http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 5 (8): 819-824, 2002

Influence of Elevational Habitat Changes on Non-volant Small Mammal Species Distribution and Diversity on Mount Nuang, Hulu Langat, Selangor, Malaysia

Zainab Batin, Shukor Md. Nor and Mohd Yusoff Ahmad
School of Environmental and Natural Resources Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

Abstract: Change in distributions, species diversity of non-volant small mammals, and habitat structure across an elevation transect at the south face of Mount Nuang, Hulu Langat, Selangor, Malaysia was studied. Elevation significantly influenced 33 out of 36 habitat variables. The same variables were analyzed using Principle Component Analysis (PCA) in which the ordinations of the first two component scores indicated that all elevational sites (except the 300 m) are arranged subsequently with a gradual continuous change from the lower to the top elevations. Scores of principal components 1 and 2 are correlated with altitudinal changes (PCA1, $r_s = 0.807$, $p < 0.001$, $N = 250$; PCA2, $r_s = 0.317$, $p < 0.001$, $N = 250$). Eigenvectors of the first two components indicates a decrease in canopy height, maximum tree height, counts of tree DBH > 15CM and seedlings with increasing altitudes. Small mammal diversity and density (individuals ha^{-1}) was found decreasing with increasing altitude. Biomass (g ha^{-1}) was maximum at the mid-elevation and lowest at the foothill and at the peak of Mount Nuang. Certain individuals of non-volant small mammal species were unevenly distributed throughout the Mount Nuang.

Key words: Small mammals, habitat changes, Mount Nuang, Malaysia, elevational diversity pattern, distribution

Introduction

The number of species at a certain defined area is the most fundamental measure of diversity. Early in the century, species diversity was regarded primarily as a historical phenomenon, a reflection of the accumulation of the species overtime. At that time, species diversity was considered a subject outside the realm of the developing discipline of ecology (Schluter and Ricklefs, 1993). However, the recent advances in population ecology have changed this perception and currently diversity is perceived as the outcome of ecological interactions (MacArthur, 1972).

The change in species diversity and distribution of organisms along an elevational gradient has remained one of the most interesting topics in biogeographical studies (Brown, 1988; Rosenzweig and Abramsky, 1993). Many studies have shown that changes in physical characteristics over a short distance along an elevational gradient would affect the species diversity, distribution, and abundance of organisms (Kano, 1940; Terborgh, 1971; Whittaker and Niering, 1975; McCoy, 1990). Change in physical characteristics along the elevational gradient initially would influence the plant diversity and subsequently would affect distribution and abundance of fauna (Shukor, 1997).

Many ecologists have recognized that individual species are not randomly distributed. It is also well accepted that an intricate interaction occurs between organisms and their environments. This close interaction reflects the pattern of their distributions. Currently, many studies have been done to investigate the general diversity patterns and at the same time to search for any appropriate explanations for the general established patterns (Rosenzweig and Abramsky, 1993; Shukor, 1997).

The objectives of this study were three folds; I) to document as many species of small mammals on Mount Nuang, ii) to investigate the habitat structural changes across an elevational transect, and iii) to investigate the relationships between habitat structural changes with small mammal diversity and distribution 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 between August 1998 and April 1999 on Mount Nuang (3°16'U and 101°54'T), which is located in the Hulu Langat Forest Reserve (13,132 ha), Selangor, Malaysia. Mount Nuang is the highest peak in Selangor, which stands at 1498 m. Area above 800 m on this mountain is primarily covered with primary forest with minor human disturbance. Detail description of this site is given by Shukor *et al.* (2001).

Data collection

Non-volant small mammals: The ecology of small mammals on this mountain was studied based on capture-mark-recapture (CMR) method. A total of 150 various size wire mesh live traps and 20 pit traps were used to trap non-volant small mammal species ranging from 30 g to 5 kg. Small mammals are categorized as mammal species, which have a body weight less than 5 kg (Fleming, 1979). Three trapping visits were made at five elevational sites (300, 500, 800, 1100 and 1350 m) situated along the main trail at the south face of Mount Nuang. Total trapping effort at each study site was set at the same count (Shukor, 1997), where trappings were carried out for 14 days on each elevation, which were breakup to three visits of 4 and 5 consecutive nights.

