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Research Article

Butterfly Diversity at the Different Elevations along Crocker Range Park, in Malaysian Borneo

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ABSTRACT

The butterfly diversity and assemblages at five substations located at the different elevations along the Crocker Range Park, ranging from 396m to 1,891m a.s.l were documented in this study. The butterfly samplings were conducted from April to December 2019, involving 10 sampling sessions. The butterflies were sampled by using 20 baited traps and an aerial net at 20 sampling stations. A total of 727 individuals were sampled comprising 187 species. Nymphalidae was the dominant family at the five substations, which accounted for approximately 53% of the total species and 71% of the total individuals recorded, while *Ypthima pandocus* was the dominant species. The highest number of species was recorded at Keningau substation (965–1,062 m a.s.l) but the highest number of individuals was recorded at Mahua substation (1060–1,249 m a.s.l). Mount Alab substation recorded the least number of butterfly species and individuals. The overall pattern indicated that the butterfly species and abundance were relatively high at an elevation range of about 960–1,250 m a.s.l. Keningau substation was the most diverse area as shown by Shannon-Wiener Index (H'=2.885), followed by Inobong, Mahua and Ulu Kimanis substations. Ten endemic species were sampled in this study with most of these found at an elevation above 965 m a.s.l. The information obtained from this study would contribute to a better understanding of the elevational diversity pattern of tropical biota and also could serve as baseline data for conservation management at Crocker Range Park in facing threats on biodiversity, including global warming.

Keywords: Butterflies, diversity, assemblages, elevations, Crocker Range Park

Introduction

Tropical butterflies have been widely used in ecological studies to assess tropical forest disturbance (e.g Dumbrell & Hill, 2005, Hamer et al., 2005; De Vries et al., 1997). However, very little information is available on how these butterflies react to environmental changes such as an increase in temperature in tropical regions. Some studies reported that tropical organisms are particularly severely affected by global warming (Corlett, 2011). In temperate regions, there is evidence that organisms are showing habitat shifts or expanding their range boundaries (Hughes et al., 2003; Root et al., 2003; Chin et al., 2009). Cooler areas in highlands would potentially be gradually occupied by lowland species as their refuge from increasing temperature. As documented in many studies, mountains serve as refuge for many lowland species during the Pleistocene (Tchouto et al., 2009; Corlett, 2012). In tropical rainforests, the highland area is demarcated at about 1,200m a.s.l (Saw, 2010).

Located on the island of Borneo, which is widely recognised as a biodiversity hotspot, Crocker Range Park (CRP) is the largest terrestrial park in Sabah and is situated in the northern part of the island. The CRP area consists of a wide range of habitats, from lowland to highland. The second highest mountain within this park, Mount Minduk Surong, is situated at 2,050m a.s.l, The park also harbours many species of flora and fauna (Majit et al., 2011). Therefore, it is a suitable area to carry out this study.

There are approximately 944 species of butterflies that have been recorded on Borneo (Otsuka, 1988; Otsuka, 2001), of which about 81 species are endemic (Aqidah et al., 2020) Most of the species can be found in Sabah. Despite the status as the largest terrestrial park in Sabah, no comprehensive information on the butterfly diversity and distribution at CRP have been documented and reported. Therefore, this study aimed to document the diversity pattern of butterflies along the different elevations of CRP. The objectives were to investigate the butterfly diversity and to compare the butterfly assemblages at different elevations at CRP.

Materials and methods

Study Area

Crocker Range Park was established in 1984 and covers an area of 139,919 hectares (latitude 5°07' to 5°56'N and longitude 115°50' to 116°28'E) and falls under the management of Sabah Parks (Tuen et al., 2002). The area is 110km in length and 15km wide (Majit et al., 2011) and consists of several substations located at different elevations (**Figure 1**). In this study, five of the substations located at different elevations were selected as study sites namely Inobong substation (396–533ma.s.l), Ulu Kimanis substation (568–713ma.s.l), Keningau substation (Headquarters of Crocker Range Park) (965–1,062ma.s.l), Mahua substation (1,060–1,249ma.s.l) and Mount Alab substation (1,784–1,891ma.s.l) (**Figure 1**).

