A Survey of the Non-Flying Small Mammals at Several Elevatios in and around Crocker Range Park

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ABSTRACT

A survey was conducted on the non-flying small mammals (<1 kg) at three elevations (500 m, 1,000 m and 1,400 m above sea level) inside Crocker Range Park and one elevation (100 m above seal level) outside Crocker Range Park. The purpose was to document several aspects of the small mammal community structure at these elevations. The variations in habitat structure and habitat-use patterns of the small mammals are described to explain the observed differences in the small mammal community structure across different elevations. Total trapping effort was 1,080 trap-nights with 106 individuals of small mammals comprising 14 species and five families caught at all elevations. One murid rodent, *Niviventer rapit*, caught at 1,400 m, is a new record for Crocker Range Park.

INTRODUCTION

Crocker Range, the longest mountain chain in Sabah, runs parallel to the west coast and separates it from the interior region. The Crocker Range partially encompasses nine districts: Kota Belud, Tuaran, Ranau, Tambunan, Papar, Penampang, Keningau, Beaufort and Tenom. The geology of Crocker Range is sedimentary formation ranging in age from the Eocene to the Pliocene and includes sandstone and mudstone. The topography of Crocker Range is mountainous with several peaks exceeding 1,500 m above sea level such as Mt. Alab (1,932 m), Mt. Tambuyukon (2,579 m), Mt. Trusmadi (2,642 m) and Mt.

Kinabalu (4,095.2 m), the highest peak in Southeast Asia (Isa *et al.* 2001). Average annual total rainfall varies considerably between different parts of the Crocker Range. Areas to the east receive about 1,800 mm annually, but the upper slopes on the western side receive more than 4,000 mm annually (Sabah Conservation Strategy 1992). For management and maintenance purposes, the Crocker Range is divided into two sectors: (1) Kinabalu Park in the north and (2) Crocker Range Park (CRP) in the south. These parks are governed by Sabah Parks, a statutory body under the Ministry of Tourism, Culture and Environment.

The CRP (5°24'N; 116°05'E), with an area of approximately 1,399.19 square km, was gazetted as a State Park in 1984 primarily for the purpose of sustaining the supply of good quality water to approximately 200,000 people residing in the West Coast and Interior Districts of Sabah (Murtedza *et al.* 2001; Murtedza, 2003), but also conservation of biodiversity (Basintal *et al.* 2003). Recent information on the flora and fauna in and around CRP is documented in Ghazally & Lamri (2001) and the present volume.

Studies on the small mammal fauna of CRP have been conducted by Tuen *et al.* (2001) and Yasuma *et al.* (2003). Both are inventory surveys. Tuen *et al.* (2001) recorded 15 small mammal species, including seven species of bats, using trapping methods (mist nets for bats and wire-mesh live cage traps for terrestrial small mammals). Yasuma *et al.* (2003) compiled all available data from published and unpublished records including Payne *et al.* (1985), Yasuma & Andau (1999), specimen collections of the Sabah Parks, Sabah Museum and the BORNEENSIS vertebrate specimen collections of the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. Aditionally, Yasuma (unpublished data) conducted a trapping programme of small mammals at 100 m, 500 m, 800 m, 1,000 m and 1,400 m above sea level in CRP from April–November 2002. Overall, 26 species in five families (excluding bats) of small mammals (< 5 kg) have been confirmed to occur inside CRP, i.e., 11 species of Muridae, eight species of Sciuridae, five Tupaidae, one Tarsiidae and one Lorisidae.

Studies on the distribution patterns of animals along elevational gradients on mountains provide useful information on the ecology, habitat selection and species compositions at different elevations. This is vital information for the conservation management of biodiversity on mountains. The aim of the present study was to document the distribution of non-flying small mammals (< 1 kg) at four elevations (100 m, 500 m, 1,000 m and 1,400 m above sea level) in and around CRP. Variations in habitat structure and microhabitat-use patterns of the small mammals across the four elevations were analyzed to explain the variations in community structure at different elevations.

MATERIALS AND METHODS

Sampling Sites

In this study the small mammals were sampled at Kampong (=Village) Wolit (100 m a.s.l.), Trail no. 1 (500 m a.s.l.), Trail no. 8 (1,000 m a.s.l.) and Trail no. 11 (1,400 m a.s.l) (Fig. 1, Plate 13). The names of trails used in this study are identical to those used during the Crocker Range Scientific Expedition in 2002 organized by Universiti Malaysia Sabah in collaboration with Sabah Parks and Japan International Cooperation Agency (JICA). All sampling sites, except at Kampong Wolit, were located in the southern part of CRP. The sampling site at Kampong Wolit was located four km outside the boundary of CRP.