At each elevation, a 150 x 150 m^2 grid was established. There were a total of ten trapping lines established at 15 m apart. 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 mesh live traps were set at approximately 2 m above ground, alternately to the ground trapping stations. The four types of baits were used in this study were bananas, fried coconut, jackfruit and oil palm seed. Those baits were set alternately between the traps. Traps were examined once a day at 1000 hours and left open until the next morning. The following parameters were noted from 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.

Habitat variables: To determine the habitat entity of each elevational site on this mountain, 36 habitat variables were measured and recorded from alternately selected trapping stations in each study plot (Patterson *et al.*, 1990; Kemper and Bell, 1985). Only those variables observed within a 3 m radius at the center of trapping station were measured and recorded. Habitat variables were examined and recorded for this study (Table 3).

Data Analysis: Cluster analysis was used to define small mammal community relationships among the elevational sites. This analysis is based on Jaccard similarity coefficients using the Unweighted

Pair Group method or UPGMA (Tongeren, 1987)). Jaccard's similarity coefficient was calculated and dendrogram was constructed using the Multi variate statistics Package (MVSP) version 3.11 (Kovach, 1999; Krebs, 1989).
The distribution of quantitative habitat data was examined for its normality. Variable transformation was performed if the distribution was not normal. This step is important if the parametric test procedures are to be performed (Sokal and Rohlf, 1981). Both parametric and non-parametric statistical techniques were employed using the program STATISTICA (Statsoft Inc., 1995). Each habitat variable was tested for its association with elevational changes using one-way ANOVA. Principal component analysis (PCA) was performed on the quantitative habitat data. The factor score of each component was tested for its correlation with altitudinal changes (Patterson *et al.*, 1990).

Results

Small mammals trapping responses and diversity: Overall, a total of 663 captures were made from 10,500 trap-nights of which 122 captures were from 2 m aboveground traps and the remaining from the ground traps. The captures from 2 m above ground traps were decreasing with increasing altitude. The captures for the ground traps were decreasing for the first 3 sites but gradually increasing at 1100 and 1350 m (Tables 1 and 2). Based on total captures and trap-nights, overall percent trap success was calculated at 6.3% and the average percent trap success for each study site were 7.62% at 300 m, 7.09% at 500 m, 5.19% at 800 m, 5.28% at 1100 m, and 6.38% at 1350 m (Table 1).
Based on trapping and observation, a total of 378 individuals were recorded (Table 1). The total individuals captured differed significantly among the sites ($\chi^2 = 21.47$, df=4, $p<0.001$) with the highest was recorded at 300 m (97 individuals), followed by 500 m (96 individuals), 1100 m (65 individuals) 800 m (63 individuals), and 1350 m (52 individuals).
Based on trapping and observation data, a total of 29 species of non-volant small mammals were recorded, where 5 of them were identified either from carcass, direct observations or pit traps. The overall total species captured were not significantly different among the sites ($\chi=2.62$, df=4, $p>0.05$), where 15 species recorded at the lowest two sites (300 and 500 m), 14 species at 800 and 1100 m, and 9 species at 1350 m. This pattern may be considered as a linear decrease in species richness from bottom to the top of the mountain (Table 1). Above ground captures also show a decrease in species number with increasing altitude. Species number of the ground captures gradually increases to the mid-elevation and slowly decreases towards the higher elevations (Table 2). Generally not only small mammal species but also density (Individuals ha^{-1}) gradually decreases from 300 to 1350 m (Table 1) (Shukor *et al.*, 2001).