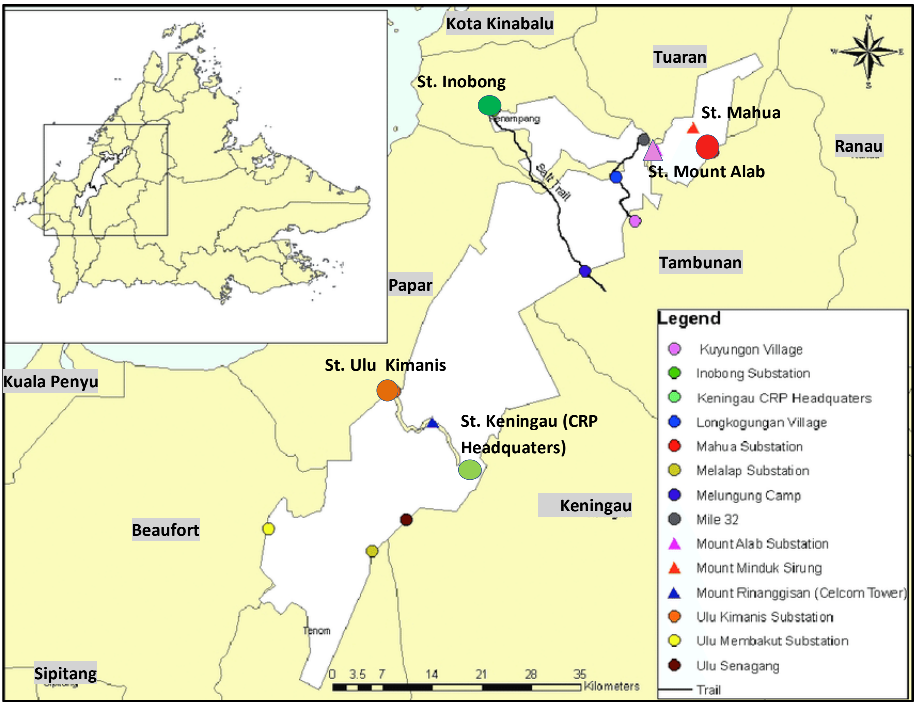

Figure 1. Map of Crocker Range Park and substations (modified from Suleiman et al., 2017)

Data collection

Butterfly samplings were conducted in two cycles starting from April – December 2019. In each cycle, the five substations were visited once (**Table 1**). Each sampling session was conducted for 10 consecutive days, for a total of 100 sampling days. At each substation, a one kilometre transect was established and divided into 20 sampling stations. The sampling activity was started from 8.00 am to 3.00 pm. Butterflies were sampled by using baited traps and an aerial net.

i. Baited traps technique

Twenty traps were hung on the tree branches along a one kilometre line transect approximately at 50m intervals. The traps were placed at least one metre high from the forest floor (DeVries, 1988). Ten traps were baited with bananas and the other ten traps were baited with shrimp paste. These were placed alternately at the sampling stations. The traps were left overnight and checked daily. This technique was used to sample the fruit-feeding guild.

ii. Aerial netting technique

The aerial netting technique was applied to sample butterflies that are not from the fruit-feeding guild and cannot be caught by the baited trap technique. An aerial net was used to catch butterflies within a five metre radius of each sampling station along the same transect used for the baited traps. Ten minutes were spent on searching butterflies at each station, which involved a one-person effort. This technique was used to sample butterflies that cannot be sampled using baited-traps.

Table 1. The sampling sessions during the two sampling cycles at the five substations.

Substation	First cycle	Second cycle
Inobong	1–11 April 2019	19–29 September 2019
Ulu Kimanis	19–29 April 2019	6–16 October 2019
Keningau	16–26 July 2019	5–14 December 2019
Mahua	7–17 May 2019	2–12 November 2019
Mount Alab	24 May–3 June 2019	17–27 November 2019

The specimens collected in the field were kept in triangular papers and brought to the Institute for Tropical Biology and Conservation (ITBC), Universiti Malaysia Sabah for the preservation and identification processes. The butterflies were identified based on Otsuka (1988).

Data Analysis

The butterfly diversity was analysed using the Shannon-Wiener's Diversity Index (H'), Simpson's Evenness Index (D) and Margalef's Index (D_{mg}) (Magurran, 2004). The analyses were performed by using the Paleontological Statistics Software (PAST) (Hammer et al., 2001).

Jaccard's coefficient index (C_j) was used to measure butterfly species similarity between the substations.

