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Beetles Species Richness along Environmental Gradients at Montane Ecosystem in Fraser's Hill, Peninsular Malaysia

(Kepelbagaian Spesies Kumbang di Sepanjang Cerun Persekitaran Ekosistem Pegunungan di Bukit Fraser, Semenanjung Malaysia)

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ABSTRACT

This study measures beetle diversity and distribution pattern along elevations at Fraser's Hill, a pristine tropical forest in Malaysia. Sites were sampled at 500 m, 1000 m, 1500 m and 1800 m a.s.l. using two light traps, two Malaise traps and 25 pitfall traps at each elevation. Sampling was carried out at three months' intervals in 2015. Altogether, 1981 beetles representing 32 families and 116 species were collected, with proportion of obtained species above 70% at all elevations. Species richness was not significant among elevations, thus forming no discernible pattern of species distribution. Higher Shannon diversity increased steadily with elevation and dominance was lowest at the two highest elevations, while beetle abundance decreases significantly with elevation. There was no significant difference between the diversity values at 500 m and 1000 m, and 1500 m and 1800 m, whereas there was significant difference between 500 m and 1500 m, and 1000 m and 1800 m. The results highlight the importance of different microhabitats for different beetle species and their own responses to environmental parameters that differ with altitudinal clines. These findings also highlight the importance of Fraser's Hill as a key location for biological conservation and as protected area.

Keywords: Beetles; biodiversity; conservation; ecosystem; tropical forest

ABSTRAK

Objektif kajian ini adalah untuk mengkaji kepelbagaian kumbang dan taburannya pada aras ketinggian yang berbeza di Bukit Fraser. Bukit Fraser adalah hutan tropika yang terletak di Malaysia dan merupakan lokasi yang sangat sesuai untuk menjalankan kajian kepelbagaian corak pada aras ketinggian yang berbeza. Empat aras ketinggian berbeza telah dipilih untuk proses pengumpulan sampel iaitu 500 m, 1000 m, 1500 m dan 1800 m dari paras laut dengan menggunakan perangkap jenis cahaya, perangkap jenis Malaise dan perangkap lubang. Dua perangkap jenis cahaya, dua perangkap jenis Malaise dan 25 perangkap lubang telah digunakan pada setiap aras ketinggian. Proses pengumpulan sampel ini telah dijalankan setiap selang tiga bulan pada tahun 2015. Secara keseluruhan, 1981 kumbang yang mewakili 36 famili dan 116 spesies Coleoptera telah berjaya dikumpulkan. Oleh itu, usaha pengumpulan sampel adalah sangat baik dan peratusan sampel yang diperoleh adalah melebihi 70% bagi setiap ketinggian yang berbeza. Kepelbagaian spesies yang lebih tinggi terdapat di kawasan yang lebih tinggi, namun perubahan pada ketinggian adalah tidak ketara. Kepelbagaian Shannon yang tinggi dan dominasi yang rendah didapati di kawasan yang lebih tinggi, manakala jumlah kumbang berkurangan dengan aras ketinggian. Korelasi Spearman merumuskan korelasi yang positif dan ketara antara jumlah kumbang dan kelembapan relatif, walaupun nilai kelembapan adalah rendah. Hasil kajian ini menekankan kepentingan kepelbagaian habitat mikro bagi spesies kumbang yang berbeza dan tindak balasnya terhadap parameter persekitaran dengan aras ketinggian yang berbeza. Pemeliharaan status kepelbagaian biologi Bukit Fraser adalah sangat penting sebagai lokasi pemuliharaan biologi dan kawasan yang dilindungi.

Kata kunci: Ekosistem; hutan tropika; kepelbagaian biologi; kumbang; pemuliharaan

INTRODUCTION

Among ecosystems, tropical forests are the most species-rich, harboring up to 80% of the world's biodiversity (Erwin 1996). Unfortunately, human disturbances continue to challenge conservation initiatives (Novotny & Miller 2014) in the world tropical biomes. Tropical mountains are among the best ecosystems for 'natural experiments' to test ecological and evolutionary studies (Nunes et al. 2016). Furthermore, tropical forests at high altitudes possess a high level of endemism and insularity (Schonberg et al. 2004), facilitating tests of hypotheses focused on local habitat change and fragmentation in relation to climate change (Chen et al. 2009). In Malaysia, high level of urbanisation, massive land use changes and the potential effects of climate change necessitates a close assessment of environmental and biological parameters in order to avoid catastrophic loss of biodiversity.