Small mammal distribution and community structure: The distribution based on the presence and absence of each species was recorded on this mountain (Fig. 1). A dendrogram generated based on cluster analysis indicated that the small mammal community on Mount Nuang may be grouped into three faunal groups; lowland fauna (300 and 500 m), sub-montane fauna (800 and 1100 m) and montane fauna (1350 m) (Fig. 2). Among these three groups, the lowland fauna has higher percentage similarity to the sub-montane fauna at about 44% (Fig. 2). However, montane fauna shares less than 20% with the first two groups. Eight species are categorized as true lowland fauna where these species were not caught or observed above 500 m (Fig. 1). Those species are *Chiropodomys gliroides, Rhizomys sumatrensis, Callosciurus nigrovittatus, Nycticebus coucang, Echinosorex gymnurus, Ratufa affinis, Rhinosciurus laticaudatus* and *Maxomys whiteheadi*. Other 8 species were found on both lowland and sub-montane habitats. A total of 4 species confined to the montane

Table 1: Abundance, percent trap success and total small mammal species at each elevational sites on Mount Nuang. Homogeneity of the individuals caught at each altitude is tested using χ^2

Species	300 m	500 m	800 m	1100 m	1350 m	Total	χ^2	df
1. *Leopoldamys sabanus*	22	42	31	16	14	125	21.44***	4
2. *Leopoldamys edwardsii*	0	0	0	17	22	39	84.28***	4
3. *Sundamys muelleri*	4	2	1	5	0	12	7.17	4
4. *Maxomys rajah*	13	26	5	3	0	47	43.51***	4
5. *Maxomys surifer*	1	4	10	3	0	18	17.00**	4
6. *Maxomys whiteheadi*	11	1	0	0	0	12	38.83***	4
7. *Maxomys inas*	0	0	0	1	12	13	21.47***	4
8. *Niviventer cremoriventer*	0	1	2	1	1	5	5.2	4
9. *Chiropodomys gliroides*	22	2	0	0	0	24	77.67***	4
10. *Rhizomys sumatrensis*	0	C	0	0	0	0	Nc	4
11. *Suncus etruscus* *	1	Obs	1	0	2	4	Nc	4
12. *Callosciurus caniceps*	7	2	0	5	0	14	13.86**	4
13. *Callosciurus notatus*	1	3	8	1	0	13	15.85**	4
14. *Callosciurus nigrovittatus*	1	7	0	0	0	8	19.43***	4
15. *Callosciurus flavimanus*	0	0	0	3	Obs	3	12.8*	4
16. *Sundasciurus lowii*	1	0	1	2	0	4	3.5	4
17. *Sundasciurus tenuis*	0	0	1	0	0	1	4.0	4
18. *Tupaia glis*	8	3	1	6	0	18	12.56*	4
19. *Ptilocercus lowii* *	0	0	Obs	0	0	1	Nc	4
20. *Nycticebus coucang*	0	3	0	0	0	3	12.0*	4
21. *Atherurus macrourus*	0	0	1	0	0	1	Nc	4
22. *Hylomis suillus**	0	0	0	0	1	1	Nc	4
23. *Echinosorex gymnurus*	1	0	0	0	0	1	Nc	4
24. *Prionailurus bengalensis* *	0	0	Obs	0	0	1	Nc	4
25. *Rhinosciurus laticaudatus*	1	0	0	0	0	1	Nc	4
26. *Dremomys rufigenis*	0	0	0	0	1	1	Nc	4
27. *Paradoxurus hermaphroditus*	0	0	0	1	1	2	3.0	4
28. *Lariscus insignis*	3	0	1	1	0	5	6.0	4
29. *Ratufa affinis* *	0	Obs	0	0	0	1	Nc	4
Total individuals caught	97	96	63	65	54	378	21.47***	4
% Trap success	7.62	7.09	5.19	5.28	6.38	Nil	Nil	Nil
Total species	15	15	14	14	9	29	2.62	4

Obs (Observations); C (Carcass); Nc, (Not calculated), $p<0.05^*$, $p<0.01^{**}$, $p<0.001^{***}$

Table 2: Total captures of each species at 2 different locations of live traps, ground only (G) and more than 2 m from the ground (> 2 m)