Jaccard Similarity index:

(C_j) = j / (a+b-j), where j = the number of species present at both sites

a = the number of species present in site A

b = the number of species present in site B

The Jaccard's index is equal to zero for two sites that are completely different and is equal to one for two completely similar sites (Jaccard, 1912).

Results and Discussions

This study focused on the pattern of butterfly diversity and assemblages along the different elevations in the rainforest of Borneo. Butterflies are sensitive towards subtle changes in their environment which make them an excellent bio-indicator to assess environmental changes (Ismail et al., 2018).

Most of the studies on butterflies in Borneo were conducted in lowland forests and very little information is available on their diversity at higher elevations. In this study, a total of 727 individuals of butterflies belonging to 187 species from five families (Appendix) were sampled. All of the five families of butterflies (Papilionidae, Pieridae, Nymphalidae, Lycaenidae and Hesperidae) were recorded from each substation, except for Mount Alab substation which recorded only Nymphalidae (**Figure 2** and **Figure 3**). Nymphalidae was the dominant family in terms of species richness and the number of individuals at all the substations compared to other families. As reported by Tabadepu et al., (2008), this family is distributed worldwide and can live in various types of habitats.

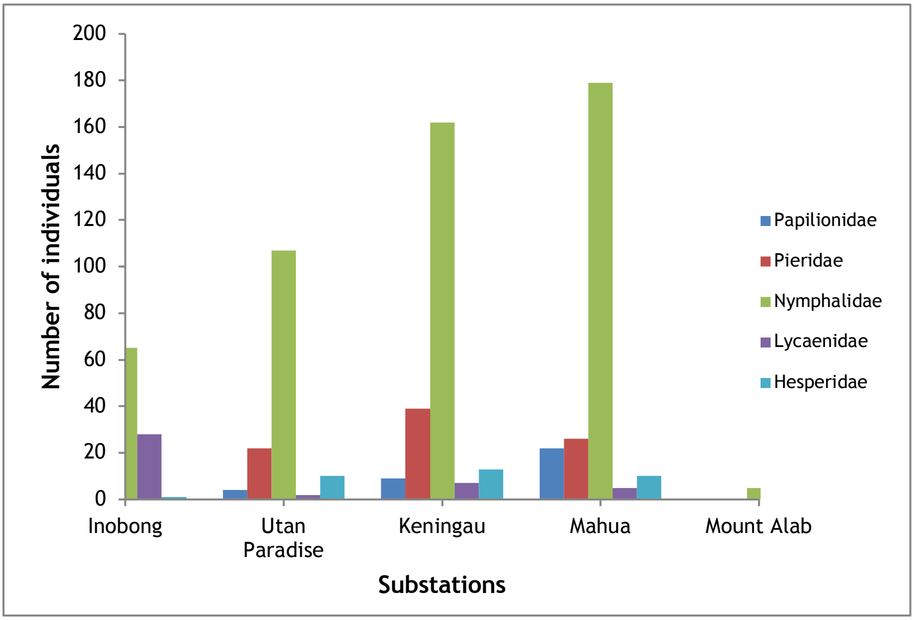

Figure 2. The number of individuals according to the families at each substation.

