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Elevational Diversity Pattern of Non-volant Small Mammals on Mount Nuang, Hulu Langat, Selangor

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Abstract: The distribution and species diversity of non-volant small mammals was studied at four elevational sites on the south face of Mount Nuang, Hulu Langat, Selangor, Malaysia. Twenty-seven species of non-volant small mammals were recorded on this mountain: 15 species were recorded at 500 m, 14 at 800 m, 14 at 1100 m and 9 at 1350 m. Although, the total number of species captured at each site was not significantly different, the total number of species decreased gradually with increasing elevation. This linear decrease in diversity from the lower to higher elevation was shown by the LOWESS analysis. Although the LOWESS analysis indicated that the general pattern was linear, regression analysis showed a non-significant ($R^2=0.801$, df=3, p=0.105) result. The explanation for the linear diversity pattern may be associated with the gradual change of habitat characteristics, which influenced by the change in physical environments such as humidity and temperature, across elevations. This suggestion is based on a strong linear relationship of small mammal species with humidity ($R^2=0.902$, df=3, p=0.05) and temperature ($R^2=0.916$, df=3, p=0.043) across elevations of this mountain.

Key words: Small mammals, Mount Nuang, Malaysia, trapping, elevational diversity pattern, physical environment

Introduction

The most fundamental measure of diversity is species richness, that is, the number of species that occur in some defined area. The number of species is the simplest and most useful measure of local or regional diversity. It is well recognized by ecologists that the number of species is quite variable and individual species are not randomly distributed. By documenting the differences and the regularities of the number of species in many places we may provide insight into the structural pattern of natural communities. Further, the number of species documented in a community may reflect the characteristics of the habitat and the interactions among species that live in that community (Giller, 1984; Schluter and Ricklefs, 1993).

For most ecologists and biogeographers, it is interesting if general and repeated diversity patterns of species can be observed and documented. The observed diversity patterns may improve understanding of mechanisms and guide us to further search for factors that might control or regulate diversity. In the last few decades, many spatial and temporal patterns of animal and plant species diversity have been observed and documented. The patterns most commonly studied have been the relationship between species diversity and latitude, climate, biological productivity habitat heterogeneity, habitat complexity, disturbance and the size and distances of islands (Brown and Gibson, 1983; Brown *et al.*, 1988; Ricklefs, 1990; Schluter and Ricklefs, 1993).

In addition to the well established patterns described above, in recent years, species diversity of plants and animals across the elevational gradient on mountains in the tropics and subtropics have come to be of particular interest to many ecologists and biogeographers (e.g., for mammals, Heaney *et al.*, 1989; Rickart *et al.*, 1991; Yu, 1994). Along elevational gradients, physical factors (temperature, precipitation, etc.) can change very rapidly, even over short horizontal distances. The vegetation along these gradients, therefore, may vary from lush tropical forests to frigid alpine tundra from low to high elevation, imitating the patterns that seen in moving from low to high latitude (Kitayama, 1992; Yu, 1994).

Although elevational diversity studies has been conducted in many montane areas throughout the world, the change in species diversity due to variation in physical and biotic characteristics across elevation that has been documented has not been consistent. Examples of diversity pattern of animals along the elevational gradients were either decreasing (Kikkawa and Williams, 1971; Terborgh, 1977; Beehler, 1981; Graham, 1983; Brown, 1988; Heaney *et al.*, 1989; Figure 26 in Voss and Emmons, 1996; Pacheco *et al.*, 1993), or increasing (Heaney *et al.*, 1989; Rickart *et al.*, 1991), or formed a hump shaped patterns (with greatest species diversity at the middle elevation) (Delibes de Castro, 1985; Brown, 1988; Yu, 1994; Kikkawa and Dwyer, 1992; Rosenzweig and Abramsky, 1993).

The general diversity of non-volant small mammals on this mountain was predicted to be highest at the middle elevations which formed a Ahump @, similar to what have been reported on Mount Kinabalu (Shukor, 1997 and 2001) and on Yushan mountain in Taiwan (Yu, 1994).

