Small mammal communities of tropical forest habitats in Mudumalai Wildlife Sanctuary, southern India

Meena VENKATARAMAN
Kartik SHANKER
Raman SUKUMAR
Centre for Ecological Sciences, Indian Institute of Science,
Bangalore 560012 (India)
rsuku@ces.iisc.ernet.in

Venkataraman M., Shanker K. & Sukumar R. 2005. — Small mammal communities of tropical forest habitats in Mudumalai Wildlife Sanctuary, southern India. *Mammalia* 69 (3-4) : 349-358.

ABSTRACT

Small mammal communities were studied in four tropical habitats (dry thorn, dry and moist deciduous, and semi-evergreen forests) in Mudumalai Wildlife Sanctuary, southern India. Species composition, community structure, and population variables of small mammals in these habitats were examined. The relationship between small mammal community structure and select habitat variables was also examined. Six species of rodents and one insectivore were represented by 396 captures of 195 individuals out of a total of 7,425 trap nights (5.3% capture rate). Small mammals showed distinct distribution patterns across habitat types. Community structure, species richness, species diversity, relative abundance, and biomass varied across habitats, with each type having a different dominant species. *Cremnomys blanfordi*, which was the most abundant species, comprised 39%, *Mus platythrix* 29%, *Rattus rattus* 12%, *M. musculus* 9%, *Tatera indica* 5%, *Suncus montanus* 5%, and *Platacanthomys lasiurus* 1% of captures. Deciduous forest habitats supported the highest abundance and biomass of small mammals. However, based on the distinct distribution patterns, all four forest types are believed to be important for maintaining the local diversity of small mammal populations. Small mammal abundance was positively correlated with habitat heterogeneity. Although the community structure of small mammals is broadly determined by habitat structure, the specific microhabitat preferences of individual species could not be determined from these data.

KEY WORDS
Small mammals,
community structure,
tropical forest,
Mudumalai,
Tamilnadu,
India.

RÉSUMÉ

Communautés de petits mammifères des habitats forestiers tropicaux dans la réserve de Mudulalai au Sud de l'Inde.

Les communautés de petits mammifères ont été étudiées dans quatre habitats tropicaux (broussailles sèches, forêts décidues sèches et humides, forêts semi-humides) dans le sanctuaire de vie sauvage de Mudumalai au Sud de l'Inde. Dans ces habitats, la composition spécifique, la structure des communautés, les variables des populations de petits mammifères ont été examinées, de même que la relation entre les communautés de petits mammifères et les variables d'habitat. Six espèces de rongeurs et une d'insectivore sont représentées par 396 captures de 195 individus soit un total de 7 425 nuits-pièges (taux de 5,3 % de capture). Il existe des différences de distribution, de structure de communauté, de richesse spécifique d'abondance et de biomasse pour chaque type d'habitat qui peuvent être caractérisés par des espèces dominantes différentes. *Cremnomys blanfordi*, représente l'espèce la plus abondante avec 39 % d'occurrence, puis *Mus platythrix* 29 %, *Rattus rattus* 12 %, *M. musculus* 9 %, *Tatera indica* 5 %, *Suncus montanus* 5 %, and *Platacanthomys lasiurus* 1 %. Les habitats de forêt décidue représentent la plus forte abondance et biomasse. Cependant lorsque l'on considère les différents patrons de distribution, les quatre types d'habitats sont importants en terme de maintien de la biodiversité des populations de petits mammifères. Leur abondance est corrélée positivement avec l'hétérogénéité de l'habitat. Bien que la structure des communautés de petits mammifères soit largement déterminée par la structure de leur habitat, les préférences spécifiques de microhabitat n'ont pas pu être déterminées lors de ce travail.

MOTS CLÉS
Petits mammifères, structure de la communauté, forêt tropicale, Mudumalai, Tamilnadu, Inde.

INTRODUCTION

Taxonomic composition, species richness, relative abundance, biomass, and density are features that characterise a biological community (Hayward & Phillipson 1979). Habitat diversity is widely considered an important determinant of local animal diversity, with more heterogeneous habitats generally having more animal species. Habitat diversity itself is a function of both horizontal heterogeneity or patchiness and structural complexity or vertical stratification of the habitat (August 1983). Increased species diversity in more complex and heterogeneous habitats may arise because there is more opportunity for niche differentiation and resource partitioning (MacArthur *et al.* 1962, Levins 1968). This partitioning has been thought to be important in decreasing competition between otherwise ecologically similar species.