Although Malaysia is described as one of the 12 biodiversity hotspots in the world, little is known about its forest reserves and beetle diversity along the elevations

(Yong 2009). With its undisturbed fauna and flora, Fraser's Hill is renowned for its rich biodiversity and has been a haven for botanists, bird watchers and scientists. According to World Wide Fund for Nature (WWF 2013), Fraser's Hill is home to more than 10% of all plant species found in Peninsular Malaysia, of which 952 are indigenous. Strange (2004) reported 247 bird species and 61 migrating bird species, while Latiff (2009) mentioned 36 Peninsular Malaysian endemic species of flora and Norhayati et al. (2011) reported the presence of 67 amphibian species, some endangered. Although there are studies on forest plant species (Adam et al. 2011), herpetofauna (Norhayati et al. 2011), geckos (Grismer et al. 2013) and Orthoptera (Tan & Kamaruddin 2014), the highly diverse beetle fauna of Fraser's Hill has been relatively unexplored. Highly diverse beetle fauna of Fraser's Hill is poorly addressed by the scientific society until today but there have been a number of studies conducted on beetle diversity and distribution and the list can be found in Table 1.

Beetles play various roles such as pollinators, parasites, mediating in nutrient recycling and seed dispersal and general ecosystem maintenance (Nichols et al. 2008). Distribution and diversity of beetles are affected by multiple factors such as anthropogenic disturbances, historical factors and numerous environmental factors.

Elevation clines and species richness/distribution have been the focus of investigations among scientists around the globe (Musthafa et al. 2018; Urban 2015). Although many hypotheses have been proposed based on species richness and elevational clines on various taxa such as mammals, birds, reptiles, plants, ferns, fish, fungi and insects, highly diverse beetles are badly under-represented (Fischer et al. 2011), except for dung beetles (Nunes et al. 2016). Therefore, the objective of this study was to determine the beetle species richness, diversity and distribution at different elevations in accordance with environmental factors along gradients in tropical rain forest of Fraser's Hill, Malaysia.

MATERIALS AND METHODS

STUDY SITES

The main mountains in Peninsular Malaysia are located in the middle on a ridge from Pahang to Kelantan states. Fraser's Hill is located at 3° 43' N; 101°45' E, running between Pahang and Selangor states. Fraser's Hill or Bukit Fraser, a pristine, permanently protected natural reserve located at the Raub district of Pahang state, was formed 250 million years ago by the molten magma that extruded upon the earth crust as a result of tectonic activities. Seven peaks of Fraser's Hill range between 1000 m and 1800 m from mean sea level with an area of approximately 28 km^2.

SAMPLING METHODS

At each site temperature, relative humidity (RH), luminance and elevation were recorded using Center 310 (RS-232) Humidity Temperature Meter, Milwaukee MW 700 portable lux meter and Garmin GPSMAP® 78s global positioning system (GPS), respectively. Sites were for sampled at 500 m, 1000 m, 1500 m and 1800 m a.s.l. with two light traps, two Malaise traps and 25 pitfall traps fixed at each elevation (Table 2). Malaise traps were made up of nylon net with a collection jar half filled with 70% alcohol fixed at a branch of a tree not more than 1 m from the ground level. Malaise

TABLE 1. Previous research works on beetles conducted in Malaysia

Author	Location	No. of beetles collected		
		Families	Species	Individuals
Chung et al. (2000)	Sabah	81	1711	8028
Chey et al. (2002)	Sabah	-	325	-
Idris et al. (2002)	Gunung Nuang	-	-	53
Abdullah (2005)	Langkawi Island	23	201	835
Abdullah (2007)	Endau Rompin	23	42	297
Abdullah (2008)	Lalang Island	8	15	135
Muslim et al. (2010)	Maliau Basin	17	61	-
Abdullah et al. (2011a)	Cameron Highland	16	68	98
Abdullah et al. (2011b)	Imbak Canyon	33	188	538
Abdullah et al. (2011c)	Royal Belum	30	132	652
Abdullah et al. (2011d)	Melaka	27	112	650
Abdullah and Shamsulaman (2011)	Gunung Benom	34	113	348
Abdullah et al. (2012a)	Pulau Pinang	25	62	234
Abdullah et al. (2012c)	Gunung Belumut	29	98	841
Abdullah et al. (2013a)	Gunung Inas	31	115	701
Abdullah et al. (2013b)	Chamah Highland	30	220	641
Abdullah and Sabri (2014)	Besar Hantu	26	190	316
Abdullah and Musthafa (2019)	Pangkor Island	26	116	277

TABLE 2. Sampling site coordinates according to each trap fixed at all the altitudinal clines