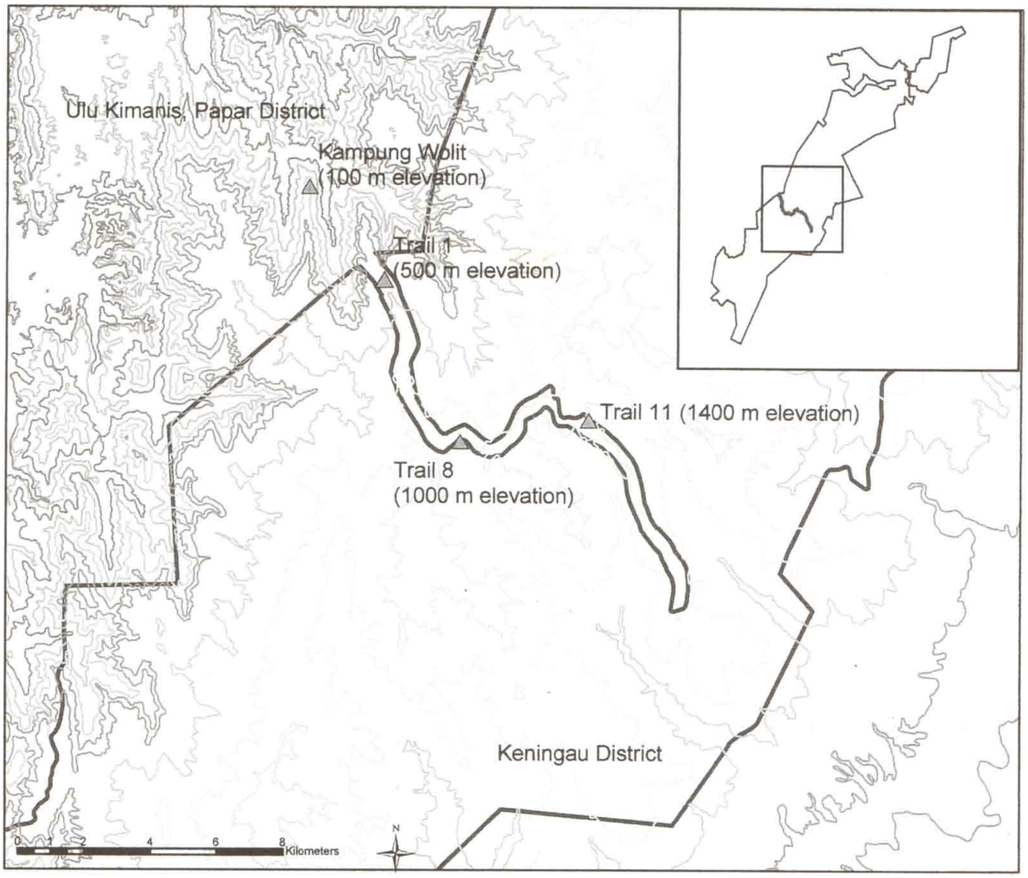

Fig. 1. Map of Crocker Range Park showing locations of small mammal sampling sites.

The sampling sites are easily accessible *via* a well maintained gravel road connecting Keningau town in Keningau district in the interior, with Ulu Kimanis in Papar District on the west coast. All sampling sites were located within approximately 25 km of this road. The slope of the CRP from the lowest to the highest elevations increases by about 25 m a.s.l. per 1 km.

Sampling Methods

The capture-release method was used in this study. Small mammals were captured using wire-mesh live cage traps (28 cm × 15 cm × 12.5 cm) baited with cut ripe bananas of the variety locally known as *pisang emas*. Three trapping lines of 200 m long each were established at each elevation. The trap-lines were placed to cover as many habitat variations as possible at a particular elevation. Each line consisted of 10 trap-stations at 20-m intervals. A single trap was placed at every trap-station on the ground or up to 2 m above ground level. Traps placed above ground level were located on tree stumps, tree branches or fallen logs. The placement of traps was random in relation to height.

Two sampling sessions were carried out at 100 m and 1,400 m elevations, and four sampling sessions at 500 m and 1,000 m elevations. All elevations were sampled simultaniously when possible. Otherwise, sampling at a particular elevation was carried out within a few days after sampling at other elevations was completed. The sampling sessions were separated by intervals of four weeks and were carried out at all elevations over a period of four months from October 2003 to January 2004. A sampling session consisted of three consecutive days and nights of trapping. All traps were checked once daily between 8:00–12:00 hrs. Fresh baits were placed in the traps after each trapping night. All captured animals were identified to species (following Payne *et al.* 1985) and individually marked by toe clipping (following Yasuma & Andau 1999) before being released at the capture stations.

Habitat Structure

Twelve habitat variables (Table 1) were used in this study to characterize the differences in habitat structure at the four elevations. These variables were used also to determine the microhabitat preferences of the small mammals. Habitat variables selected in this study were largely those identified in previous studies as good descriptors of microhabitats of terrestrial and understorey small mammal species (e.g., Kemper & Bell 1985; Patterson *et al.* 1990; Lynam 1997).

Aspects of Small Mammal Community Structure

Five aspects of community structure were used in this study: (1) species diversity; (2) species richness; (3) species similarity; (4) population density; and (5) population biomass.

The Shannon-Wiener and Simpson indices of diversity were used as measures of species diversity. Both indices incorporate two components i.e., species richness and species evenness. Species richness is the cumulative species number caught over the total sampling period. Species evenness is a measure of how equal, in terms of abundance, each of the species in the community is distributed. A community is said to have high species diversity if it is composed of many equally or nearly equally abundant species. Shannon-Wiener index, however, is richness biased, whereas the Simpson index is evenness biased (Magurran 1988). Both Shannon and Simpson methods were used in this study as they perform reasonably well with small data sets (Magurran 1988), as is normally the case with small mammal studies in the Asian tropics (Bernard 2003). Moreover, both indices are widely used. The diversity indices in this study were calculated using "Species Diversity and Richness" software (Henderson & Seaby 1998). In addition, the pattern of species abundance-distribution was determined by plotting histograms of species rank versus abundance.

Species overlap (or similarities) between small mammal communities at various elevations was calculated using Sørensen's coefficient (Southwood & Henderson 2000) and cluster analysis (Krebs 1999). Sørenson's coefficient is given in percentages of similarity. Cluster analysis was conducted on all 12 trap-lines established at all four elevations. This analysis was used to assess whether or not there are any groupings among the trap-lines based on presence and absence of small mammal species. Ward's method was chosen as the preferred method of clustering, while Euclidean distance was used as a measure of distance. A dendogram was produced from the cluster analysis, which was performed using PC-ORD version 4.14 (McCune & Mefford 1999).

Table 1. Habitat variables used in the study at Crocker Range Park.