Several studies have examined the relationship of small mammal (less than 5 kg) abundance and diversity to competition and habitat (e.g., Dueser & Shugart 1978; August 1983; Dueser & Porter 1986; Canova & Fasola 1991; Adler 1996), as well as to disturbance regimes (e.g., Lehmann & Perevolotsky 1992; Chandrasekar-Rao & Sunquist 1996; Wu *et al.* 1996). Several habitat variables including vegetation density, foliage height diversity, and soil structure significantly influence species distributions both between and within habitats (Rosenzweig & Winakur 1969). In southern India, small mammals have been studied in natural and human-impacted habitats (Chandrasekar-Rao & Sunquist 1996; Shanker & Sukumar 1998; Shanker 2001).

This study was undertaken to investigate small mammal communities in different forest types in Mudumalai Wildlife Sanctuary, southern India,

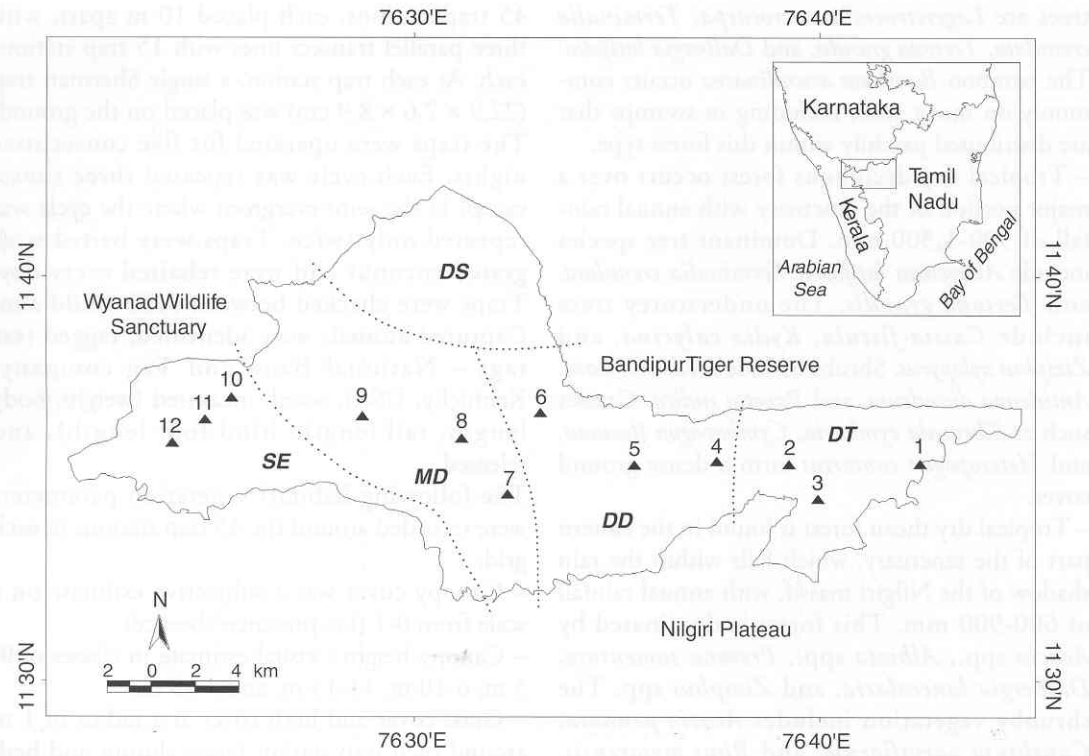

FIG. 1. — Location of Mudumalai Wildlife Sanctuary in southern India, and the study area showing locations of plots across the different vegetation types; plots 1-3 are in dry thorn forest (**DT**), plots 4-6 in dry deciduous forest (**DD**), plots 7-9 in moist deciduous forest (**MD**), and plots 10-12 in semi-evergreen forest (**SE**). The dotted lines indicate the broad boundaries of the various original vegetation types. Some of these potential vegetation types are presently in a degraded state (see text for details). *Shorea* dominated dry deciduous forest (**DS**) was not sampled.

and species composition in different habitats and differences in community structure and population variables were explored.