	Altitude (m)											
	300		500		800		1100		1350		Total	
Species	G	> 2 m	G	> 2 m	G	> 2 m	G	> 2 m	G	> 2 m	G	> 2 m
1. L. sabanus	29	10	56	16	53	12	20	4	24	3	182	45
2. L. edwardsii							50	2	84	1	134	3
3. C. gliroides	12	20	0	2							12	2
4. M. rajah	21	1	36	2	6	0	3	0			66	3
5. T. glis	10	2	4	0	2	0	4	2			20	4
6. M whiteheadi	26	0	1	0							26	0
7. M. inas							1	0	19	0	20	0
8. M. surifer	2	0	7	0	13	1	4	0			26	1
9. S. muelleri	9	1	2	0	1	0	5	0			17	1
10. C. caniceps	3	6	0	2			3	2			6	10
11. R. laticaudatus	1	0									1	0
12. L. insignis	3	0			1	0	1	0			5	0
13. E. gymnurus	1	0									1	0
14. C. notatus	1	0	1	4	3	9	2	0			7	13
15. C. nigrovittatus	0	1	6	4							6	5
16. S. lowii	1	0			1	2	2	1			4	3
17. N. coucang			0	5							0	5
18. N. cremoriventer			0	1	1	2	0	1	0	1	1	5
19. A. macrourus					1	0					1	0
20. S. tenuis					0	1					0	1
21. P. hermaphroditus							1	0	1	0	2	0
22. C. flavimanus							2	1		*	2	1
23. D. rufigenis									1	0	1	0
24. R. affinis				*							-	-
25. P. lowii						*					-	-
26. S. etruscus	*		*		*				*		-	-
27. R. sumatrensis			*								-	-
28. H. suillus									*		-	-
29. Prionailurus bengalensis					*						-	-
Total capture	119.0	41.0	113.0	36.0	82.0	27.0	98	13.0	129.0	5.0	541.0	122.0
Trap success %	8.5	5.9	8.1	5.1	5.9	3.9	7	0.4	9.2	0.7	7.73	3.49
Total species	14.0	7.0	10.0	9.0	12.0	7.0	13	7.0	7.0	4.0	29.0	

* Observation or pit trapping not calculated

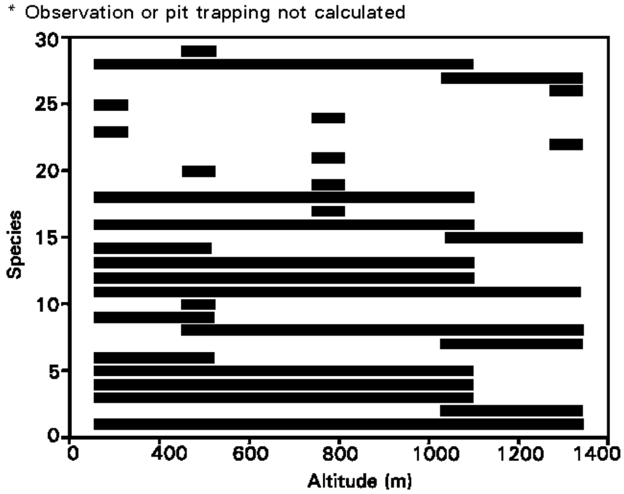

Fig. 1: Distribution of small mammal across an altitudinal transect on Mount Nuang. Species sorted according to these numbers: 1. *Leopoldamys sabanus*; 2. *Leopoldamys* edwardsii; 3. *Sundamys muelleri*; 4. *Maxomys rajah*; 5. *Maxomys surifer*; 6. *Maxomys whiteheadi*; 7. *Maxomys inas* 8. *Niviveventer cremoriventer*; 9. *Chiropodomys gliroides*; 10. *Rhizomys sumatrensis*; 11. *S. etruscus*; 12.*Callosciurus caniceps*; 13. *Callosciurus notatus*; 14. *Callosciurus nigrovittatus*; 15. *Callosciurus flavimanus*; 16. *Sundasciurus lowii*; 17. *Sundasciurus tenuis*; 18. *Tupaia glis*; 19. *Ptilocercus lowii*; 20. *Nycticebus coucang*; 21. *Atherurus macrourus*; 22. *Hylomys suillus*; 23. *Echinosorex gymnurus*; 24. *Prionailurus bengalensis*; 25. *Rhinosciurus laticaudatus*; 26. *Dremomys rufigenis*; 27. *Paradoxurus hermaphroditus*; 28. *Lariscus insignis*; 29. *Ratufa affinis*