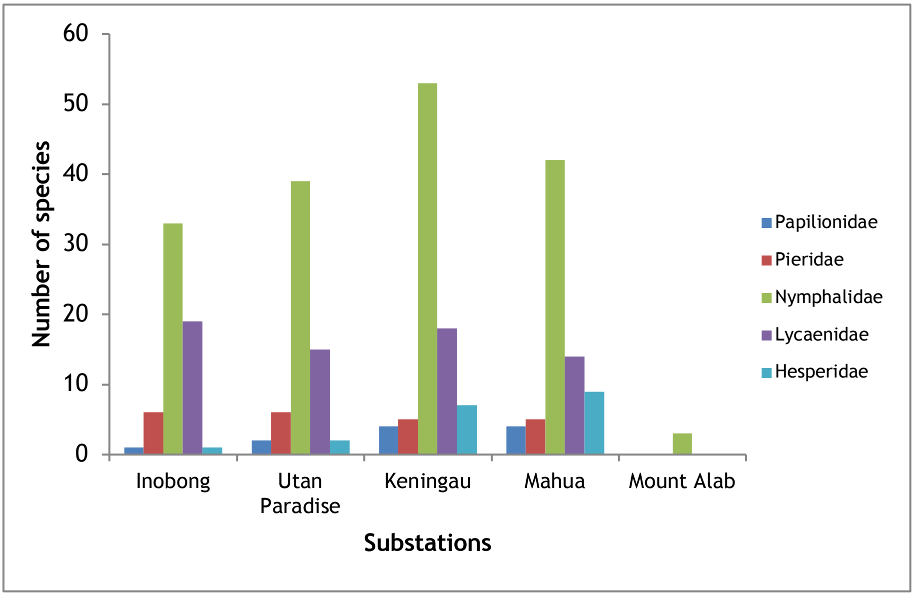

Figure 3. The number of species according to the families at each substation.

In this study, the overall pattern showed that the butterfly species richness and abundance peak at higher elevations (Keningau and Mahua substations) compared to lower elevations (Inobong and Ulu Kimanis substations) and sharply decrease at the highest elevation. As shown in **Table. 2**, Keningau and Mahua substations recorded the highest number of butterfly species (87 and 74 species, respectively) and also the highest number of individuals (220 and 242 individuals, respectively). These results indicate that most of the species distributed at the elevations range from about 950–1,250m a.s.l. The least number of species and individuals were sampled at Mount Alab substation which is the highest elevation in this study, where only five individuals from three species were recorded (**Table 2**). Zainol (2017) also reported a low number of butterfly species and individuals at this substation. Inobong substation which is located at the lowest elevation in this study, recorded the second lowest number of species and individuals.

As shown in many studies, species richness and abundance of organisms decline with increasing elevation (Tattersfield et al., 2001; Zhang et al., 2016). On the other hand, the `humped-shape' pattern of altitudinal diversity was reported and discussed in several studies (Guo et al., 2013). The environment at a higher elevation with low temperature, high humidity, cloudy and less sunlight, less plant species and compact forest canopy could affect the butterfly abundance (Ismail et al., 2018). In contrast, a study conducted at Gunung Ledang in Peninsular Malaysia found that the number of butterfly species and abundance were high at an altitude of 400m, but showed a sharp decrease with increasing altitude (Ismail et al., 2018). The difference in the butterfly diversity pattern could be explained by the distribution of their food resources and breeding habitat (Jemal & Getu, 2018).

Table 2. The number of species and individuals sampled at each substation

Substation (Elevation, m)	No. of species	No. of individual
Inobong (396–533)	59	105
Ulu Kimanis (568–713)	63	145
Keningau (965–1062)	87	230
Mahua (1,060–1,249)	74	242
Mount Alab (1,784–1,891)	3	5

Based on the result, three species were dominant at CRP namely *Ypthima pandocus* (49 individuals), *Ragadia makuta* (43 individuals) and *Kallima limborgi* (42 individuals). They all belong to the family Nymphalidae. *Ypthima pandocus* and *Ragadia makuta* were found at all the substations except Mount Alab, whereas *Kallima limborgi* was found only at Keningau and Mahua substations, but not at the other study sites. *Ypthima pandocus* was the most abundant species and most of the individuals were found at the Ulu Kimanis substation. This species is known as an edge species and is frequently found at the forest edge and is fond of high light intensity. *Ragadia makuta* and *Kallima limborgi* are categorized as forest species and can only be found in shady areas in forests (Corbet & Pendlebury, 1992). Both species were found most abundant at higher elevations (Mahua substation). This result could explain the habitat preference of the butterfly species at CRP.

In the family Lycaenidae, *Eooxylides tharis* was the dominant species with 18 individuals, and this species was found at all the study sites except Mount Alab. Most of the species was caught at Keningau substation. On the other hand, *Hasora schoenherr* was the dominant species in the family Hespiriidae with 14 individuals sampled, most of them were found at Mahua substation. All the species caught from the family Pieridae and Papilionidae were represented by less than 10 individuals.