Habitat variables	Definition
UPPER STRATA	**>10 m from the forest floor**
Canopy cover[a]	Canopy layer that sometimes blocks the sun from penetrating to the forest floor.
Tree height[b]	The average height of all trees in each trap station.
LOWER STRATA	**0.5–5 m**
Shrub density[a]	Understorey vegetation such as bushes, pioneer plants, low level plants, wild ginger and other herbs.
Climbers[a]	Understorey climbers, woody climbers and palm climbers such as lianas and epiphytes.
GROUND LEVEL	**0–0.5 m**
Soil type[c]	Type of soil.
Bare soil[a]	Area with no vegetation.
Water type[d]	Water resource.
Rocky area[a]	Area covered by rocks, stones or pebbles.
Bryophytes[a]	Bryophytes grow on the ground, rotting logs, decayed trees, tree trunks, tree branches, rocks and leaves.
Grasses[a]	Grasses and sedges coverage.
Forest litter[a]	Litter such as dead leaves and twigs that pile up and rot on the forest floor.
Fallen trees[a]	Naturally or deliberately fallen trees (diameter > 10 cm)

Description:
a. rank data
[a]rank ranging from 0–5. 0 = not present, 5 = common/ 100% coverage
[b]height in metres. 0 = 0–10 m, 1 = 10–20 m, 2 = 20–30 m, 3 = 30–40 m, 4 = 40–50 m, 5 = 50–60 m
b. nominal data
[c]types: 1 = peat, 2 = clay, 3 = loam, 4 = sandy, and 5 = stony or rocky
[d]if present: 1 = river, 2 = stream, 3 = pond, 4 = stagnant water, and 5 = spring water

Note: All habitat variables were assessed within 10 m radius from trap stations.

Population density was estimated at each elevation following the method adapted from Stuebing & Gasis (1989). This method involves the calculation of a 'Maximum Effective Trapping Area'—the area of a rectangle whose width is twice the distance between traps (20 m), multiplied by the total length of the trap-line. Two areas at each end of the line (20 m) were added in the calculation. This gave an estimated maximum effective trapping area of approximately 0.88 ha per line or 2.64 ha per sampling elevation (i.e., three trap-lines). Population density was then estimated by dividing the highest number of individuals caught during any one of the trapping sessions with the maximum effective trapping area. Population biomass was calculated by taking the total biomass of the trapping session with the highest number of individuals caught. In this study the population density and biomass were calculated as such to allow direct comparisons between sampling sites subjected to unequal trapping efforts. For this reason both population density and biomass estimated in this study are relative measures only.

Canonical Discriminant Function Analysis (CDFA) was used to characterize the differences in habitat structure at different elevations (McCune & Mefford 1999). In this analysis all 12 habitat variables were treated as the discriminating variables, while elevation was used as the grouping or classifying variable. Analysis was run using SPSS version 10.0 (Coakes & Steed 2001).

Canonical Correspondence Analysis (CCA) was used to analyse the relationship between small mammal species and habitat variables. All 12 habitat variables were included in the analysis. CCA was performed using PC-ORD version 4.14 (McCune & Mefford 1999). In this analysis, small mammal species (abundance data) was treated as the main matrix and the 12 habitat variables were treated as the second matrix. For both matrices, species abundance and habitat variables data were arranged by trap-stations. Trap-stations were classed by elevations.

RESULTS

Overall Captures

Overall trapping efforts totalled 1,080 trap-nights. The total number of small mammal captures (excluding recaptures) was 106 individuals. Trapping success was lowest (2.8%) at 500 m elevation and highest (13.3%) at 1,400 m elevation. Combined total trapping success at all elevations was 9.8%. The 14 species caught represented three families: five species of treeshrews (Family: Tupaidae) (*Tupaia tana*, *T. glis*, *T. montana*, *T. gracilis* and *T. minor*), eight species of murid rodents (Family: Muridae) (*Rattus rattus*, *Leopoldamys sabanus*, *Maxomys surifer*, *M. rajah*, *M. whiteheadi*, *Niviventer cremoriventer*, *N. rapit* and *Sundamys muelleri*), and one species of squirrel (Family: Sciuridae) (*Sundasciurus lowii*) (Plate 14). All species caught in this study were those commonly trapped using the wire mesh-live cage traps, which are mainly terrestrial species (Bernard 2003).

From the total of 106 individuals captured, eight were caught at 100 m elevation, 11 at 500 m, 62 at 1,000 m and 25 at 1,400 m elevation. Species with the greatest number of captures was *T. montana* with 60 captures (~57% of total captures), followed by *R. rattus* (17 captures or 16% of total captures). Six species (*T. gracilis*, *S. muelleri*, *T. glis*, *M. surifer*, *M. rajah* and *N. rapit*) were represented by only a single capture each (Table 2). The six species combined represented ~ 6% of total captures. Species accumulation curves have not reached asymptote at all sampling sites (Fig. 2).

Species Diversity

Species diversity was not similar at all elevations. Both Shannon-Wiener and Simpson Diversity indices showed highest species diversity at 500 m elevation, followed by (in order of decreasing diversity) 100 m, 1,400 m and 1,000 m elevations. In general, species diversity was closer at 100 m and 500 m and at 1,000 m and 1,400 m as indicated by the 95% CI of the diversity indices at the respective elevations (Table 3) and the species rank-abundance distribution histograms (Fig. 3). The species rank-abundance distribution histograms also show that species richness was higher at 100 m and 500 m elevations, but no dominant species was recorded at these elevations. Species richness was lower at 1,000 m and 1,400 m elevations, but the small mammal communities were dominated by one species, *T. montana*.

Sørensen's coefficients indicated that species compositions at 100 m and 500 m, and at 1,000 m and 1,400 m elevations are more similar, though it is interesting to note that some overlapping of species occurred between 500 m and 1,400 m elevations (Table 4). The dendogram shows that all trap-lines located at 100 m and 500 m elevations formed one cluster, while all trap-lines located at 1,000 m and 1,400 m elevations formed another cluster (Fig. 4).

Density and Biomass

Highest population density was recorded at 1,000 m elevation, followed by 1,400 m elevation. Population densities were lowest at 100 m and 500 m. Variations in population biomass at different elevations showed almost the same pattern as population density (Fig. 5).

Table 2. Overall captures of small mammals at four elevations in Crocker Range Park.