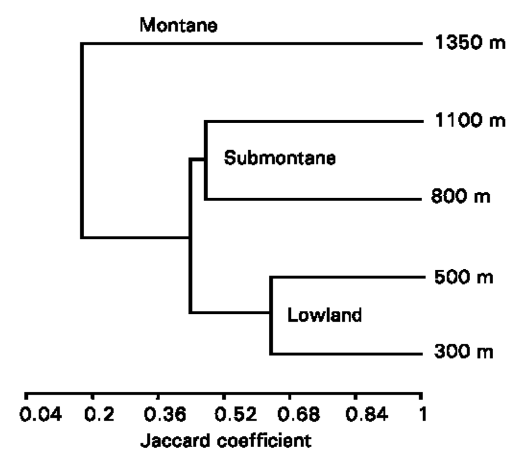

Fig. 2: Dendrogram of small mammal's community at Mount Nuang based on Jaccard similarities index

and sub-montane habitat namely *Leopoldamys edwardsii*, *Maxomys inas*, *Callosciurus flavimanus* and *Paradoxurus hermaphroditus*. *Dremomys rufigenis* and *Hylomys suillus* are the montane species that were caught only at 1350 m. Overall, only 3 species utilized all 3 habitats, lowland, sub-montane and montane. Those species are *Leopoldamys sabanus*, *Suncus etruscus* and *Niviventer cremoriventer*. Density of *Leopoldamys sabanus* was found high at the first 4 lower elevational sites and low at the upper 2 elevational sites (Table 1).

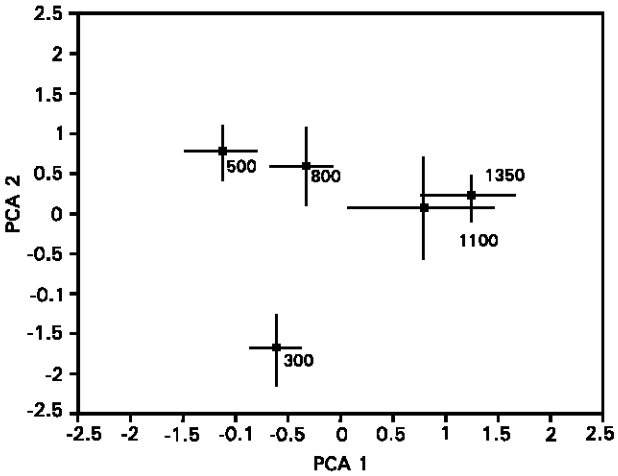

Fig. 3: Ordination of habitat variations on Mount Nuang. Projections are centered (square) and ± 1 standard deviation (line) for both principal components. Both axis accounts for 23% of the variation in the original data

Table 3: Habitat variations at 5 elevational sites on Mount Nuang

Habitat variable//Micro habitat	ANOVA
Upper story	
Canopy cover (%)	**
Canopy height)	***
Canopy density	***
Maximum tree height	***
Tree DBH > 5 cm	***
Tree DBH > 15 cm	***
Woody climber DBH < 1 cm	***
Woody climber DBH 1-5 cm	***
Woody climber DBH > 5 cm	***
Under story	
Shrub >50 cm height	***
Shrub >100 cm height	***
Climber	***
Bamboo	***
Palm	***
Rattan	***
Ground cover	
Seedling DBH < 5 cm	***
Fern	***
Herb	***
Bryophyte cover (%)	***
Fall DBH > 5 cm	***
Fall DBH > 15 cm	***
Litter cover (%)	***
Water cover (%)	***
Stone cover (%)	***
Bare soil (%)	***
Grass cover	N.S
Stump DBH >15CM	N.S
Litter depth	***
Physical criteria (Ground)	
Slope	***
Clay	***
Loam	***
Sand	***
Roots network	***
Gravel	***
Stone	***
Drainage	N.S

$p<0.05$*, $p<0.01$**, $p<0.001$***, NS= Not Significance,
DBH = Diameter at breast height.