MATERIAL AND METHODS

STUDY AREA

Mudumalai Wildlife Sanctuary (11°32' to 11°43'N and 76°22' to 76°45'E) is situated in the Nilgiris (Tamilnadu state), a part of the Western Ghats range in peninsular India. It covers an area of 321 km^2, and has an undulating terrain with elevation ranging from about 350 m to 1250 m asl. There is a decreasing rainfall gradient from the west and south to the east and north (Suresh *et al.* 1996). Mudumalai encompasses a range of tropical vegetation types from semi-evergreen/moist deciduous forest in the west through dry deciduous forest over most of the reserve to dry thorn forest in the eastern part of the sanctuary (Suresh *et al.* 1996) (Fig. 1). The major vegetation types are:

– Tropical semi-evergreen forest occurs in small patches in the southwestern part of the sanctuary where annual rainfall is ~ 1,800 mm. The dominant trees are *Olea dioica*, *Toona ciliata*, *Glochiodion velutinum*, and *Elaeocarpus tuberculatus*.

– Tropical moist deciduous forest is found in the southern and western parts of the sanctuary where annual rainfall is ~ 1,500 mm. Dominant

trees are *Lagerstroemia microcarpa*, *Terminalia crenulata*, *Tectona grandis*, and *Dalbergia latifolia*. The bamboo *Bambusa arundinacea* occurs commonly on moist soils, including in swamps that are distributed patchily within this forest type.

– Tropical dry deciduous forest occurs over a major portion of the sanctuary with annual rainfall of 900-1,300 mm. Dominant tree species include *Anogeissus latifolia*, *Terminalia crenulata*, and *Tectona grandis*. The understorey trees include *Cassia fistula*, *Kydia calycina*, and *Ziziphus xylopyrus*. Shrubs include *Helicteres isora*, *Antidesma diandrum*, and *Pavetta indica*. Grasses such as *Themeda cymbaria*, *Cymbopogon flexuous*, and *Heteropogon contortus* form a dense ground cover.

– Tropical dry thorn forest is found in the eastern part of the sanctuary, which falls within the rain shadow of the Nilgiri massif, with annual rainfall of 600-900 mm. This forest is dominated by *Acacia* spp., *Albizia* spp., *Premna tomentosa*, *Dalbergia lanceolaria*, and *Ziziphus* spp. The shrubby vegetation includes *Acacia pennata*, *Canthium parviflorum*, and *Rhus mysorensis*. Succulents like *Opuntia dillenii*, *Euphorbia* spp., and *Caraluma adscendens* are common.

Field methods

Live trapping of small mammals was carried out at Mudumalai for a period of three months (March-May 1997) during the dry and pre-monsoon seasons for a total of 7,425 trap nights. Twelve sites representing four major vegetation types within Mudumalai were chosen for the study (Fig. 1). They included: (a) dry thorn forest, (b) dry deciduous forest, (c) moist deciduous forest, and (d) semi-evergreen forest. Two types of deciduous forest habitats, one tending towards drier forest (closer to thorn forest) and the other more humid forest (closer to semi-evergreen forest) were chosen for the study in order to examine small mammal distribution. Many parts of the moist deciduous forest are in a degraded state because of past logging and resemble the dry deciduous forests in species and structural attributes.

Three trapping grids were placed in each of the four vegetation types. Each grid consisted of 45 trap stations, each placed 10 m apart, with three parallel transect lines with 15 trap stations each. At each trap station, a single Sherman trap (22.9 × 7.6 × 8.9 cm) was placed on the ground. The traps were operated for five consecutive nights. Each cycle was repeated three times, except in the semi-evergreen where the cycle was repeated only twice. Traps were baited with grated coconut and were rebaited every day. Traps were checked between 7.00-10.00 a.m. Captured animals were identified, tagged (ear tags – National Band and Tag company, Kentucky, USA), sexed, measured (weight, body length, tail length, hind foot length), and released.

The following habitat/ vegetation parameters were recorded around the 45 trap stations in each grid:

– Canopy cover was a subjective estimate on a scale from 0-1 (i.e. presence/absence).

– Canopy-height : visual estimate in classes of 0-5 m, 6-10 m, 11-15 m, and > 15 m.

– Grass cover and herb cover at a radius of 1 m around each trap station (grass clumps and herb were counted around each trap station).

Distance to nearest tree in metres using a calibrated stick.

Distance to nearest log in metres.

Data analyses

Three population variables were calculated for each habitat using trapping data within each grid.

Abundance: the total number of individuals captured per grid or Minimum Number Known Alive (MNKA) (Krebs 1966).

Biomass: total weight (g) of the individuals captured per grid.

Average weight: the average weight (g) of each species captured per grid.