	Coordinates at different elevations of sampling site			
Traps	500 m	1000 m	1500 m	1800 m
Malaise 1	N03° 42.712’ E101 ° 46.259’	N03° 42.018’ E101° 45.100’	N03° 43.536’ E101° 43.084’	N03° 42.569’ E101° 46.752’
Malaise 2	N03° 42.754’ E101 ° 46.222’	N03° 42.051’ E101° 45.060’	N03° 43.561’ E101° 43.116’	E03° 42.685’ N101° 46.810’
Pitfall Set 1	N03° 42.749’ E101° 46.258’	N03° 45.078’ E101° 45.078’	N03° 43.542’ E101° 43.035’	N03° 42.346’ E101° 46.687’
Pitfall Set 2	N03° 42.778’ E101° 46.210’	N03° 42.045’ E101° 45.053’	N03° 43.541’ E101° 43.094’	E03° 42.700’ N101° 46.235’
Pitfall Set 3	N03° 42.779’ E101° 46.207’	N03° 42.064’ E101° 45.050’	N03° 43.561’ E101° 43.134’	E03° 42.911’ N101° 46.855’
Pitfall Set 4	N03° 42.812’ E101° 46.214’	N03° 42.085’ E101° 45.081’	N03° 43.535’ E101° 43.172’	E03° 42.959’ N101° 46.889’
Pitfall Set 5	N03° 42.721’ E101° 46.366’	N03° 43.005’ E101° 45.210’	N03° 43.454’ E101° 43.209’	E03° 42.701’ N101° 46.399’
Light Trap 1	N03° 42.728’ E101° 46.304’	N03° 42.254’ E101° 45.190’	N03° 43.129’ E101° 43.408’	N03° 42.654’ E101° 46.887’
Light Trap 2	N03° 40.280’ E101° 45.094’	N03° 42.201’ E101° 46.711’	N03° 43.552’ E101° 42.552’	N03° 42.410’ E101° 46.125’

traps and pitfall traps were set for 24 h starting from 0800. Pitfall traps are 200 mL plastic cups (65 mm diameter, 9.5 cm depth) sunk into the ground with the brim at the same level as the ground. Beetles were sampled using pitfall traps partially filled with 70% alcohol at each elevation gradient. Large leaves were positioned to protect the traps from rain. Light traps were made of mosquito net with a 160-watt mercury bulb connected to a portable Honda EU10i portable power generator. It was fixed just above ground level and the beetles attracted to the light were collected using collection bottles. Sampling was carried out every three months during 2015/2016 season. There is no clear-cut wet or dry season in Malaysia where rain is experienced almost every month with an average 2000 to 3500 mm per year (Ya’cob et al. 2016).

SPECIMENS AND TAXONOMIC IDENTIFICATION

All the collected samples were sorted and tallied to morphospecies level based on established taxonomic key (Triplehorn & Johnson 2005). Every sample was identified by morphospecies name, collection place, date and trapping method.

DATA ANALYSIS

Mean values for the temperature, relative humidity and luminance. Data for temperature, RH and luminance were tested for correlation with species richness and abundance, via Spearman correlation analysis in STATISTICA 8.0 (StatSoft Inc. 2007). Species richness was analysed by tabulating total number of species present at each the four sampling sites.

Commonly used nonparametric estimators calculated were ACE (Abundance-based Coverage Estimator), Chao 1, Chao 2, Jackknife 1 and Jackknife 2, where ACE is calculator of species richness, Chao is an additional richness estimator and Jackknife is a first-order Jackknife richness estimator (Chao & Chiu 2016). ACE, Chao and Jackknife estimators were used to calculate the species richness at each altitudinal cline (Hortal et al. 2006; Magurran 2004) using the software EstimateS 9.1 (Colwell 2013), with 100 randomisations without replacement and the species abundance was measured per sampling unit. Furthermore, Clench model was used to estimate the sampling effort efficacy with the use of estimated species richness and slope of the species accumulation curve, which estimates the sampling quality based on the method described by Jiménez-Valverde and Hortal (2003) and were performed using STATISTICA 8.0 (StatSoft Inc. 2007).

Species abundance differences among sampling sites were analysed using Kruskal-Wallis nonparametric tests as the data set did not follow the assumptions of normality. Shannon-Weiner index was used as a principal component of alpha diversity measurement (Magurran 2004), while obtained diversity values were transformed to a true diversity values based on Jost (2007) for whole study site and for each site. ANOVA test was conducted to assess the Shannon-Weiner index differences among the tested elevations. PERMANOVA analysis was conducted to assess the differences in species composition between each pairwise comparison of sites, via Bray-Curtis index as distance measure. All calculations were made in PAST 3.07 (Hammer et al. 2001) and STATISTICA 8.0 (StatSoft Inc. 2007).