Species	**Elevation**				**Total**
	100 m	**500 m**	**1,000 m**	**1,400 m**	
T. minor	4	-	-	-	4
T. gracilis	1	-	-	-	1
S. muelleri	1	-	-	-	1
T. tana	1	4	-	-	5
S. lowii	1	1	-	-	2
T. glis	-	1	-	-	1
M. surifer	-	1	-	-	1
M. rajah	-	1	-	-	1
M. whiteheadi	-	2	-	-	2
N. cremoriventer	-	1	-	2	3
T. montana	-	-	43	17	60
L. sabanus	-	-	2	5	7
R. rattus	-	-	17	-	17
N. rapit	-	-	-	1	1
No. of species	5	7	3	4	14
Total captures	8	11	62	25	106
Total trap-nights	180	360	360	180	1080
% trap success	4.4%	2.8%	17.2%	13.3%	9.8%

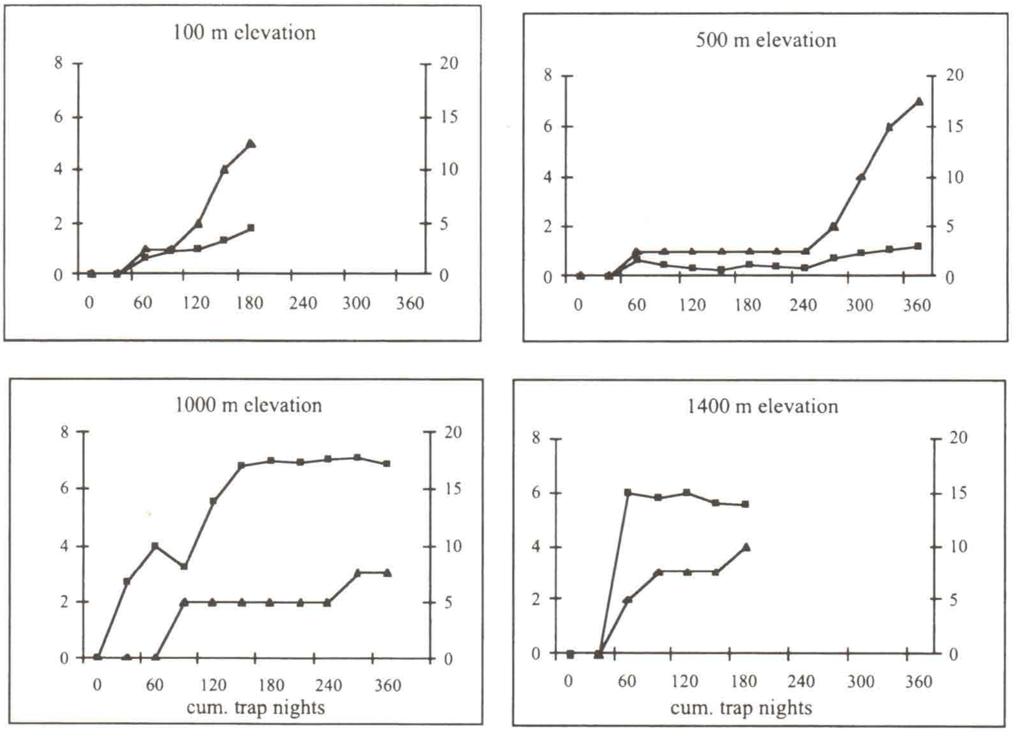

Fig. 2. Cumulative numbers of species (triangle) and percentage trap-success (square) over time (cumulative number of trap-nights) at four elevations in Crocker Range Park.

ELEVATIONAL HABITAT VARIATIONS

In general, CDFA showed that sampling locations at the four elevations differed based on all 12 habitat variables recorded. The first and second discriminant functions explained 69% and 22% of the total variations in the data, respectively. Both functions are significant in explaining the separation of habitat characteristics between sampling locations (test of functions 1–3: Wilks'λ = 0.058, χ^2 = 315.4, df = 36, P < 0.001; test of functions 2– 3: Wilks'λ = 0.290, χ^2 = 137.6, df = 22, P < 0.001). Number of trap stations classified correctly to elevations was 90% (108 of 120).

Table 3. Shannon-Wiener and Simpson diversity indices at four elevations in Crocker Range Park with 95% bootstrap confidence interval.

		Shannon-Wiener Index			Simpson Diversity Index		
Elevation	**H'**	**Variance H'**	**Lower 95%**	**Upper 95%**	**D_s**	**Lower 95%**	**Upper 95%**
100 m	1.39	0.091	0.38	1.56	4.67	1.33	9.33
500 m	1.77	0.060	0. 89	1.84	7.86	2.50	11.00
1,000 m	0.72	0.007	0.53	0.86	1.82	1.46	2.14
1,400 m	0.91	0.031	0.44	1.15	2.04	1.39	2.99

