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Beetle Diversity and Distribution at Lower Altitudinal Montane Ecosystems in Peninsular Malaysia

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ABSTRACT

Malaysia, as one of the biodiversity hotspots in the world, however, very little has been studied at lower elevational mountain reserves and their beetle diversity, which could be decisive in resolving mysteries in tropical biogeography. Objective of this study is to assess and compare the beetle diversity at three selected lower elevational mountains to enlighten our understanding. Measuring the beetle diversity at Fraser's hill, Gunung Besar Hantu and Gunung Angsi at lower altitudinal (500 m) cline was selected for sampling, where light, malaise and pitfall traps were utilized during 2013-2014 season. Altogether from these three sampling sites 1,575 beetle samples were collected and they went through with some diversity analysis. The Margalef index for Gunung Besar Hantu, Fraser's Hill and Gunung Angsi showed 9.210, 7.214 and 6.777 respectively while Shannon-Weaner index ranged between 2.546 to 3.083. Evenness is very high at Gunung Angsi (0.930) and Fraser's hill showed moderate level (0.51). Simpson diversity index is ranging from 0.859 to 0.946 while Shannon Weiner diversity index showed very close values for Gunung Besar Hantu and Gunung Angsi but slightly lower value for Fraser's Hill. Highest Simpson diversity index and highest evenness index were shown by Gunung Angsi. Lower elevational ecoregions of Malaysian tropical mountains are good laboratories to assess beetle diversity which can be utilized for climate change studies and ecological disturbances. Long term monitoring program between different mountains on beetle diversity and distribution would enhance the understanding of their habitat pattern in relation to seasonal pattern and anthropogenic disturbances.

INTRODUCTION

Earth's tropical biodiversity patterns have been a central theme discussed extensively since the expeditions by Alexander von Hamboldt (1799-1804) and Charles Darwin (1831-1836) (Grytnes and McCain, 2007; Sanders *et al*., 2007; Fischer *et al*., 2011; Rull, 2014). This has resulted in two main theories on tropical biodiversity namely, 'cradle hypothesis' (high speciation rates) and 'museum hypothesis' (low extinction rates) or combination of both (Novotny and Miller, 2014; Rull, 2014). As the mirror effect of latitudinal biodiversity, altitudinal (elevational) gradient related researches were gradually piqued over the past thirty years and became bastions for biodiversity studies (McCain and John-Arvid, 2010; Fischer *et al*., 2011; Sanders and Rahbak, 2012; Guo *et al*., 2013; Bouzan *et al*., 2015).

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Elevational gradient studies offer more insight to uncover the underlying mechanism(s) of biodiversity pattern/s (Körner, 2007; Sanders and Rahbak, 2012; Herzog *et al*., 2013; Ashton *et al*., 2016). Elevational transect studies are based on mountains and mountain ranges (Grytnes and McCain, 2007; Guo *et al*., 2013), which covers approximately 25% of the earth surface with providing spectacular sites for biodiversity studies (Hoorn *et al*., 2013). Tropical mountains have been considered not only as outstanding laboratories to test various hypothesis related to biodiversity (Körner, 2007; McCain and John-Arvid, 2010; Fischer *et al*., 2011; Guo *et al*., 2013; Rull, 2014; Fine, 2015) but also highly discussed climate change (Ashton *et al*., 2016).

The early phenomenal exploration in Malay Archipelago by Alfred Russel Wallace had shed initial lights on general biodiversity pattern along the mountains, where biodiversity decreases with increase in elevation as one travels further away from the equator, for most taxa, the number of species declines (Wallace, 1869). This baseline research paved way for many theories later on, proposed on species richness and elevational clines based on various species such as mammals, birds, reptiles, plants, ferns, fish, fungi and insects (Fischer *et al*., 2011). On the other hand the altitudinal predictable pattern became the basis for researches all over the world (Fischer *et al*., 2011). Therefore, understanding on species richness and elevation has been immature especially in tropics (Longino and Colwell, 2014). One of the primary objectives of repeated study on elevational clines against various taxonomic groups is to determine the fundamental phenomena underlying patterns which are seldom explained thoroughly (Sanders *et al*., 2003) even at biodiversity hotspots.