Results and Discussion

Abiotic Factor Assessment

Environmental data (temperature, relative humidity and luminance) varied among the four sampling sites (Figures 1, 2 and 3). Average temperature was highest at 500 m (24.36±0.93ºC), with 1500 m (22.46±1.32ºC) and 1800 m (22.5±0.97ºC), showing almost identical values. Average RH was also highest at 500 m elevation (94%) and lowest at 1800 m (89%), as expected for tropical rain forests. In contrast, luminance was lowest at 1500 m (675 l×), compared to other elevations observed at 500 m (1344 l×) and 1800 m (1237 l×) which were approximately equal. There was a low but significant correlation between abundance and RH (Table 3), indicating that environment affects beetle species diversity and distribution, as has been reported from different parts of the world (Guo et al. 2013; Nunes et al. 2016). Some of the studies have shown that low humidity or dry conditions might have detrimental impacts on larvae and pupae stages of different beetle species (McKee & Aukema 2015; Norhisham et al. 2013). Both temperature and relative humidity displayed positive and negative influences on different insect groups (Jaworski & Hilszczański 2013). Moreover, luminance has influence on flight initiation of some beetle species (Drury et al. 2016).

Beetles Richness at Fraser's Hill

Beetle families Bosteridae and Curculionidae where observed at all elevations. Overall, 1981 beetles representing 36 families and 116 species of beetles were collected at Fraser's Hill. At the 500 m elevation gradient, the most abundant families were Staphylinidae, Scolytidae and Chrysomelidae where *Orphnebius* sp. (Staphylinidae) was the dominant species. *Anomala* sp. (Scarabaeidae), *Xyleborus* sp. (Bostrichidae) and *Brachypeplus* sp. (Nitidulidae) were the dominant species at 1000 m, 1500 m and 1800 m, respectively (Table 4).

The results also showed the importance of different microhabitats for beetle species assemblages. Staphylinidae beetle abundance was high in sandy or sandy-loam soils than in clay soils according to Balog and Markó (2006), whereas Irmerler and Gurlich (2007) reported that they depend on the presence of nests and specific succession status of dead wood. Generally, lower montane cloud forests in Peninsular Malaysia shows well-drained soils mainly at elevations between 1000 m and 1500 m, where soil composition changes with elevation from that of the lowland forest to more humic with the depletion of nutrients (Saw 2010). No study has been found on the succession status of dead wood at Fraser's Hill.

Mobility of Staphylinid was supported by their ability of the rear wings to fly (Assing 2011). Abundance of Aleocharinae and Staphylininae was likely to be influenced by their ability to forage, detect and locate dung and decaying mushroom from long distance (Pohl et al. 2008). At 1000 m a.s.l. the presence of dung beetles (family Scarabaeidae) is high, where the human interaction is high too. There are a number of hotels, recreational activities and cultivations that can be seen around 1000 m a.s.l. Furthermore, the land use pattern around these localities has some influences on the beetle distribution based on this study. Scarabaeidae beetles were good indicators of human impact on ecosystems and land use pattern (Barragán et al. 2011; Spector 2006). Therefore, further studies can be conducted focusing on dung beetle diversity and the land

TABLE 3. Spearman correlation analysis for abundance and species richness of beetles with temperature, relative humidity and luminance at Fraser's Hill

Indices	Temperature	Relative humidity	Luminance (l×)
Abundance	0.077905	0.337777*	-0.186796
Species richness	-0.013704	0.298600*	-0.229848