The relative abundance of each species in each habitat was calculated. This indicated dominant species and the distribution patterns of the small mammals in the different habitats. Species diversity and evenness indices were calculated for each grid (Magurran 1988).

Z-values of the habitat parameters were calculated to standardise the variables for comparison.

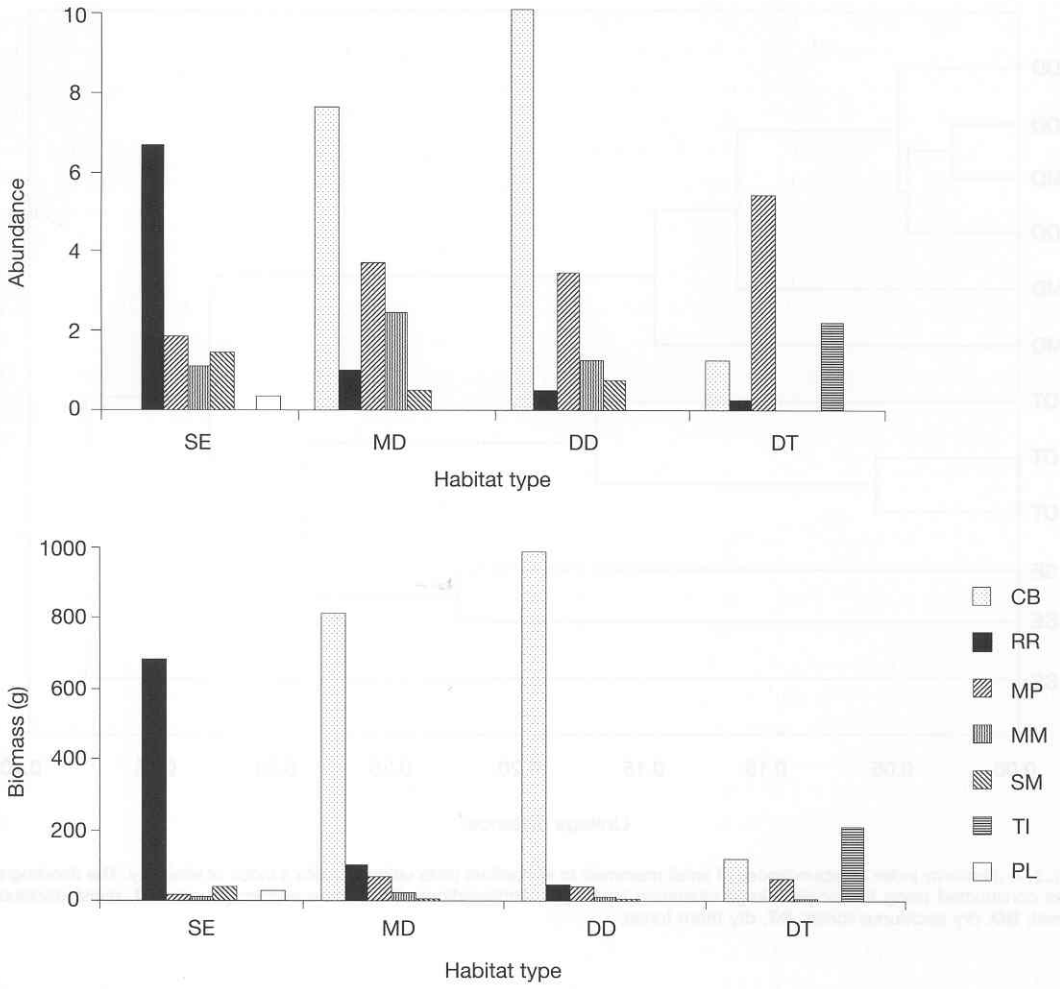

FIG. 2. — **A** Abundance (individual/ha) and **B** biomass (g.ha^{-1}) of different species of small mammals in the four habitat types: *Cremnomys blanfordi* (**CB**), *Rattus rattus* (**RR**), *Mus platythrix* (**MP**), *Mus musculus* (**MM**), *Suncus montanus* (**SM**), *Tatera indica* (**TI**), and *Platacanthomys lasiurus* (**PL**). **SE**, semi-evergreen forest; **MD**, moist decidous forest; **DD** dry decidous forest; **DT**, dry thorn forest.

A standardised Euclidean distance matrix was computed for the 12 grids based on six habitat parameters. The distance matrix was then used for a single linkage clustering analysis (Kaufman & Rousseeuw 1990). Small mammal abundance and biomass values were correlated with habitat values in each grid using Spearman's rank order correlation (Siegel & Castellan 1988). The relationship between small mammal abundance and habitat was also examined using the Mantel test (Hemelrijk 1990) by comparing the similarity matrix of small mammal abundance and correlation matrix of habitat variables.