Lower elevational diversity patterns varied by taxonomic groups have less attracted the research groups all over the globe, especially on species diversity and distribution but it might possess some valuable research models on species diversity (Guo *et al*., 2013). Moreover, the low altitudinal ecosystems are facing numerous pressures from various fronts such as human activities, land use pattern and climate change (Becker *et al*., 2007). As repeatedly shown by several studies, study of the distribution of different species would provide a better in-depth insight into our understanding on species dynamics at elevational clines in mountain ranges (Bayne *et al*., 2015; Fisher *et al*., 2015). Herzog *et al*. (2013) reported on Bolivian dung beetles diversity showed hump around 400 m to 750 m elevation owing more research on lower elevational regions for a more conservation priority under climate change. In tropics coarseness of biodiversity sampling cannot precisely locate the diversity peak: it can be observed from slightly below 500 m to somewhere between 500 and 1000 m. Due to the fact that, rate of downslope decline in diversity is much lower than the rate of upslope decline. In some tropical diversity gradient analyses are able to reveal a pattern such as this due the lower elevations are often deforested (Nogues-Bravo *et al*., 2008; Longino and Colwell, 2011). Moreover, lower altitudinal gradients biotic attrition may be a possible effect of global warming, where lowland species sifting their habitat upwards (Colwell and Rangel, 2009). Further, lower elevations molecular evolution is higher, opposing the prediction of UV as a possible driving force of biodiversity. It has been reported that, lower latitudinal plants and vertebrates show higher within species genetic diversity producing more undescribed species in tropics (Martin and McKay, 2004). Since Malaysia serves as a biodiversity hotspot in tropical world, it could serve as an excellent place to assess lower elevational species diversity patterns.

Malaysia is one of the twelve mega-store of biological diversity in the world however little known about mountains, which cover a considerable amount of the country (Doll *et al*., 2014). Relatively fewer studies conducted in these important montane ecosystems in Peninsular Malaysia, though some studies on insects (Khaironizam *et al*., 2009) were conducted in Gunung Besar Hantu. Gunung Angsi is a virgin jungle reserve of Malaysia which has been studied for its biodiversity by different research groups in the past (Al-Shami *et al*., 2013; Doll *et al*., 2014). Highly diverse tropical mountains of Malaysia are relatively less attracted in terms of lower altitudinal beetles diversity and their role on shaping the biodiversity. Therefore, the objectives of this study are, to determine the beetle diversity and distribution at lower elevational gradients at Gunung Besar Hantu, Gunung Angsi and Fraser's Hill and to obtain better understanding of beetle assemblages along lower elevational gradients.

METHODOLOGY

Study area

Main mountains in Malaysia are located at the middle like a ridge from Pahang to Kelantan states. Fraser's Hill (FH) is bisecting Pahang and Selangor States whereas Gunung Besar Hantu (GBH) and Gunung Angsi (GA) are located in Negeri Simbilan state. The lower elevational gradient (500 m) ranges were selected based on sampling sites and as well as accessibility upon these mountains (Fig. 1).

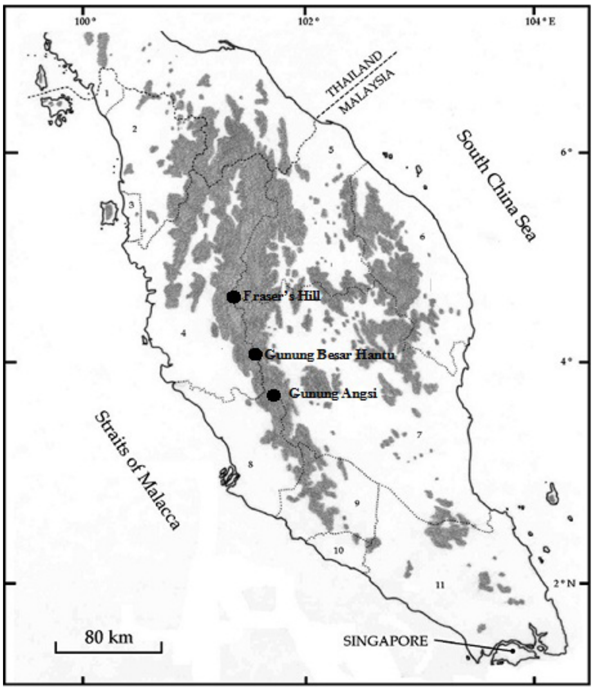

Fig. 1. The locations of Fraser's Hill, Gunung Besar Hantu and Gunung Angsi in Malaysian map.

Table I.- Diversity indices of elevational clines found at Fraser's Hill.