*is significant at $p<0.05$

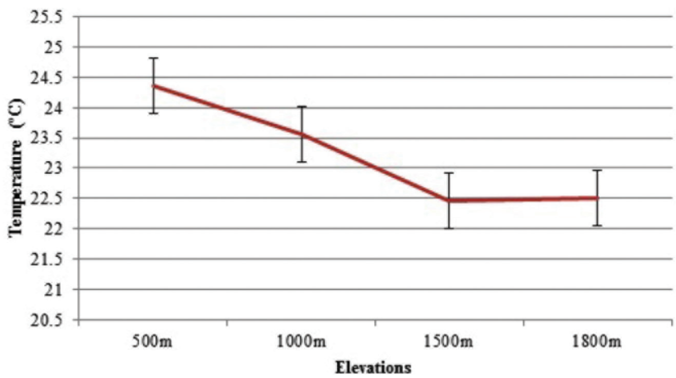

FIGURE 1. Average temperature change across elevations

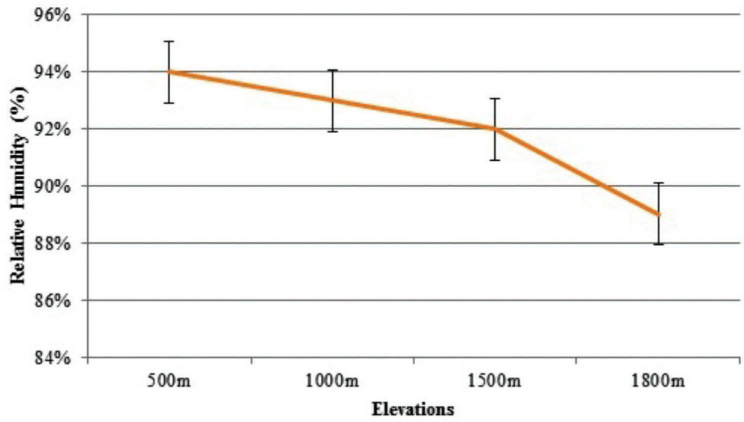

FIGURE 2. Average relative humidity change across elevations

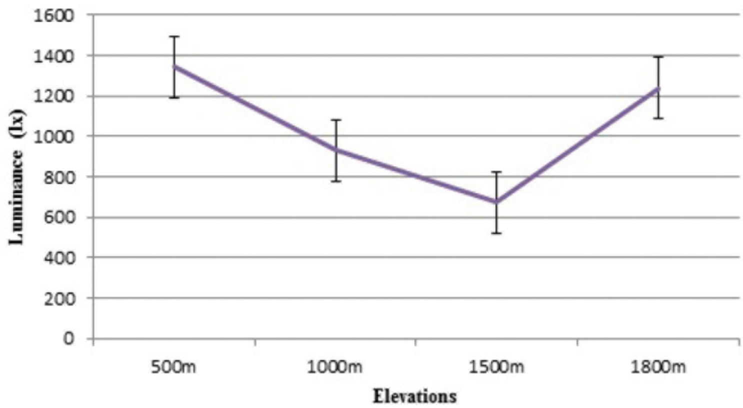

FIGURE 3. Average luminance change across elevations

TABLE 4. Species collected from four elevational gradients at Fraser's Hill

Families	Species	Elevations (m)	No. of specimens (N)		
			MT	PT	LT
Anthicidae	*Anthicus* sp. 1	500	6	22	1
		1800	4	10	1
	Anthicus sp. 2	1800	3	0	2
Anobidae	*Anobi* sp. 1	500	7	0	0
Anthribidae	*Acorynus* sp. 1	1500	1	0	2
Bostrichidae	*Xylothrips* sp. 1	500	15	12	8
		1000	10	26	0
		1500	11	2	6
		1800	12	15	0
	Xylothrips sp. 2	500	14	27	2
		1000	16	2	4
	Anisandrus sp. 1	500	1	20	2
		1000	5	2	5
	Anisandrus sp. 2	1500	5	1	3
Brentidae	*Arrenodes* sp. 1	1000	1	0	0
		1800	0	0	1
		1500	0	1	0
Bupresidae	*Endelus* sp. 1	1000	1	0	1

continue

Continued TABLE 4.

Families	Species	Elevations (m)	No. of specimens (N)		
			MT	PT	LT
Carabidae	*Harpalus* sp. 1	500	0	35	2
		1000	0	19	0
	Harpalus sp. 2	500	0	3	0
		1000	0	9	1
		1500	0	0	0
		1800	0	10	0
	Lesticus sp. 1	1500	0	10	0
	Colpodes sp. 1	1000	0	8	0
	Pterostichus sp. 1	500	0	22	0
	Pterostichus sp. 2	500	0	2	0
	Parena sp. 1	1500	0	4	0
		1800	0	9	0
	Colpodes sp. 3	1500	0	9	0
		1800	0	12	0
	Parena sp. 2	1500	0	4	0
		1800	0	8	0
Cerambycidae	*Sarmydus* sp. 1	1000	3	0	4
	Hoplocerambyx spinicornis (Newman 1842)	1800	0	0	1
	Neocerambyx gigas (Thomson 1878)	1800	0	0	3
	Macrotoma sp. 1	1500	0	0	3
		1800	0	0	7
	Sarmydus antennatus (Pascoe 1867)	1500	1	0	1
	Epepeotes lateralis (Guérin-Méneville 1831)	500	0	0	4
Chrysomelidae	*Phyllobrotica* sp. 1	1500	10	0	3
	Alticinae sp. 1	1000	4	0	0
	Alticinae sp. 2	1000	3	0	2
	Nistora sp. 1	1000	0	0	2
	Phyllobrotica sp. 2	1500	7	0	4
	Colasposoma sp. 2	500	3	0	0
	Altica sp. 1	500	2	0	1
	Cleorina sp. 1	500	2	0	3
	Nisotra sp. 2	1500	6	0	6
		1800	4	0	0
	Phyllobrotica sp. 3	1500	6	0	1
		1800	5	0	4
	Galerucinae sp. 1	1500	2	0	6
	Colasposoma sp. 4	500	1	0	6
	Cleorina sp. 2	500	4	0	3
		1000	6	0	6
	Trichochrysea sp. 1	1000	1	0	2
Cicindelidae	*Cicindela* sp. 1	500	0	0	5
		1000	0	0	1
	Cicindela sp. 2	1800	0	0	2
	Cicindela sp. 3	1800	0	0	1

continue

Continued TABLE 4.