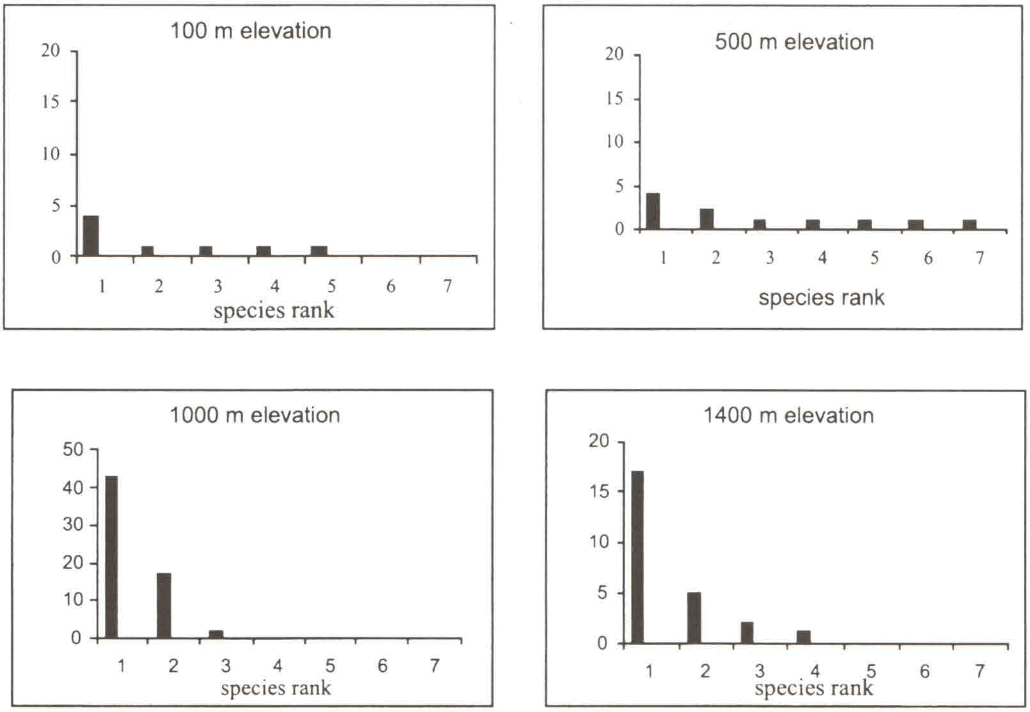

Fig. 3. Species rank-abundance distribution histograms at four elevations in Crocker Range Park.

The relative contributions of each of the habitat variables (with all other variables present) to the power of the discriminating functions are presented in Table 5. Function 1 indicates a contrast between sites with higher coverage of bryophyte and sites with greater number of tall trees (> 20 m high), higher coverage of peat soils, grasses, and rocky areas. In general, Function 1 seemed to describe the main differences between lowland forests and mountain forests (Fig. 6). Function 2 shows a contrast between sites with many tall trees (> 20 m high) and sites with greater canopy cover, higher coverage of bare soil, forest litter and denser vegetation at the understorey level (i.e., climbers and epiphytes). Although Function 2 seemed to describe the similarities of habitat structure of sampling sites at 100 m and 1,000 m elevations and at 500 m and 1,000 m elevations, there is no easy explanation as to what Function 2 may be describing in general.

MICROHABITAT-USE PATTERNS

Results of CCA showed that cumulatively only ~10% of the variations in the data were explained by the first and second canonical axis. For both axes, correlations were moderate between small mammal species and the habitat variables (Table 6). These show that the habitat variables used in this study are not sufficient to explain the small mammal species and habitat relationships at the four sampling sites. Nevertheless, they do provide a very general picture of the preferred microhabitats of the small mammal species. The distribution of *T. montana* and *L. sabanus* appeared to be associated with bryophytes; *R. rattus* and *S. muelleri* with grasses; *N. cremoriventer*, *M. surifer* and *N. rapit* with understorey vegetation (climbers); and *T. minor*, *T. tana*, *T. glis*, *T. gracilis*, *M. rajah*, *M.*

Table 4. Sørensen similarity indices (%) of small mammal species compositions at four different elevations at the Crocker Range Park.

	100 m a.s.l	500 m a.s.l	1,000 m a.s.l	1,400 m a.s.l
100 m a.s.l	*			
500 m a.s.l	33%	*		
1,000 m a.s.l	0%	0%	*	
1,400 m a.s.l	0%	18%	57%	*

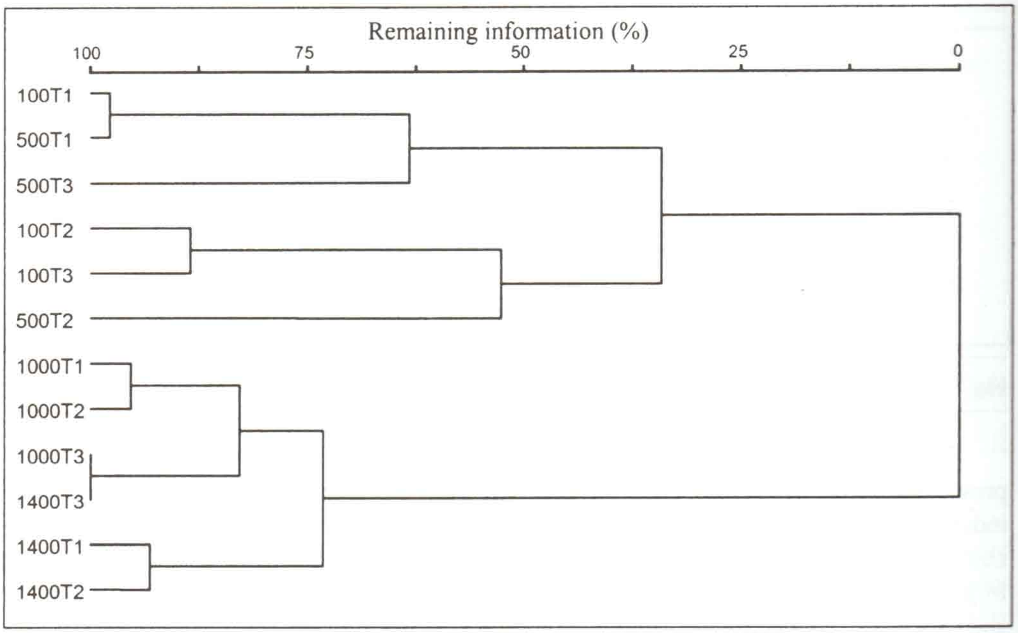

Fig. 4. A dendogram of the distribution of small mammals based on captures at 12 trap-lines at four elevations. The dendogram was based on Cluster Analysis using Ward's Method and Euclidean Distance. (Abbreviations; 100T1 = first trap-line at 100 m elevation)

whiteheadi and *S. lowii* with rocky habitats (Fig. 7). In terms of elevations, three species appeared to be associated with high elevations (1,000 m and 1,400 m) i.e., *R. rattus* was more likely found at 1,000 m, while *T. montana* and *L. sabanus* were more likely found at 1,000 m and 1,400 m s. The other species were associated with low elevations (100 and 500 m) (Fig. 7, see also Table 2).