Mountains	Number of individuals collected	Margalef index	Shannon Weiner	Simpson diversity index	Evenness index
Gunung Besar Hantu (GBH)	416	9.210	3.083	0.904	0.836
Gunung Angsi (GA)	299	6.777	3.060	0.946	0.930
Fraser's Hill (FH)	860	7.214	2.546	0.859	0.510
Total	1,575	-	-	-	-

Sampling methods

At every site elevation was measured using Garmin GPSMAP® 78s global positioning system (GPS). Three types of sampling methods were employed as described by Noyes (1990), including, Malaise traps, pitfall traps and light traps during 2013-2014 seasons. At each sampling sites two light traps and six malaise traps were fixed while 20 pitfall traps were used. Malaise traps were fixed for 48 h while pitfall traps were fixed in the site for 24 h starting from 0800. Pitfall traps are small containers (in this case regular plastic cups) that are sunk into the ground with the brim at the same level as the ground. Beetles were sampled using pitfall traps partially filled with 90% Alcohol at each sites. Light traps were made up of mosquito net with a 160 watt mercury bulb connected to a portable Honda EU10i power generator. It was fixed just above the ground level and the beetles attracted to the light were collected using collection bottles and aspirators.

Collected specimens were sorted and tallied based on the morphospecies and cross checked with the available keys and Forestry Department of Malaysia collections. The data collected from these samples were analyzed for Margalef index, Shannon Weiner, Simpson diversity index and evenness index for the diversity and distribution across the sites. Generally beetle distribution increases proportionately to the value of Margalef index, while Simpson index, value ranges between 0 to 1 and maximum value for Shannon-Weaver index is 5. Simpson diversity index is the most meaningful and robust diversity index currently utilized in measuring species diversity and its even effective than species accumulation curves when ranking communities (Magurran, 2004).

Statistical analysis was conducted using Microsoft Excel program in order to calculate the diversity indices. Moreover, species accumulation curves are plotted to evaluate the total sampling efforts which show the number of species against of the number of individuals collected. When all the samples are collected in sampling sites, the plot lines usually reaches a horizontal asymptote and accumulation curve was constructed using Microsoft Excel.

RESULTS

Altogether from these three sampling sites 1,575 beetle samples were collected (Table I). Environmental parameters at each mountain were recorded and biodiversity indices have been calculated. Margalef index, Shannon Weiner index, Simpson diversity index and evenness index for the above mentioned three mountains were calculated (Table I). Out of those three mountains, Gunung Besar Hantu showed higher abundance (Margalef index; 9.210) while Gunung Angsi showed the lowest (6.777). Shannon Weiner diversity index showed very close values for Gunung Besar Hantu and Gunung Angsi while slightly lower value for Fraser's Hill. Highest Simpson diversity index and highest evenness index were shown by Gunung Angsi, whereas, Fraser's Hill displayed moderate values for evenness index. Evenness index expresses how evenly the individuals in the population are distributed over the different species (Heip *et al*., 1998). Evenness index numbers showed by Gunung Besar Hantu and Gunung Angsi high when compared to Fraser's Hill.

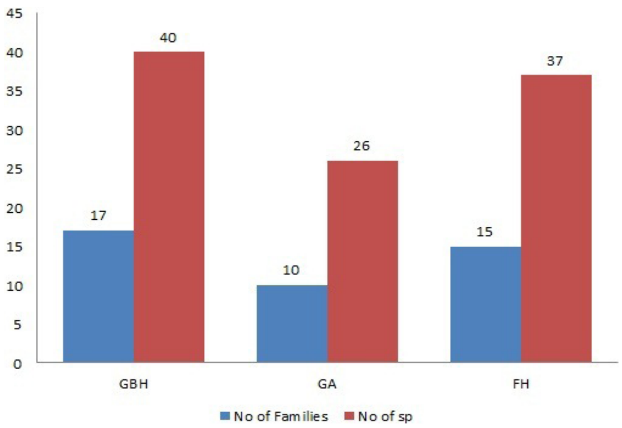

Fig. 2. Collected number of families and species at every mountains. For abbreviations, see Table I.

Since the species accumulation curve reaches asymptote the sampling efforts are covered the representing the species can be found in these sampling sites. Highest number of Families and Species were collected at Gunung Besar Hantu (Number of Species Collected: Gunung Besar Hantu > Fraser's Hill > Gunung Angsi) (Fig. 2). Family Brentidae was reported only from Gunung Angsi and Family Scydmaenidae collected only from Fraser's Hill. More interestingly Family Carabidae and Family Cerambycidae weren't collected at Gunung Angsi.