Families	Species	Elevations (m)	No. of specimens (N)		
			MT	PT	LT
Cleridae	*Strotocera* sp. 1	1000	5	0	6
		1500	0	2	5
		1800	1	0	0
Coccinelidae	*Chilocorinae* sp. 1	500	0	0	2
	Illeis sp. 2	500	6	0	4
		1500	3	0	1
		1800	2	0	2
Curculionidae	*Acalles* sp. 1	500	6	0	1
		1500	0	0	7
	Athesapeuta sp. 1	500	1	0	1
		1000	2	0	2
		1500	5	0	3
	Acalles sp. 2	500	1	0	0
	Rhadinomerus sp. 1	500	19	0	15
		1000	6	0	4
	Lechriops sp. 1	1000	1	0	4
Dytiscidae	*Hydaticus fabricii* (Macleay 1825)	500	12	0	7
		1800	6	0	5
	Hydrovatus enigmaticus (Biström 1997)	1800	2	0	1
Elateridae	*Mulsanteus* sp. 1	500	0	0	1
		1000	0	0	4
		1800	0	0	2
	Mulsanteus sp. 2	500	0	0	3
		1800	0	0	2
	Mulsanteus sp. 3	500	0	0	2
	Nipponoelater sp. 1	1000	0	0	1
Endomychidae	*Idiophyes* sp. 1	500	10	0	0
Erotylidae	*Megalodacne* sp. 1	1500	3	1	5
		1800	1	0	0
Eucnemidae	*Fornax* sp. 1	1500	7	0	8
		1800	1	0	1
	Fornax sp. 2	1500	3	0	4
	Agriotes sp. 1	500	0	0	3
Histeridae	*Hypocaccus* sp. 1	500	0	3	0
		1500	0	0	1
		1800	0	4	0
Hydrophilidae	*Lacconeatus* sp. 1	500	3	1	0
		1800	3	1	0
Lampyridae	*Luciolinae* sp. 3	1000	0	0	5
	Luciola sp. 1	1000	3	0	4
		1500	1	0	0
	Lampyris sp. 1	500	4	0	2
	Luciola sp. 2	1800	0	0	1
Lucanidae	*Aegus* sp. 1	1800	0	0	2
	Figulus sp. 1	1000	0	0	2
Lycidae	*Metriorrhynchus* sp. 1	1000	2	0	0
	Diatrichalus sp. 1	500	0	0	1

continue

Continued TABLE 4.

Families	Species	Elevations (m)	No. of specimens (N)		
			MT	PT	LT
Meloidae	Meloi A	1500	4	0	4
Nitidulidae	*Brachypeplus* sp. 1	500	5	1	0
		1500	7	2	0
	Brachypeplus sp. 2	1000	2	27	0
Passalidae	*Aceraius* sp. 1	500	0	1	0
		1000	0	4	0
		1500	0	0	1
Platypodidae	*Dinoplatypus* sp. 1	1000	1	0	0
Ripiphoridae	Ripi A	1000	3	0	0
Scarabaeidae	*Anomala* sp. 1	500	0	1	3
		1000	14	1	20
		1500	3	1	9
		1800	0	1	9
	Apogonia sp. 1	500	5	5	5
		1500	5	1	8
	Apogonia sp. 2	500	1	3	7
		1000	5	2	8
		1500	7	1	5
	Apogonia sp. 3	1000	5	3	7
		1500	1	1	17
		1800	0	2	6
	Anomala sp. 2	500	3	1	0
	Polyphylla sp. 1	500	2	4	1
	Phaeochrous sp. 1	1000	5	1	0
	Phaeochrous sp. 2	1500	0	3	2
	Anomala sp. 4	500	3	2	7
	Apogonia sp. 4	1800	0	1	3
	Onthophagus sp.1	1500	0	0	4
	Apogonia sp 5	1000	1	0	1
	Scaphisoma sp. 1	1500	0	0	2
	Cratna sp. 1	1800	0	0	2
Scolytidae	*Sinoxylon* sp. 1	500	12	31	0
		1800	3	9	0
	Sinoxylon sp. 2	1000	15	20	0
	Xyleborus sp. 1	500	1	18	0
Scydmanidae	*Euconnus* sp. 1	500	1	10	0
	Lophioderus sp. 1	500	20	31	0
		1000	8	28	0
Staphylinidae	*Orphnebius* sp. 1	500	0	97	0
		1000	0	21	0
	Orphnebius sp. 2	1500	0	37	0
	Oxytelus sp. 1	1000	0	14	0
	Anotylus sp. 1	1800	0	15	0
	Lispinus sp. 1	500	0	10	0
		1000	0	15	0

continue

Continued TABLE 4.