DISCUSSION

Overall Captures

The number of small mammal species documented in CRP in this study is relatively high, though undoubtedly still lower than what it could potentially be (Yasuma *et al.*

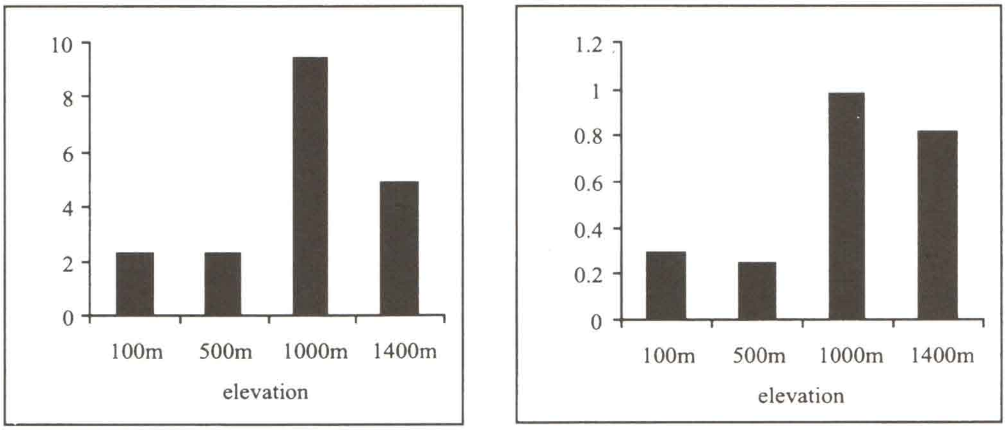

Fig. 5. Density (N/ha) and biomass (kg/ha) of small mammal populations at four elevations in Crocker Range Park.

Table 5. Standardized canonical discriminant function coefficients of functions 1 and 2. Highlighted values are the first five habitat structures that contributed the most to the power of the canonical discriminant functions.

Habitat structures variables	**Discriminant functions** 1	2
UPPER STRATA		
Canopy cover	.426	**.651**
Tree heights	**.620**	**-.773**
LOWER STRATA		
Shrub density	-.029	.023
Climbers	-.219	**.439**
GROUND LEVEL		
Soil type	**.958**	-.192
Bare soil	-.016	**.708**
Water	-.075	.236
Rocky area	**.505**	.410
Bryophytes	**-.681**	.170
Grasses	**.633**	.398
Litter	.489	**.480**
Fallen trees	.070	-.125

2003). This is due to the relatively low trapping effort at each sampling site (180–360 trap-nights per site). The survey period also coincided with heavy rainfall when low trap success is not uncommon (Bernard *et al.* 1997). In addition, trap bias due to trap design, trap placements and the usage of only a single type of bait contributed to the narrow spectrum of small mammal species captured. Banana as bait for trapping small mammals has been found to be biased in favour of capturing treeshrews (Bernard 2003).

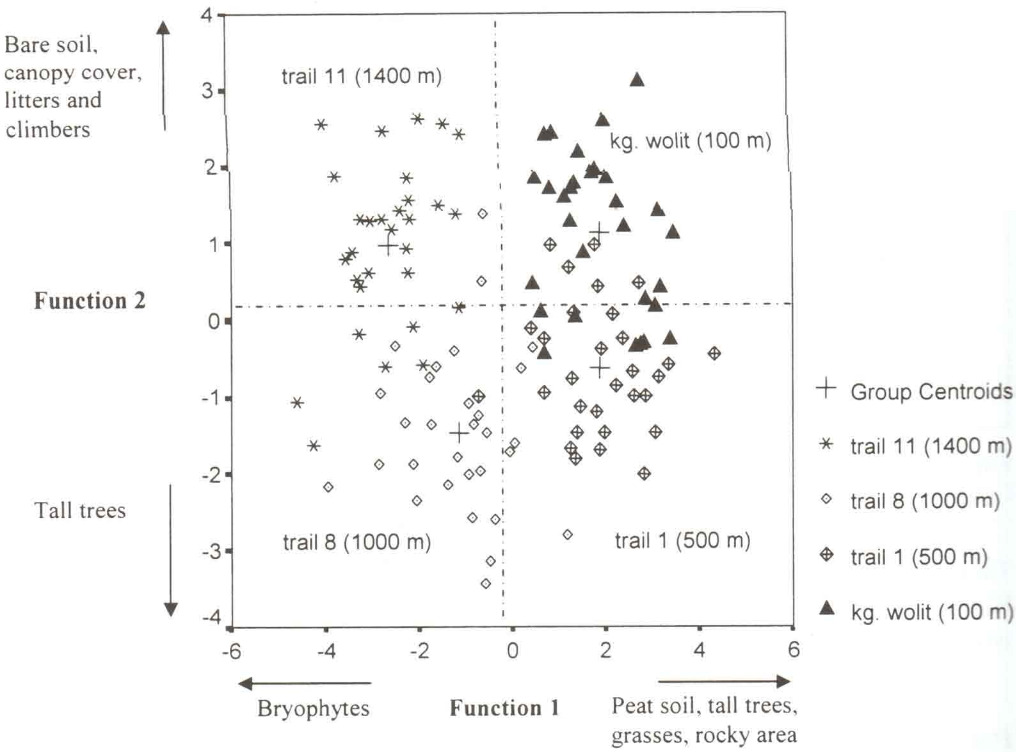

Fig. 6. Distributions of 120 trap stations based on 12 habitat variables at four elevations according to functions 1 and 2 of Canonical Discriminant Analysis.