Elevational habitat changes: Results indicate that change in altitudes would significantly influence the change in habitat structure on this mountain, where 33 out of 36 habitat variables studied differs significantly among the five study sites (Table 3). Principal component analysis for habitat structure data yielded two components that would explain the overall habitat changes with changing altitude. Both component scores correlate well with altitudinal changes (PCA1, $r_s=0.807$, $p<0.001$, N=250; PCA2, $r_s=0.317$, $p<0.001$, N=250, respectively). Each principal component explains a different dimension of original data. Eigenvectors for each component explain different entities in the original data (Table 4). Principal component 1 axis depicts that the decreasing of forest canopy height and maximum tree height, and increasing of Under story climber, bryophyte cover, litter depth, and stone cover with increasing altitude. Principal component 2 axis portrays the decreasing tree DBH>15CM, seedlings, and bamboo but increasing number of shrub with more than 50 cm height and fern with increasing altitude.

Ordination of the two principal component scores yielded clusters of the similar habitat structures for each study sites. Fig. 3 explained 33% variation in the original data. Each altitude reflects different habitat structure characteristics. All study sites except 300 m shows a gradual continuous change. It appears that habitat structure characteristics at 300 m elevations were not within a continuous range with other study sites.

Discussion

Based on the number of small mammal species that were recorded from several elevational sites on this mountain, the number of species or diversity gradually decreases with increasing altitude (Table 1). The same pattern is shown by the habitat structure ordinations of PCA-1 to PCA-2 where the gradual habitat changes occurring only on the top four altitudinal sites, but not on the lowest site at 300 m (Fig. 3). Different habitat characteristics at 300 m elevations compared with other altitudinal sites may be associated as one major factor, a bad drainage system where over 30% of the area is swampy. This factor may have contributed to its overall PCA score ordinations and provide a different set of small mammal micro habitats and different kind of resources. There were several small mammal species that found abundant and confined only at this particular habitat. The existence of these species may be associated with the specific habitats and resources that can only be found at this site. Those species are the true lowland species such as *Echinosorex gymnurus* and *Rhinosciurus laticaudatus* which require flat and moist habitat (Medway, 1983). Small mammal community on this mountain like on most of other tropical mountains can be categorized into several faunal groups such as lowland, sub-montane and montane fauna (Shukor *et al.*, 2001; Patterson *et al.*, 1990; Yu, 1994). On this mountain several species were recorded confined at certain altitudinal range. This could be due to the facts that these species are adapting to specific environmental conditions and change in altitude would change specific Micro habitat or resources required for this species.

Changes of physical characteristics such as temperature, relative humidity, air pressure and direct sunshine across elevational gradients were documented influencing habitat structures (Mani and Giddings, 1980; Lieberman *et al.*, 1996). A gradual change in habitat structures would mean that the plant physiognomy should have gone through some changes that possibly would alter available Micro habitat and other important resources on this mountain. Changes of habitat structures were documented affecting animal distribution and diversity (Yu, 1994; Happold and Happold, 1989) and high Micro habitat heterogeneity and complexity should promote a higher small mammal (non-volant) species diversity (Rosenzweigh, 1991).

Explanation on the linear decrease of small mammal diversity with increasing elevation were discussed by many researchers in the past, but the most convincing explanation was from Lawton *et al.* (1977). They suggested four reasons, why animal species typically decline with increasing elevation; 1) habitat area declines with increasing elevation, 2) resource diversity declines with increasing elevation, 3) there are increasingly unfavorable climatic environments at higher elevations and 4) primary productivity declines with increasing elevation.