The main objective of this study was to investigate the general diversity pattern of non-volant small mammals across elevations on Mount Nuang.

Materials and Methods

Study site: Hulu Langat is the second largest district in Selangor with a total land area of about 82,620 ha. Within this district, there are several permanent forest reserves (FR). Among them are the Hulu Langat FR (13,132 ha), Sungai Lalang FR (17,591 ha), Sungai Jeloh FR (200 ha), Bukit Sungai Puteh FR (332 ha) and Bukit Sungai Putih South FR (109 ha) (Selangor State Secretariat Office, 1995). All of these reserves are classified as lowland and hill dipterocarp forests.

This study was conducted on Mount Nuang, which is located in the Hulu Langat FR (3°16=U and 101°54=T). Mount Nuang is the highest peak in Selangor, which stands at 1493 m. At altitude 800 m and above, the mountain is mainly covered with primary forest with minor human disturbance. Since the objective of this study is to determine the diversity pattern of non-volant small mammals on Mount Nuang, it is important that the study sites chosen are located along the same transect or face of the mountain (Shukor, 1997). In this study we chose the main transect on the south face of Mount Nuang. This is to equalize the affect of physical environment on study sites such as wind and light intensity. Four study sites were chosen at 500, 800, 1100 and 1350 m.

Data collection: Small mammals are categorized as species which have a body weight less than 5 kg (Fleming, 1979). The ecology of small mammals on this mountain was studied using capture-mark-recapture (CMR) method. Various sized wire mesh live traps were used to trap small mammals. Three trapping visits were made at each of four elevational sites (500, 800, 1100 and 1350 m). Trapping was carried out for 4 consecutive nights at each elevation for the first visit and 5 consecutive nights for subsequent visits. Each study site has the same total trapping effort of 2100 trap-nights.
At each elevational site, a 150 x150 m^2 grid was established. There were a total of ten trapping lines established at 15 m apart in the grid. Along these ten lines a total of 100 wire mesh live traps were set on the ground roughly at about 15 m intervals. Apart from these traps another 50 life cage traps were set alternately to the ground trapping stations, at approximately 2 m above ground.
Since one of the main objectives of this study was to document as many species of non-volant small mammals present on this mountain, four kinds of baits were used; bananas, fried coconut, jackfruit and oil palm seed. Those baits were set alternately between the traps.
These traps were examined once a day at 1000 hours and left open until the next morning. The following parameters were noted for each captured individual: reproductive status, weight, sex, age and species. Species identifications were based on Medway (1983) and Payne *et al*. (1985). Each individual animal caught was tagged with a uniquely numbered ear tag before being released at the point of capture.
Temperature and humidity data at each site were recorded using data loggers.

Data analysis: To determine the general diversity pattern of small mammals on this mountain, the overall trend was first analyzed with LOWESS (locally weighted sum of squares), a regression technique designed to identify the underlying trend in a data set without specification of a model (Systat for Windows version 5.01, 1992; Cleveland 1979). Then, a simple linear model and a quadratic polynomial regression model were used to test for linear and curvilinear patterns, respectively. Data used in these analysis were both, trapping data and combinations of observation and trapping data. The same procedure was done on the temperature and humidity measurements.

Results

Trapping responses: A total of 503 captures were made over 8,400 trap-nights. This yielded an overall trap success of 5.98%. A total of 278 individuals and 23 species were recorded from trapping and 4 species from observations. These species includes one species each of primate (*Nycticebus coucang*), rhizomyid (*Rhizomys sumatrensis*), hystricid (*Atherurus macrourus*), mustelid (*Prionailurus bengalensis*) and viverrid (*Paradoxurus hermaphroditus*), two species of threeshrews (*Tupaia glis, Ptilocercus lowii*), two species of shrews (*Suncus etruscus, Hylomys suillus*) nine species of murid rodents (*Leopoldamys sabanus, Leopoldamys edwardsii, Sundamys muelleri, Maxomys rajah, Maxomys surifer, Maxomys whiteheadi, Maxomys inas, Niviventer cremoriventer, Chiropodomys gliroides*) and nine species of squirrels (*Callosciurus notatus, Callosciurus flavimanus, Callosciurus nigrovittatus, Callosciurus caniceps, Sundasciurus lowii, Sundasciurus tenuis, Lariscus insignis, Dremomys rufigenis, Ratufa affinis).* Average trap success for each study site varied from 7.1% at 500 m, 5.2% at 800 m, 5.3% at 1100 m and 6.4% at 1350 m (Table 1). The highest number of individuals were captured at 500 m (96 individuals), followed by 800 m (63 individuals), 1100 m (65 individuals) and 1350 m (54 individuals). The total number of individuals captured differed significantly from each site (X^2 =14.46, df=3, p<0.01).

