Overall, the heterogeneous vegetation in the secondary forest has sustained the most diverse array of nymphalids. In order to further understand the community structure of insects specifically, more studies on the species diversity and distribution of the focal taxa are suggested. Related studies are vital especially in the tropical region to learn more on the patterns of species diversity. In general, knowledge on nymphalids as focal taxa would contribute to the efforts of conservation biology. Future similar studies are recommended but to be conducted extensively to gain comprehensive data for data analysis.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Christharina S G carried out the field sampling, data analysis and wrote the article.

Fatimah Abang designed and supervised the whole research progress and the write-up.