Table 4: Eigenvectors for component 1 and component 2. Loading value exceeding ±0.3 were used to explain each components

Habitat variables	PCA1	PCA2	PCA3	PCA4
Canopy cover			-0.57036	-0.41112
Canopy height	-0.39772		-0.30621	-0.33407
Canopy density			-0.45714	
Max. tree height	-0.36757		-0.41015	
Tree DBH>5 cm			-0.63119	
Tree DBH>15 cm		-0.48942	-0.37735	-0.45976
Seedling		-0.44596	-0.38531	
Fall>5 cm	0.298311			
Fall>15 cm				
Stump >15 cm				
Bamboo	-0.39092	-0.33384		
Rattan				
Under story climber	0.583211			
Woody climber <1 cm				
Woody climber 1-5 cm		-0.65907		
Woody climber >5 cm		-0.44502		
Shrub <100 cm height		-0.50807	0.485956	
Shrub <50 cm height		0.295266	0.330846	
Bare soil			0.622486	-0.39721
Stone cover	0.350105			
Water cover		-0.48558		
Grass cover				
Bryophyte cover	0.764477			
Litter cover	-0.32827		-0.67491	0.378621
Litter depth	0.59858			
Stone	0.526398			
Gravel				
Sand	-0.30503	-0.70935	0.403668	
Loam	0.343302			
Clay		0.622211	0.29879	
Roots network	0.830181			
Slope	0.449715			-0.36344
Drainage				
Palm	0.695031			
Fern	0.512447	0.370715	-0.3938	
Herb				-0.4638
Eigenvalue	4.556538	3.681583	3.615331	2.034615
% Explained variation	0.126571	0.102266	0.100426	0.056517

PCA = Principle Component Analysis, DBH = Diameter at breast height

Strong evidences suggested that change in altitude would influence habitat structure on Mount Nuang (Table 3). Increasing altitude would influence canopy height and number of big trees therefore decreasing habitat complexity can be expected (Table 4). Resource diversity then declines with increasing altitude and affecting small mammal species diversity on this mountain. Decreasing availability of resources may explain the decrease of species richness and density of small mammals with increasing altitude (Rosenzweih and Abramsky, 1993).

A decreasing trend in catches of Upper story and Under story dwelling species with increasing altitude may be due to the decreasing number of tall and big trees, which may contribute to the decreasing canopy height and cover. Less arboreal species at the higher altitudes may be the primary contribution to the decrease of small mammal species diversity with increasing altitude.

There are four general conclusions that can be made from this study. First, habitat structures at 300 m altitude are not within a continuous range with other elevational study sites. Second, habitat structures at the other four elevational sites are within a continuous range and principal component analysis indicates that habitat structure complexities are decreasing with increasing altitude. Third, small mammal species decreasing linearly from the bottom to the top of this mountain. Fourth, declining in habitat structure complexities may at the same time reduce resource availability with increasing altitude. Lowering the resources availability can be one of the causes of declining small mammal species diversity on this mountain.

Acknowledgment

Special thanks to Prof. Dr. Abdul Latiff Mohamad for his generosity to support this project under a grant IRPA 08-02-02-009. The support includes all field and laboratory equipment, transportation and field assistance. Many thanks to Assoc. Prof. Dr. Tajudin Mahmud for his guidance on statistical application, and the Selangor Forest Department and the Wildlife Department and National Parks for permission to conduct this study in the Virgin Jungle Forest No. B6 and part of Compartment No. 64.

References

Brown, J.H., 1988. Species Diversity. In: Analytical Biogeography: An integrated approach to the study of animals and plants distribution. Myers, A.A. and Giller, P.S. (Eds.)., pp: 57-90. New York: Chapman and Hall

Fleming, T.H., 1979. Life History Strategies. In: Ecology of Small Mammals, Stoddart, D.M. (Ed.). London: Chapman and Hall, pp: 1-61.

Happold, D.C. and M. Happold, 1989. Demography and habitat selection of small mammals on Zomba Plateau, Malawi. J. Zool. (London), 216: 581-605.