RESULTS

A total of 195 individuals, representing six species of rodents and one insectivore, were captured (396 captures in 7425 trap nights or

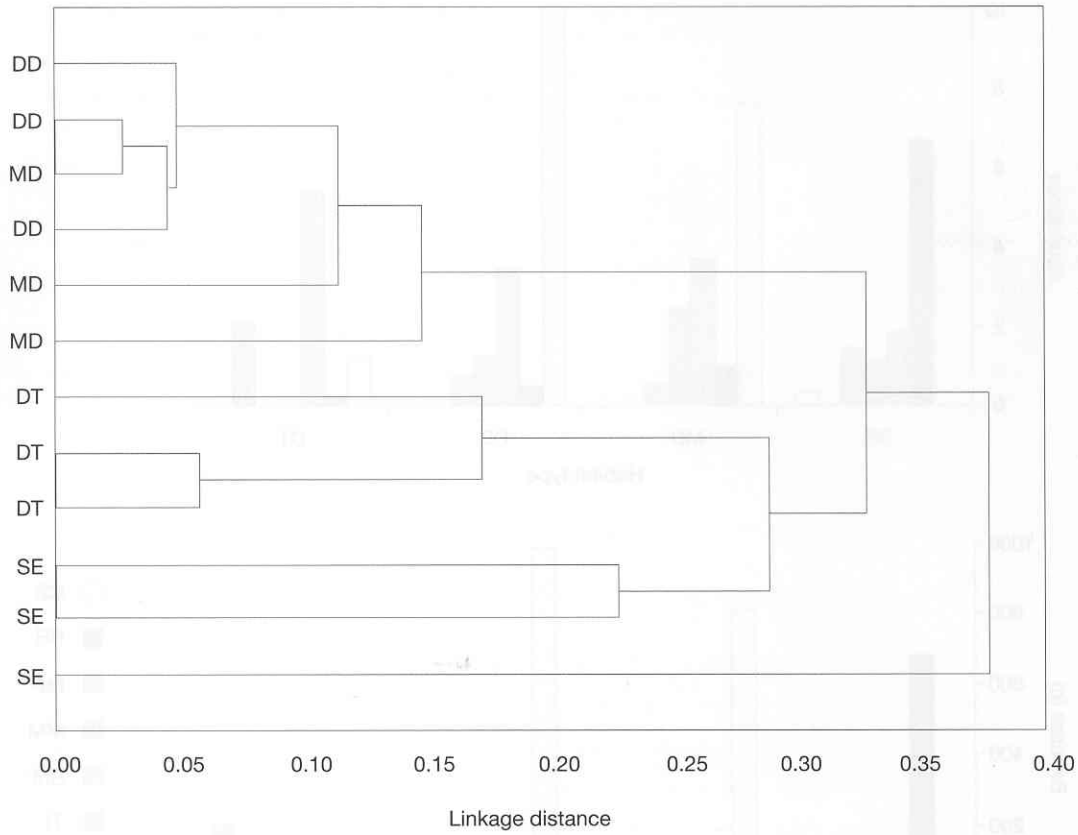

FIG. 3. — Similarity index on abundances of small mammals in all habitats plots using Morisita's index of similarity. The dendrogram was constructed using the single linkage clustering technique. Abbreviations: **SE**, semi-evergreen forest; **MD**, moist deciduous forest; **DD**, dry deciduous forest; **DT**, dry thorn forest.

5.3%). *Cremnomys blanfordi* was the most commonly trapped species representing 39% of total captures. *Mus platythrix* (29%), *Rattus rattus* (12%), *M. musculus* (9%), *Tatera indica* (5%), *Suncus montanus* (5%), and *Platacanthomys lasiurus* (1%) were the other species captured. The abundance, distribution, and biomass of small mammal species varied across habitats (Table 2). Abundance and biomass were highest in the deciduous forest habitat, followed by the semi-evergreen forest habitat. Not only abundance but also biomass was particularly low in the dry thorn forest, in spite of the presence of a large-bodied species *T. indica*. The total abundance of small mammals averaged 11.5 animals ha^{-1} (range 6.7-20.0 ha^{-1}) for semi-evergreen forest, 15.3 animals ha^{-1} (range 8.9-31.1 ha^{-1}) for moist deciduous forest, 16.1 animals ha^{-1} (range 11.1-26.7 ha^{-1}) for dry deciduous forest, and 9.1 animals ha^{-1} (range 0-20 ha^{-1}) for dry thorn forest. *C. blanfordi* had the highest abundance of 20 individuals ha^{-1} in a dry deciduous forest plot. The total biomass of small mammals averaged 790 g ha^{-1} for semi-evergreen forest, 1017 g ha^{-1} for moist deciduous forest, 1095 g ha^{-1} for dry deciduous forest, and 391 g ha^{-1} for dry thorn forest.