Table 1: Total number of individuals and species and average trap success of non-volant small mammal across elevations on mount Nuang. Data were gathered from live trapping and observation (Obs) and carcass © found in the field.

Species	Elevation (m)			
	500	800	1100	1350
Rodents				
L. sabanus	42	31	16	14
L. edwardsii	0	0	17	22
S. muelleri	2	1	5	0
M. rajah	26	5	3	0
M. surifer	4	10	3	0
M. whiteheadi	1	0	0	0
M. inas	0	0	1	12
N. cremoriventer	1	2	1	1
C. gliroides	2	0	0	0
Squirrels				
C. flavimanus	0	0	3	Obs
S. lowii	0	1	2	0
S. tenuis	0	1	0	0
C. notatus	3	8	1	0
C. nigrovittatus	7	0	0	0
L. insignis	0	1	1	0
C. caniceps	2	0	5	0
D. rufigenis	0	0	0	1
R. affinis	Obs	0	0	0
Threeshrews				
T. glis	3	1	6	0
P. lowii	0	Obs	0	0
Primate				
N. coucang	3	0	0	0
Mustelid				
F. bengalensis	0	Obs	0	0
Rhizomid				
R. sumatrensis	C	0	0	0
Hystricid				
A. macrourus	0	1	0	0
Shrews				
Hylomys suillus	0	0	0	1
S. etruscus	Obs	1	0	2
Viverrid				
P. hermaphroditus	0	0	1	1
Total no. of Individuals captured	96	63	65	54
Total no. of species captured	15	14	14	9
Average trap success (%)	7.1	5.2	5.3	6.4

Species diversity pattern: Based on trapping and observation data, a total of 27 species of non-volant small mammals were recorded at Mount Nuang. Fifteen of these species were recorded at 500 m, 14 at 800 m, 14 at 1100 m and 9 at

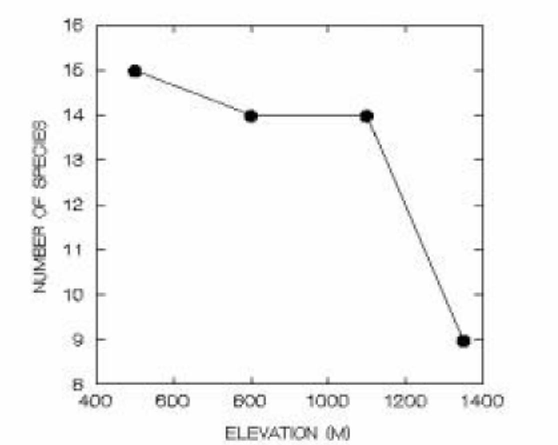

Fig. 1: Species diversity pattern of non-volant small mammals across elevation (m) on Mount Nuang, analyzed using the LOWERS regression

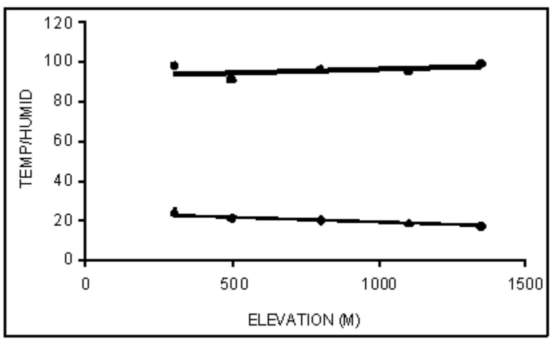

Fig. 2: Change in mean air temperature (°C) and relative humidity across elevations on Mount Nuang. The mean air temperature decreases (R^2= 0.986, df = 3, p = 0.014) and the mean relative humidity increases ($R^2$0.994, df = 3, p = 0.006) linearly with increasing elevation. Both temperature and humidity regression curves above represented by regression equations $y = 23.78 + 0.0047x$ and $y = 84.29 + 0.011x$, respectively.