Kano, T., 1940. Zoogeographic studies of the Tsugitakata mountains of Formosa. Tokyo: Institute for Ethnogeographical Researches.

Kemper, C. and D.T. Bell, 1985. Small mammals and habitat structure in lowland rain forest of peninsular Malaysia. J. Trop. Ecol., 1: 5-22.

Kovach, W. L., 1999. A Multi variate Statistical Package. United Kingdom: Kovach Computing Services.

Krebs, J., 1989. Ecological Mothodology. New York: Harper and Row Publishers.

Lawton, J.H., M. MacGravin and P.A. Heads, 1987. Effect of altitude on the abundance and species richness of insect herbivores on bracken. J. Anim. Ecol., 56: 147-160.

Lieberman, D., M. Lieberman, R. Peralta and G.S. Hartshorn, 1996. Tropical forest structure and composition on a large scale altitudinal gradient in Costa Rica. J. Ecol., 84: 137-152.

MacArthur, R.H., 1972. Geographical Ecology: Patterns in distribution of species. New York: Harper and Row.

Mani, M.S. and L.E. Gidding, 1980. Ecology of Highlands. London: The Hague.

McCoy, E.D., 1990. The distribution of insects along elevational gradients. Oikos, 58: 313-332.

Medway, L., 1983. The Wild Mammals of Malaya (Peninsular Malaysia and Singapore). New York: Oxford University Press.

Patterson, B.D., P.L., Meserve, and B.K. Lang, 1990. Quantitative habitat association of small mammals along an elevational transacts in temperate rainforests of Chile. J. Mammal., 71: 620-633.

Payne, J., C.M. Francis and K. Phillips, 1985. A field guide to the mammals of Borneo. Kota Kinabalu: The Sabah Society.

Rosenzweigh, M.L., 1991. Species diversity gradients: We know more and less than we thought. J. Mammal., 73 : 715-730.

Rosenzweigh, M.L. and Z. Abramsky, 1993. How are diversity and productivity related?. In: Species diversity in ecological communities. Schluter, D. and Ricklefs R. E. (Eds.), The University of Chicago Press, Chicago, pp: 66-74.

Schluter, D. and R.E. Ricklefs, 1993. Species Diversity. pp. 1-2. In: Species diversity in ecological communities. Schluter, D. and Ricklefs R. E. (Eds.) The University of Chicago Press.

Shukor, Md. Nor., 1997. An Elevational Study of Small Mammals On Mount Kinabalu, Sabah, Malaysia. Ph.D. Dissertation. University of Illinois Chicago, Chicago Illinois.

Shukor, M.N. B. Zainab and A. Zubaid, 2001. Elevational diversity pattern of non-volant small mammals on Mount Nuang, Hulu Langat Selangor. Online J. Biol. Sci., 1: 1081-1084.

Sokal, R.R. and F.J. Rholf, 1981. Biometry (2nd ed.). W.H. Freeman and Company, New York.

Statsoft, Inc., 1995. STATISTICA for Windows [Computer program manual]. Tulsa, Oklahoma, Statsoft, Inc., 2325 East 13th Street, Tulsa, OK, 74104, (918) 583-4149, fax: (918) 583-4376.

Terborgh, J., 1971. Distribution on environmental gradients: theory and a preliminary interpretation of distributional patterns in the avifauna of the cordillera Vilcabamba, Peru. Ecol., 52: 23-40

Tongeren, V.O.F.R. 1987. Cluster Analysis. pp. 174-206. In: Data analysis in community and landscape ecology. Jongman, R.H.G., T. C.J.F. Braak, and V.O.F.R. Tongeren (Eds.) Centre for Agricultural Publishing and Documentation, Wageningen.

Whittaker, R.H. and W.A. Niering, 1975. Vegetation of the Santa Catalina Mountains, Arizona. V. Biomass, production, and diversity along an elevational gradient. Ecology, 56: 771-790.

Yu, H. T., 1994. Distribution and abundance of small mammals along a subtropical elevational gradient in central Taiwan. J. Zool. (London), 234: 577-600.