Interestingly, 10 species that are endemic to Borneo were recorded in this study. Most of them were sampled at elevations above 965m a.s.l, except *Stibichiona schoenbergi* which was also sampled at a lower elevation, while

Tanaecia orphne was sampled only at an elevation of 568–713ma.s.l (Ulu Kimanis substation). Two out of three species sampled at Mount Alab are endemic, namely *Elymnias pellucida* and *Lethe perimede*. There were a total of 91 species (48.7%) collected as singletons along the different elevations at CRP. Most of the singletons were sampled at Keningau substation (30 species, 16%), followed by Ulu Kimanis substation (22 species) and Mahua substation (21 species) both of which accounted for about 11.7% respectively. Ismail et al. (2018) also reported that high a proportion (49%) of singletons were recorded in their study. Some of the species are considered rare including *Agathasa calydonia* and *Rhinopalpa polynice* (Corbet & Pendlebury, 1992). This finding highlighted the conservation values of butterfly assemblages at different elevations at CRP.

Based on the diversity indices, the Shannon-Wiener index showed that three substations (Keningau > Inobong > Mahua) were moderately diverse. The similar pattern was shown in the Simpson evenness index (Keningau > Inobong > Mahua). While the Margalef richness index showed a different pattern (Inobong > Ulu Kimanis > Mahua) (**Table 3**). In general, all the three diversity indices showed very little difference among the substations, except for Mount Alab. Some studies reported a significant difference in tropical butterfly diversity at different elevations (Jemal & Getu, 2018; Ismail et al., 2018).

Table 3. The value of Shannon-Wiener, Simpson and Margalef indices at the substations

Substation	Shannon-Wiener Index	Simpson's Evenness Index	Margalef's Index
Inobong	2.826	0.9358	3.971
Utan Paradise	2.645	0.9134	3.917
Keningau	2.885	0.9393	3.586
Mahua	2.812	0.9316	3.753
Mount Alab	1.332	0.72	1.864

Based on Jaccard's Similarity index, the Keningau and Mahua substations shared the highest species similarity, while the lowest similarity was found between Mahua and Mount Alab substations. Due to very few species recorded at Mount Alab, no similarity was found between Mount Alab and other substations (Inobong, Ulu Kimanis and Keningau). Based on the values, it can be concluded that the species similarity between the substations was relatively low, less than 0.25 (**Table 4**).

Table 4. Jaccard's similarity index between the substations.

	Inobong	Ulu Kimanis	Keningau	Mahua	Mount Alab
Inobong	-	0.196	0.20	0.187	0
Ulu Kimanis	0.196	-	0.155	0.142	0
Keningau	0.20	0.155	-	0.22	0
Mahua	0.187	0.142	0.22	-	0.013
Mount Alab	0	0	0	0.013	-

There were only 8 species (4.28%) out of the total 187 species that were found at all substations, except Mount Alab. The species are *Mycalesis orseis, Ragadia makuta, Ypthima fasciata, Ypthima pandocus, Zeuxidia aurelius, Zeuxidia doubledayi, Eooxylides tharis* and *Jamides pura*. These species are generally not confined to undisturbed habitats (Corbet & Pendlebury, 1992).

It can be suggested that the butterfly assemblages were different at each of the substations, thus might reflect the habitat suitability at different elevations of CRP. Some studies suggested that ectothermic organisms such as invertebrates could be vastly affected altitudinally by changes in abiotic factors such as temperature, humidity and wind speed, along with biotic factors (vegetation and competitions) (Levanoni et al., 2011). At CRP, Mahua and Keningau substations have a cooler and more humid environment compared to other substations, but there is not much difference in terms of canopy coverage. Chen et al. (2009) reported that upward elevation shifts of moth species on Mount Kinabalu are consistent of being responses to climate change observed in the region, either as a direct physiological response to climate or as a consequence of altered interactions with other species. Highlands in tropical regions and their surrounding lowland habitats represent some of the most important locations in the world to maintain biodiversity in face of climate change (Chen et al., 2009).

Conclusion

From this study, information regarding butterfly diversity and assemblages at different elevations at CRP were obtained. A more comprehensive butterfly checklist of CRP was established, which includes the conservation value of the species as well as their distribution at CRP. The information would be useful as baseline data and reference for future research. More importantly, the information could be used as a monitoring tool in assessing the impact of environmental changes, including global warming, on biodiversity. There is an urgent need to monitor how tropical biota is responding to the changes in their environment, not only by anthropogenic disturbance but also climatic factors such as global warming. By documenting sufficient information on their diversity and assemblages, we could gain a better understanding of the impact on tropical biodiversity. Therefore, conservation management could be planned and implemented with effective approaches.

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