Families	Species	Elevations (m)	No. of specimens (N)		
			MT	PT	LT
	Eleusis sp. 1	1500	0	10	0
		1800	0	3	0
	Eleusis sp. 2	500	0	2	0
		1000	0	8	0
		1500	0	3	0
	Paedarus sp. 1	500	0	39	0
	Bolitogyrus sp. 1	1000	0	16	0
	Bledius sp. 1	500	0	15	0
	Orphnebius sp. 3	500	0	10	0
		1000	0	20	0
		1800	0	11	0
	Sunius sp. 1	500	0	16	0
		1500	0	19	0
		1800	0	22	0
	Actiastes sp. 1	500	0	25	0
		1000	0	8	0
Tenebrionoidea	*Upis* sp. 1	500	29	0	15
	Lupropini sp. 1	500	20	0	13
		1000	14	0	4
	Lupropini sp. 2	1500	20	0	15
	Lupropini sp. 3	1800	29	0	10
	Bradymerus sp. 1	500	13	0	0
	Bradymerus sp. 2	1000	1	0	0
Zophoridae	*Monomma* sp. 1	500	0	4	6

use pattern at Fraser's Hill. Presence of water beetles (Dytiscidae and Hydrophilidae) can ensure the availability of water resources. The number of rivers were found around 1000 m and 1500 m a.s.l. at Fraser's Hill. Some of the woodboring beetles were also found widely showing the diversity of different tree communities.

FRASER'S HILL SAMPLING COMPLETENESS, SPECIES RICHNESS AND BIODIVERSITY MEASUREMENTS

Observed species richness at all elevations was 116 species whereas, ACE, Chao 1, Jackknife and Clench models estimated species richness values ranged between 131 and 145 (Figure 4). When Clench model slope value is close to or less than 0.10 beetle sampling is considered complete and reliable according to Jiménez-Valverde and Hortal (2003) (the value for Fraser's Hill was 0.03). For all sites, sampling completeness was above 70%, with a minimum of 75% at 500 m and the maximum of 85% at 1000 m. Moreover, the slopes of species accumulation curves are not correlated with elevation, thus the pattern is random.

Values of more than 70% sampling completeness throughout when all methods were employed indicated that the beetle composition collected at each level is representative (Jiménez-Valverde & Hortal 2003). Species accumulation curves are good indicator for alpha level diversity (direct comparison), countering the drawbacks of other diversity indicators such as Shannon and Simpson indices (Musthafa & Abdullah 2019; Veech & Crist 2010). The species accumulation curve presented in this study follows the expected trends for tropical insects, with no immediate evidence of asymptotic shape in the curve, which would indicate that the beetle fauna has not been fully sampled. Due to the high diversity insects in the tropics, a continuously increasing species accumulation curve would be expected (Escobar et al. (2005).

Although the highest species richness was obtained at the 1800 m elevation site, changes among altitudinal gradients were not significant (Table 5). The highest diversity (Shannon) and lowest dominance were obtained also at the highest elevation (1800 m) (Table 5). There was no significant difference between the diversity values at 500 m and 1000 m, and 1500 m and 1800 m, whereas there was significant difference between 500 m and 1500 m, and 1000 m and 1800 m. Figure 5 shows the species accumulation curves at each altitude where the curve approaches but did not fully reach the asymptote. The peak in Shannon diversity at 1800 m could be due to many reasons such as random sampling effects, increased human influences at