1350 m (Table 1). Although the total number of small mammal species captured at each site were not significantly different (X^2 = 4.48, df = 3, p > 0.05), the total number of small mammal species showed a gradual decline from 500 m upwards. This linear diversity pattern was detected when this data was analyzed using LOWESS. Although the LOWESS analysis indicated that the general diversity pattern was linear (Fig. 1), but linear regression analysis gives a non-significant (R^2 = 0.801 df = 3, p = 0.105) result. The non-linear (quadratic) regression analysis also indicated the non-significant result (R^2 = 0.975, df = 3, p = 0.22).

Elevational physical environmental changes: The change in air temperature and humidity across elevations in this study was strongly correlated with altitude. The mean air temperature at each site decreased linearly (R^2 = 0.986, df = 3, p = 0.014), while the mean humidity at each site increased linearly (R^2 = 0.994, df = 3, p = 0.006) with increasing altitude (Fig. 2).

Discussion

The results indicate that the number of small mammal species decreased gradually from 500 to 1350 m^2. This pattern of species richness is different from earlier prediction, a hump-shaped pattern with increasing elevations. Unlike this study, a hump-shaped diversity pattern was reported on Mount Kinabalu (Shukor, 1997) and on a mountain peak in Taiwan (Yu, 1994).

Compared to hump-shaped pattern, the linear decreased pattern is the most prominent and widely described on small mountains in the tropics and subtropics (Brown and Gibson, 1983). Since Mount Nuang is a low mountain, with the peak below 1500 m the hump-shaped diversity may not be detected. On Mount Kinabalu, the highest diversity of small mammals was in the zone between 1700 to 1900 m^2. This area is also known as a sub-montane zone and this zone is not clearly defined on Mount Nuang.

The explanation for the linear decrease in species diversity with increasing elevation have been discussed by many researchers, but the most convincing explanation was by Lawton *et al.* (1987). They suggested four reasons why species typically decline with increasing elevation: firstly, habitat area declines with increasing elevation, secondly, resource diversity declines with increasing elevation and thirdly, there are increasingly unfavorable climatic environments at higher elevations and finally, primary productivity declines with increasing elevation.

Generally, the pattern of species diversity across a geographical gradient is primarily determined by the change in the physical environment (Brown, 1988). Physical parameters such as temperature, precipitation and atmospheric pressure which normally changes drastically across elevations are known to shape the local diversity and abundance of plants and animal (Rickart *et al*., 1991; Yu, 1994).

On Mount Nuang, humidity and temperature may be the two most important factors influencing diversity. The number of small mammal species decreases as the temperature decreases with increasing elevations (R^2 = 0.916, df = 3, p = 0.043). The opposite pattern was found with the humidity (R^2 = 0.902, df = 3, p = 0.05). These two findings suggested that the decrease in number of small mammal species with increasing elevation on this mountain might be associated with the unfavourable climatic condition at higher elevations.

At higher elevations, changes of physical characteristics such as temperature, relative humidity and thinning air and direct sunshine were documented influencing habitat characteristics (Mani and Giddings, 1980; Patterson *et al*., 1993). Changes of habitat structure were documented affecting animal distribution and diversity (Yu, 1994; Happold and Happold, 1989; Langham, 1983).

Gradual change of habitat characteristics across elevations would mean that the plant physiognomy should have gone through some changes that could alter available microhabitat and other important resources in the area. Changes of microhabitat and other important resources will affect plant diversity and distribution. Animal diversity normally tends to be more diverse in a floristically diverse habitat (Beehler, 1981; Rosenzweigh and Abramsky, 1993).

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