Each habitat type had a different dominant species. In the semi-evergreen forest plots, *R. rattus* accounted for 58% of the captures. In the two deciduous forest types (dry and moist), *C. blan-*

TABLE 1. — Occurrence of small mammal species in three major habitat types in Mudumalai Wildlife Sanctuary, southern India. Data from dry and moist deciduous forest are combined as they have similar plant and small mammal compositions.

Species/Habitat	Dry thorn forest	Deciduous forest	Semi-evergreen forest
Cremnomys blanfordi	+	+	-
Rattus rattus	-	+	+
Mus platythrix	+	+	+
Mus musculus	-	+	+
Suncus montanus	-	+	+
Tatera indica	+	-	-
Platacanthomys lasiurus	-	-	+

TABLE 2. — Diversity indices of small mammal community structure for four habitats in the Mudumalai Wildlife Sanctuary, southern India. Abbreviations: **SE**, Semi-evergreen forest; **MD**, Moist deciduous forest; **DD**, Dry deciduous forest; **DT**, Dry Thorn forest.

Diversity index	SE	MD	DD	DT
Shannon-Weiner index of diversity H'	1.21	1.27	1.07	1.02
Simpson's index of diversity S	2.56	2.94	2.21	2.31
Pielou's index of evenness J'	0.80	0.79	0.66	0.74
Species richness	5	5	5	4

TABLE 3. — Habitat parameters: average values and comparative scores. **Canopy cover**: sum of presences for each trap point summed for each plot (< 20 = low; 20-30 = medium; > 30 = high, for each plot of 45 points); **height**-class (scores of each height class 0-5 m; 6-10 m; 11-15 m, and >15 m added up for each plot and rated based on comparative scores); **grass and herb cover**: number of clumps in 1 m radius plots at each trap point (means and standard errors are reported); **Log presence**: comparative ranks based on sum of scores for each habitat. (Score = 1 if log distance < 3 m, 0 if > 3 m; plots ranked based on comparative sum of log distance scores); **tree presence**: comparative ranks based on sum of scores for each habitat (Score = 1 if tree distance < 5 m, 0 if > 5 m; plots ranked based on comparative sum of tree distance scores).

	SE	MD	DD	DT
Canopy cover	high	high	medium	low
Canopy height	medium	medium	medium	low
Grass	12.7 ± 1.2	13.1 ± 0.6	16.5 ± 0.7	17.6 ± 0.5
Herb	13.9 ± 0.8	9.4 ± 0.4	8.3 ± 0.4	9.2 ± 0.5
Log presence	2	3	1	4
Tree presence	1	2	3	4

fordi accounted for 63% and 50% of the trapped individuals, respectively. *M. platythrix* was the most abundant species in the dry thorn forest, accounting for 59% of the captures.

The average weight of *C. blanfordi* ranged from 98 g to 110 g whereas that of *R. rattus* ranged from 82 g to 100 g. *T. indica* was trapped only in dry thorn forest and, with an average weight of 142 g, contributed substantially to the biomass of small mammals in this habitat. *Platacanthomys lasiurus* was represented by a single capture in the semi-evergreen forest. The other species were found in more than one habitat, although only *Mus platythrix* was found in all three habitats (Table 1). Indices of species diversity, evenness, and richness were generally higher in the wetter semi-evergreen and the moist deciduous forests (Table 2).

Cluster analysis of small mammal similarity in each of the four habitats revealed that species variation between habitats was greater than within habitat (Fig. 3). The four habitats were

ranked based on average quantified values (grass and herb count), as well as scores derived from more subjective estimates (canopy cover, canopy height, tree, and log distance). Canopy cover and herb cover were denser in the semi-evergreen forest. Canopy height values were comparable in both the deciduous and the semi-evergreen plots while grass cover was the highest in the dry thorn forest (though grass biomass is higher in the dry deciduous forest) (Table 3).