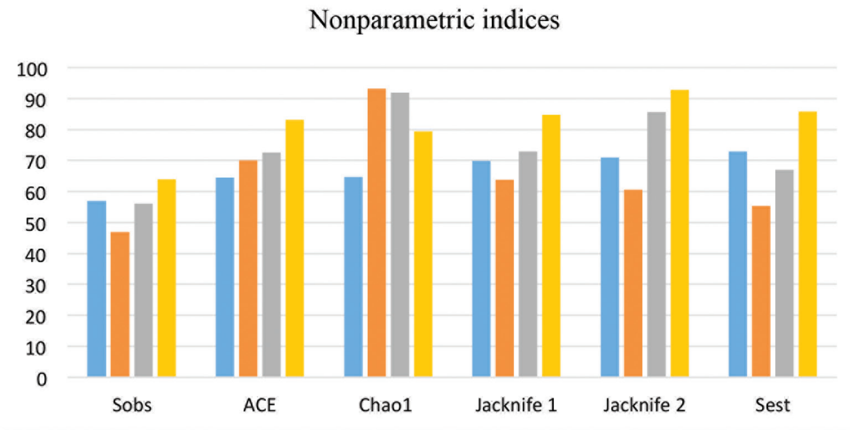

FIGURE 4. Estimated nonparametric indices according to elevations

TABLE 5. Ecological parameters at four altitudes in Fraser's Hill

Altitudes	500 m	1000 m	1500 m	1800 m
Number of observed species	57	47	55	63
Abundance	675	487	425	394
Dominance	0.07781	0.04881	0.03048	0.03327
Shannon-Weiner Index	3.08[a]	3.262[a]	3.660[b]	3.701[b]
Margalef Index	8.815	7.625	9.183	10.84
Fisher alpha	15.73	13.6	18.14	24.1

Shannon diversity index denoted with the same latter are not significantly different by ANOVA (p<0.05)

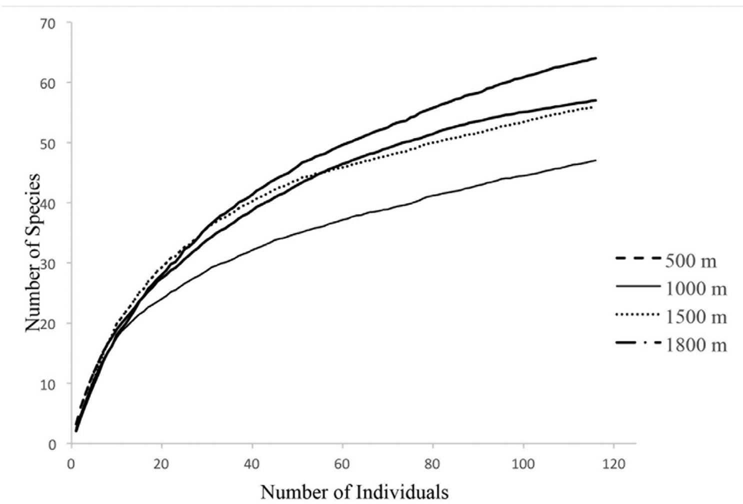

FIGURE 5. Species accumulation curve for the four elevations at Fraser's Hill

lower elevations, increased temperature at lower elevations and increased infrastructure developments at the lower levels of Fraser's Hill which has been discussed in details by Er et al. (2013). From this study, there is randomness and no discernible pattern of species distribution observed at Fraser's Hill for beetles.

Warmer temperatures and climate changes at lower elevations may lengthen the flight activity period and increase the number of generations produced per year, thus inducing the beetles to move to higher elevations (Bale et al. 2002; Williams & Liebhold 2002). Furthermore, approximately 1300 m a.s.l. beetle diversity is higher than the lower elevations (Rahbek 1995; Sanders & Rahbak 2012). A study by Abdullah et al. (2011a) in the montane forests of Cameron Highlands showed similar beetle diversity indices at 1200 m elevation (Shannon-Weiner Index 2.92) which is very close to our findings at Fraser's Hill. At Cameron Highlands, the insect abundance and species richness was lower compared to Fraser's Hill (Margalef index 5.9) which was considerably lower than the Fraser's Hill data presented here. Another study by Idris et al. (2002) on Gunung Nuang, Selangor insect diversity at different altitudes showed very low values for Coleoptera diversity values. This pattern has been the commonly reported pattern in tropical mountains, but more research is needed to adequately test the related theories (Barry 2008; McCain & John-Arvid 2010). Future studies on different beetle communities in Malaysia need to be oriented at the specific species patterns. The links with environmental variation and the interplays between ecosystem components and beetle species would enhance the understanding.

Conclusion

In conclusion, Fraser's Hill, a pristine tropical forest, can be utilised to assess the tropical beetle diversity pattern at different elevations, where there was little or no variation in raw species richness and with almost all additional indicators of species richness with altitude. The overall patterns were not statistically different, which could be due to low replication, since there was only one location sampled at each elevation and only one mountain slope. This study could be a very good baseline for further research on altitudinal movements of beetles in Malaysia in relation to climate change. Furthermore, this study employed multiple sampling techniques throughout the year compared to many studies, which only used one technique and did not sample through the seasons. Additional testing with much higher sample sizes (i.e. sites and slopes) are needed to fully test basic hypotheses, such as whether Coleoptera species abundance is correlated with altitude in tropical forests.

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