Only one study has been conducted on the small mammals in CRP at similar elevations and sampling sites (except at 1,000 m elevation) as the present study (Yasuma unpublished data). Yasuma's study consisted of a seven-month trapping programme with the main aim of producing an inventory list of small mammal fauna occurring in CRP, He recorded six species at 100 m elevation, three at 500 m, 20 at 1,000 m and six at 1,400 m. The present study recorded five species at 100 m, seven at 500 m, three at 1,000 m and four at 1,400 m. In general, the small mammal species assemblages caught by Yasuma at different elevations are comparable with those caught in the present study. The noticeably higher species richness recorded by Yasuma at 1,000 m elevation could be due to habitat disturbance. Although not equal to primary forest in terms of species composition, species richness is usually high in disturbed forest on a local scale (Bernard *pers. obvs.*). Yasuma's sampling site at 1,000 m elevation was located at the CRP headquarters 10 km from the sampling site at similar elevation in the present study. This site is mainly secondary forest dominated by pioneer trees, wild gingers and patches of grasslands (*Pennisetum* spp.). In addition, it is located near human settlements where some areas have been cultivated with vegetables and other crops. Some of the small mammals caught by Yasuma at this site were those have been recorded in disturbed habitats elsewhere (incl. gardens, plantations and young secondary forests) such as *C. notatus*, *C. orestes*, *M. whiteheadi*, *R. exculans*, *T. glis* and *T. minor* (Payne *et al.* 1985; Yasuma & Andau 2000; Yasuma *et al.* 2003). This finding has important implications as it suggests that two different sites at a similar

Table 6. Summary statistics of the first two axes of the Canonical Correspondence Analysis performed with small mammal species as the main matrix and habitat variables as second matrix and their canonical coefficients

Axis summary statistics	**1**	**2**
Eigenvalue	0.640	0.493
Variance in species data		
% of variance explained	5.7	4.4
Cumulative % explained	5.7	10.1
Kendall (Rank) Correlation, Species-habitat structures	0.667	0.627

Habitat structures	**Standardized Canonical Coefficients**	
Canopy cover	-0.331	-0.374
Tree heights	-0.063	1.221
Shrub density	0.032	-0.431
Climbers	0.094	-0.907
Bare soil	-0.181	0.014
Water	0.100	0.287
Rocky area	-0.218	0.219
Bryophytes	0.747	0.018
Grasses	0.042	0.541
Litter	-0.551	0.062

elevation may not necessarily share similar small mammal species assemblages. All sampling sites in the present study, except at 100 m elevation, were located in relatively undisturbed habitats.

Compared to Yasuma's study, the small mammal species not recorded in the present study are two primate species (*Nycticebus coucang* and *Tarsius bancanus*), five species of squirrels (*Callosciurus notatus*, *C. prevostii*, *C. orestes*, *Lariscus hosei*, *Sundasciurus brookei*), four species of murid rodents (*Maxomys baeodon*, *M. ochraceiventer*, *Rattus exulans*, *Chiropodomys major*) and one species of treeshrew (*Dendrogale melanura*). The squirrels are definitely underrepresented in the present study due to the trapping method employed. Even so, at 1,400 m elevation the present study caught one species, *Niviventer rapit*, which is a new record for CRP.

Previous records have indicated that *N. rapit* is distributed from 0–1,200 m and has been recorded in only a few places in Sabah: Mt. Kinabalu, Maliau Basin, Poring and Tawau Hills Park (Yasuma & Andau 2000). On Mt. Kinabalu, *N. rapit* has been recorded from 940–3,360 m elevations (Payne *et al.* 1985; Md. Nor 2001). *N. rapit* resembles *L. sabanus* and *N. cremoriventer* in appearance. However, *L. sabanus* is usually larger (head-body length 215–273 mm) than *N. rapit* (head-body length 122–163 mm) (Payne *et al.* 1985). *N. cremoriventer* has whitish underparts usually with a yellow or buff tinge, expecially on the chest, but this characteristic is absent in *N. rapit* even in the juvenile