The similarity matrix of small mammal abundance and correlation matrix of habitat variables for all the study grids were significantly positively correlated with each other (Mantel test, $p < 0.05$). When the habitat preferences of each mammal species were examined by correlating their abundance with the six habitat parameters, *C. blanfordi* did not show significant correlation with any of the habitat parameters. *R. rattus* abundance was correlated to understory with canopy cover ($r_s = 0.7$, $p < 0.01$), herbs ($r_s = 0.9$, $p < 0.001$), and trees ($r_s = 0.7$, $p < 0.01$). *M. platythrix* was correlated with canopy cover ($r_s = 0.7$, $p < 0.01$) and presence of logs ($r_s = 0.7$, $p < 0.05$).

DISCUSSION

Overall, small mammal species richness is low in the tropical forest habitats in southern India. Seventeen out of 76 known species of murid rodents and seven out of 26 species of ground shrews known to occur in India have been recorded in the Western Ghats (Kumar *et al.* 2001). Forest contiguity, disturbance factors, size of forest patches (Shanker & Sukumar 1998; Shanker 2000) and habitat structure (Chandrasekar-Rao & Sunquist 1996) have been shown to determine the small mammal distribution from studies in other areas of the Western Ghats. Shanker & Sukumar (1998) recorded nine species of rodents and shrews from montane evergreen forests and grasslands (> 2000 m asl) in the Nilgiris (a part of the Western Ghats), but most studies recorded four to five species or less in a wide range of habitats (Chandrasekhar-Rao & Sunquist 1996; Kumar *et al.* 2001).

A total of seven species of rodents and shrews were recorded in this study. The species composition and the dominant species varied with habitat type. Deciduous forest habitats supported the highest small mammal abundance and biomass in Mudumalai Wildlife Sanctuary. Species diversity and richness values were also high in these habitats. *C. blanfordi* was the most common species captured, while *R. rattus* and *C. blanfordi* contributed significantly to the biomass. The twelve plots chosen for this study were spatially spread out in the east-west direction with a change from dry thorn forest through dry deciduous forest and moist deciduous forest to semi-evergreen forest along a rainfall gradient. Comparisons revealed that small mammal composition within each habitat type generally clustered together, though the moist and dry deciduous habitats could not be distinguished.

Different mammal species were dominant in different habitats, *C. blanfordi* in deciduous habitats and *R. rattus* in the semi-evergreen forest. Interestingly, the white-bellied form of *R. rattus* has also been found to be dominant in middle elevation evergreen forests in the Anamalais (Chandrasekhar-Rao & Sunquist 1996) and montane evergreen forests in the Nilgiris (Shanker & Sukumar 1998), both in the Western Ghats. In the montane ecosystem of the upper Nilgiris, *R. rattus* was the dominant species of the forests while *Millardia meltada* was the dominant species of the adjoining grassland habitats (Shanker 2001). *Suncus montanus* was captured only in the dry deciduous and semi-evergreen forests. *Platacanthomys lasiurus* (the Malabar spiny dormouse), an arboreal species, was recorded from semi-evergreen forests only, highlighting the importance of this habitat. Endemics such as *P. lasiurus* have been found to be associated with habitat features typical of undisturbed mature rain forest only and any alterations of this habitat result in local extinction (Kumar *et al.* 2001; Mudappa *et al.* 2001). Fragmentation of natural forest leads to structural changes in the rodent and shrew communities. The changes include invasion of human commensals, loss of endemics, and changes in species richness and

abundance (Kumar *et al.* 2001). In the Western Ghats many of these habitats are currently being degraded, and since *P. lasiurus* does not seem to adapt to other habitats, the future of the species will depend on the survival of its habitat.

The dry thorn forest had low canopy and tree presence but high grass cover. *Mus platythrix* and *Tatera indica* were the main species present in this habitat. Thus, while some small mammal species were unique to a given habitat, others were found in more than one habitat type. Although the deciduous habitat supported more diversity and higher abundances, all habitats were found to be equally important for supporting small mammal populations.

In conclusion, small mammal distribution is very distinct with respect to habitat type in the forests of Mudumalai Wildlife Sanctuary. Longer term studies dealing with food habits, behaviour, seasonal variation, and activity patterns need to be undertaken to better understand the structure and functioning of these small mammals communities. The factors that determine such distinct species composition with respect to habitat pose questions that are worth examining in detail.