DISCUSSION

This study displayed higher beetle diversity and abundance at lower elevational gradient (500 m) via Margarlef index, Shannon Weaver diversity index, Simpson diversity index and evenness indices. This could be due to many reasons such as ambient temperature at lower elevations, increased temperature at higher elevations, more primary producers and low requirements for flight activity for beetle communities. Moreover, beetle diversity at elevational clines have been depend upon many non-exclusive factors proposed to explain altitudinal patterns of species richness, including, micro-sites, vegetation, and even historical factors (Fischer *et al*., 2011).

Generally, if the Shannon Weiner index is less than one (1) considered to be below average whereas 1-3 considered moderate and above 3 to be a good diversity. At the same time, typically managed ecosystem shows 1.5-3.5 Shannon Weiner index (MacDonald, 2003), while the value rarely surpasses 4. Lower values for Shannon-Weiner index and Simpson diversity index at Fraser's hill might be due to the higher disturbances through recreational and touristic activities. Furthermore, illegal logging, forest fragmentation, slope failures and soil erosion are also influencing for certain extent (Er *et al*., 2013). Gunung Besar Hantu is highly diverse and relatively evenly distributed beetle diversity. The resulted differences in abundance and diversity among species might have reflected differences in trapping methods (Hamer *et al*. 2003). On the other hand, sampling efforts (species accumulation curve) are almost reaching the asymptote displaying the expected trends in tropical beetles, when all the samples combined. Novotny and Basset (2000) reported in sampling at tropical sites, beetles accumulation curves rarely reach an asymptote probably owing to the failure to collect some geographically restricted species. Furthermore, Escobar *et al*. (2005) reported that a rapidly increasing species accumulation curve is expected for tropical beetles due to the fact that the tropics are highly diverse.

Margalef's index is used to measure species richness, while, Simpson's index consider both richness and relative abundance which is equivalent to the probability of the next individual sampled being from a different species to the last individual (Hurlbert, 1971). Shannon index takes into account the evenness of the abundance of species and assumes that individuals are randomly sampled from an 'infinitely large' population. When we consider all these indices, Simpson's index has low sensitiveness to species richness but high sensitiveness to the species abundance (Magurran, 1988).

Since Margalef index consider number of species, it's considered for sampling site comparisons and it's always sensitive to sample size (Gamito, 2010; Engemann *et al*., 2015). Even though Simpson index vary between 0 to 1, stable and mature populations display higher values between 0.6 to 0.9 lower values (around 0) when the population faces stress (Dash, 2003). In this study Simpson diversity index showed higher values reflects the maturity and stableness on these mountains. When the Shannon Weiner index value less than 1 shows the environment is highly polluted while ranging 1-2 moderately polluted and >3 stable environment. According to our results, Fraser's hill is slightly disturbed since it's facing numerous anthropogenic disturbances. There is a necessity to use different diversity measurement indices since every index considers different aspects of biodiversity (Schleuter *et al*., 2010). Lower evenness undex shown by Fraser's hill expresses that the community is not evenly distributed while at Gunung Besar Hantu and Gunung Angsi it's the opposite.

Since the tropics serve as the cradle (high speciation rates) and museum (low extinction rates) of species diversity, more research focus should be addressed by the scientific community (Brown, 2014). But unfortunately, the efforts are so sparsely and rarely executed to considerable level when compared to some of the other parts of the world. This is the first study on beetle diversity at different tropical mountains in Malaysia and it shows a good range of beetle diversity, abundance and distribution based on various indices mentioned above. Biodiversity researches related to elevational clines are particularly related since they can serve as bastations on climate change (Deutsch *et al*., 2008). Predicted amount of climate change would be intense among tropical species due to their narrow thermal specialization induce the scientific community to consider more towards tropical beetles sooner rather than later (Deutsch *et al*., 2008). Therefore, it's a high time to study the beetle diversity of Peninsular Malaysia in relation to climate change since they are pristine tropical forests. It could also serve as a good base to formulate a universal elevational diversity pattern for beetle diversity in tropics.

CONCLUSIONS

In conclusion, among these three tropical mountains Gunung Besar Hantu and Gunung Angsi has higher beetle diversity at lower elevational gradient (500 m) in comparison to Fraser's Hill. Fraser's Hill is facing numerous pressures from human activities while Gunung Besar Hantu and Angsi are relatively protected under Malaysian department of forestry. This study could be utilized to enhance the protection measures of Malaysian tropical forests at lower elevational clines since they are more prone to human interference and illegal logging. This study could be steppingstone on tropical beetle diversity pattern at different elevations in Malaysia.

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Statement of conflict of interest

There is no conflict of interests regarding the publication of this article.

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