

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).

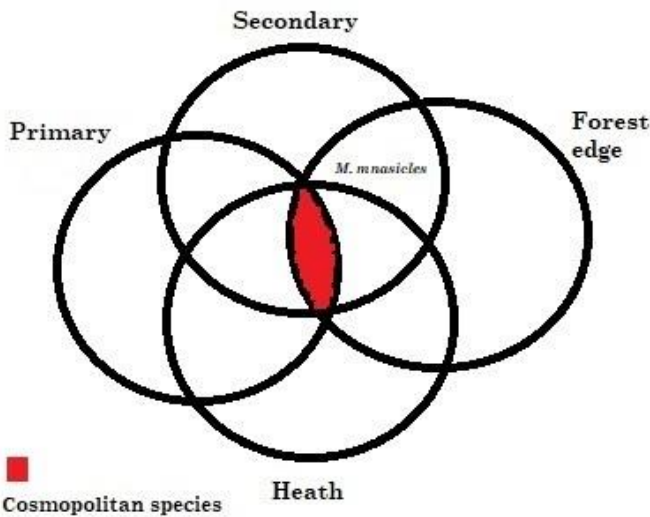


Figure 4. Venn diagram showing the 14 most abundant nymphalids species sampled as cosmopolitan species, which

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					
<i>Prothoe franckii borneensis</i> Fruh 1913	4	3	10	8	ns
Nymphalinae					
<i>Bassarona dunya monara</i> Fruh 1913	24	14	33	22	ns

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

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