Acknowledgements

We thank the Tamilnadu Forest Department for research permissions to work in Mudumalai Wildlife Sanctuary, Dr. N. V. Joshi for his suggestions in data analysis, Dr. Renee Borges for giving comments on the manuscript, and R. Saandeep for help with the figures. Further, we would like to acknowledge our field assistants: Annadurai, Bomma, Keta, Krishna, Mayavan, and Mohan. The Centre for Ecological Sciences provided a visiting position to M. V. during this study.

REFERENCES

ADLER G. H. 1996. — Habitat relations of two endemic species of highland forest rodent communities in Taiwan. *Zoological Studies* 35: 105-110.

AUGUST P. V. 1983. — The role of habitat complexity and heterogeneity in structuring tropical mammal communities. *Ecology* 64: 1495-1507.

CANOVA L. & FASOLA M. 1991. — Communities of small mammals in six biotopes of northern Italy. *Acta Theriologica* 36: 73-86.

CHANDRASEKAR-RAO A. & SUNQUIST M. E. 1996. — Ecology of small mammals in tropical forest habitats of southern India. *Journal of Tropical Ecology* 12: 561-571.

DUESER R. D. & PORTER J. H. 1986. — Habitat use by insular small mammals – relative effects of competition and habitat structure. *Ecology* 67: 195-201.

DUESER R. D. & SHUGART H. H. 1978. — The microhabitats in a forest-floor small mammal fauna. *Ecology* 59: 89-98.

HAYWARD G. F. & PHILLIPSON J. 1979. — Community structure and functional role of small mammals in ecosystems, *in* STODDART D. M. (ed.), *Ecology of Small Mammals*. Chapman and Hall, London: 135-212.

HEMELRIJK C. 1990. — Models of, and tests for reciprocity, unidirectionality and other social interaction patterns at a group level. *Animal Behaviour* 39: 1013-1029.

KAUFMAN L. & ROUSSEEUW P. J. 1990. — *Finding Groups in Data: an Introduction to Cluster Analysis*. Wiley, New York.

KREBS C. J. 1966. — Demographic changes in fluctuating populations of *Microtus californicus*. *Ecological Monographs* 36: 239-273.

KUMAR A., CHELLAM R., CHOUDHURY B. C., MUDAPPA D., VASUDEVAN K., ISHWAR N. M. & NOON B. 2001. — *Impact of Rainforest Fragmentation on Small Mammals and Herpetofauna in the Western Ghats, South India: a Summary of Research Findings*. Wildlife Institute of India, Dehradun.

LEHMANN T. & PEREVOLOTSKY A. 1992. — Small mammals in coniferous plantations and native environment in southern Mt. Carmel, Israel. *Mammalia* 56: 575-585.

LEVINS R. 1968. — *Evolution in Changing Environments: some Theoretical Explorations*. Princeton University Press, Princeton.

MACARTHUR R. H., MACARTHUR J. W. & PREER J. 1962. — On bird species diversity. II. Prediction of bird census from habitat measurement. *American Naturalist* 96: 167-174.

MAGURRAN A. E. 1988. — *Ecological Diversity and its Measurement*. Cambridge University Press, Cambridge, UK.

MUDAPPA D., KUMAR A. & CHELLAM R. 2001. — Abundance and habitat selection of the Malabar spiny dormouse in the rainforests of the southern Western Ghats, India. *Current Science* 80: 424-427.

ROSENZWEIG M. L. & WINAKUR J. 1969. — Population ecology of desert rodent community: habitat and environmental complexities. *Ecology* 50: 558-572.

SHANKER K. & SUKUMAR R. 1998. — Community structure and demography of small mammal populations in insular montane forests in southern India. *Oecologia* 116: 243-251.

SHANKER K. 2001. — The role of competition and habitat in structuring small mammal communities in a tropical montane ecosystem in southern India. *Journal of Zoology* London 252: 1-9.

SURESH H. S., DATTARAJA H. S. & SUKUMAR R. 1996. — Tree flora of Mudumalai Sanctuary, Tamilnadu, Southern India. *Indian Forester* 122 (6): 507-519.

SIEGEL S. & CASTELLAN N. J. JR. 1988. — *Nonparametric Statistics for the Behavioural Sciences.* McGraw-Hill Book Company, New York.

WU D. L., LUO J. & FOX B. J. 1996. — A comparison of ground dwelling small mammal communities in primary and secondary tropical rainforests in China. *Journal of Tropical Ecology* 12: 215-220.

Submitted on 15 November 2003;
accepted on 17 February 2005