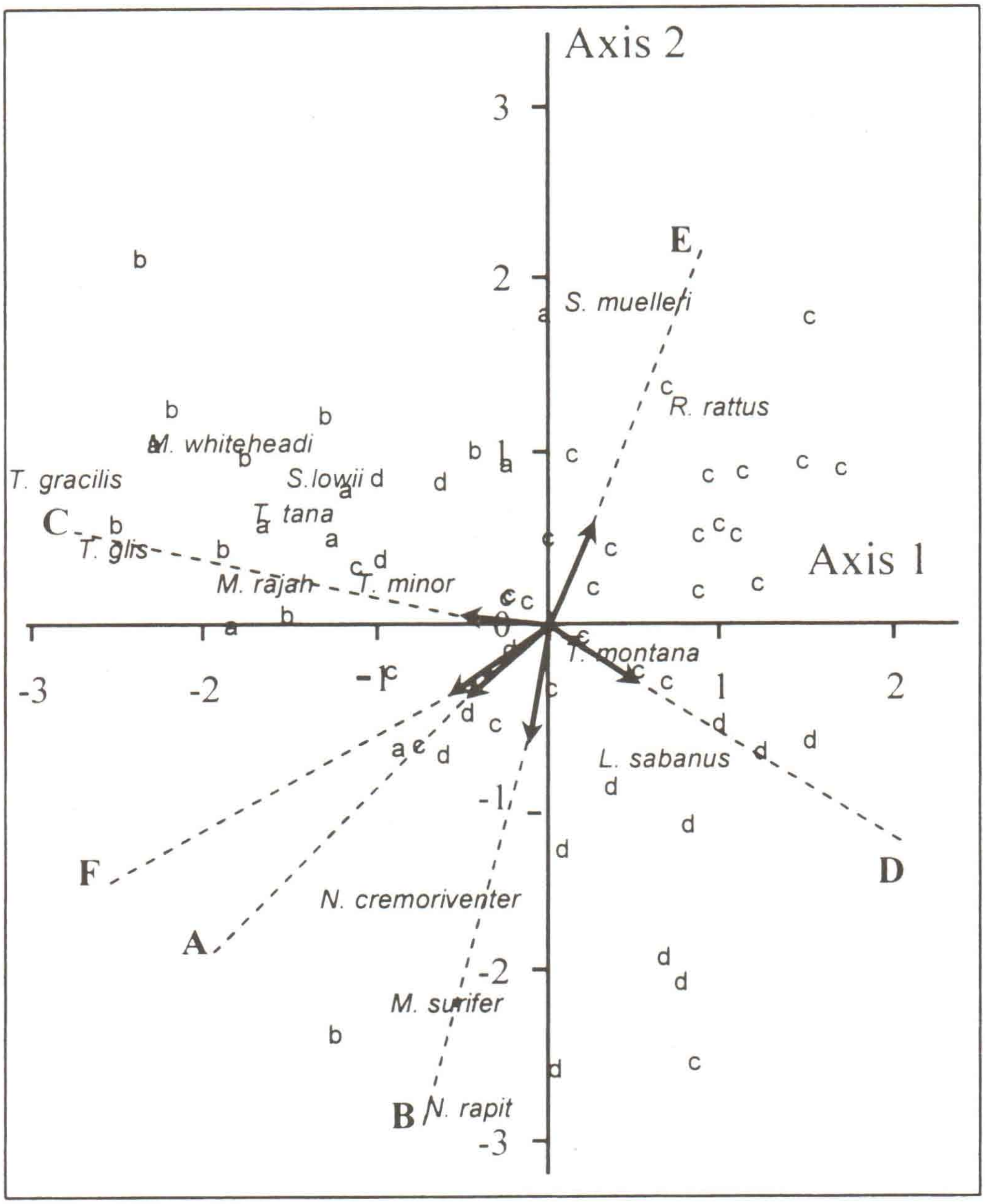

Fig. 7. Ordination diagram based on Canonical Correspondence Analysis of small mammal species (main matrix) and habitat variables (second matrix).

Note: Only six habitat variables that have the strongest influence on the small mammal species occurrence are shown). Small alphabets a–d represent four different elevations i.e., a; 100 m elevation, b; 500 m elevation, c; 1,000 m elevation, and d; 1,400 m elevation. Arrows A to F refer to direction of the gradients of six habitat variables, i.e., A = canopy cover, B = climbers, C = rocky area, D = bryophytes, E = grasses, and F = forest litters.

stage (Payne *et al.* 1985; Yasuma & Andau 2000). Morever, *N. rapit* is somewhat larger than *N. cremoriventer* (head-body length 106–160 mm) (Payne *et al.* 1985).

Variations in Aspects of Small Mammal Community Structures

Small mammal species diversity, species richness and species assemblages in the present study clearly depict two groups of small mammals i.e., one representing low elevation (100 m and 500 m) and the other representing high elevations (1,000 m and 1,400 m). Species-abundance distribution patterns also depict this pattern. Both the present study and that of Yasuma (unpublished data) showed the absence of dominant species at low elevations (100 m and 500 m), but recorded the dominance of *T. montana* at high elevations (1,000 m and 1,400 m).

In general, in this study species diversity and richness decreased with increasing elevations (i.e., 10 species at low elevations and five species at high elevations). This is typical pattern of mountain forest of low height (1,200–1,800 m) (Mackinnon *et al.* 1996; Earl of Cranbrook 1988). It needs to be stressed, however, that this pattern is not true for all mountain forests. Mt. Kinabalu (4095.2 m), for example, showed a hump-shaped pattern, where maximum species diversity and richness are at 1,700–2,200 m, low species diversity and richness at 700–1,200 m and moderate at 2,700–3,200 m (Md. Nor 2001). Maximum diversity of small mammals on Mt. Kinabalu occurred at the elevation where lowland and highland assemblages overlapped (Md. Nor 2001). Several types of plants reached their maximum diversity at these elevations where rainfall and humidity also reached their maxima (Md. Nor 2001).

Population density and biomass were higher at 1,000 m and 1,400 m than at 100 m and 500 m elevations in this study due to the dominance of *T. montana* (a moderate sized mammal, 93–220 g) in the sample data at higher elevations. Only one species of squirrel, *S. lowii*, which is of comparable size to *T. montana*, was caught at low elevations in this study. Scansorial squirrels can be caught in traps laid 0–2 m above ground level, but arboreal squirrels often are difficult, or in some cases impossible, to capture using the trapping method adopted in this study (Md. Nor 2001; Bernard 2003). Therefore, the patterns of small mammal population density, and especially biomass, across elevational gradient in this study may be misleading and should be treated with caution.

Habitat Preferences of Small Mammals

In terms of habitat structure the four sampling sites clearly differed by elevation. Two groups can be distinguished: habitats at low elevations (100 m and 500 m) and habitats at high elevations (1,000 m and 1,400 m). The small mammals clearly showed a preference for a particular elevation, though one species, *Niviventer cremoriventer*, was caught at both low and high elevations, indicating the species has a wide elevational distribution. *N. cremoriventer* has previouslybeen recorded in lowlands and hills throughout Borneo, up to 1530 m in lower montane forest on Mt. Kinabalu (Payne *et al.* 1985). There is some evidence from the present study suggesting microhabitat preferences of small mammals in CRP. These microhabitats appear to be influenced by elevation.

Conservation Implications

Information from this study and Yasuma's study (unpublished data) indicate that CRP and its vicinity harbour a rich small mammal fauna. Yasuma *et al.* (2003) indicated that CRP may have the same number of mammals as Kinabalu Park or even more because CRP occupies a wider area than Kinabalu Park, and still possesses good forests (Yasuma *et al.* 2003). In general the present study on non-flying small mammals showed that there are two elevationally associated faunas, one in the highlands (1,000 m and 1,400 m) and another in the lowlands (100 m and 500 m) which appear to be related to differences in habitat structure. For that reason it appears that conservation of the entire spectrum of small mammals in CRP requires the protection of the whole range of habitats from lowland to highland forests.

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