



Non-volant small mammals of the Western Ghats of Coorg District, southern India

Sanjay Molur¹ & Mewa Singh²

¹ Zoo Outreach Organisation, 9A Lal Bahadur Colony, Peelamedu, Coimbatore, Tamil Nadu 641004, India

² Department of Psychology, University of Mysore, Manasagangotri, Mysuru, Karnataka, India

Email: ¹ herpinvert@gmail.com; ² msingh@psychology.uni-mysore.ac.in

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Author Details: Sanjay Molur is the Executive Director of ZOO Trust and is involved in various conservation activities such as assessments, legislation, policies at the national and international levels. Mewa Singh is Professor of Psychology and is involved in research on primates and behaviours. He has several international publications on mammalian taxa.

Author Contribution: SM designed and conducted the field work as part of his PhD and wrote the paper. MS helped with the design and writing the paper.

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Abstract: A study to understand diversity and changes in non-volant small mammal composition in the Western Ghats of Coorg District, Karnataka was conducted from April 2004 to April 2008. A total of 11060 trap nights of sampling in various habitats such as forest fragments, coffee and cardamom plantations, open areas including grasslands, agricultural fields including paddy and ginger cultivations, bamboo and in and around human habitations across the two vegetation zones of the district. Totally, 14 species of non-volant small mammals were trapped as 412 unique individuals contributing to an overall trap success of 3.8%. *Rattus wroughtoni* was the most commonly caught taxon followed by *Suncus murinus* and *S. niger* although *S. murinus* was trapped in 10 habitats followed by *Mus musculus* in 9 of 11 habitats. The abundance of small mammals was the highest in bamboo (12.1%) and in forest fragments (7.2%); the plantations supported very low abundances (< 3.1%). Endemic mammals such as *Rattus satarae*, *Vandeleuria nilagirica*, *Platacanthomys lasiurus*, *Funambulus tristriatus* and *Suncus niger* were recorded in Coorg although *P. lasiurus* and *V. nilagirica* were trapped in only one habitat each. Changes in land use and rapid decline in quality of habitat is pushing the endemics into local extinctions while non-endemic commensals are displacing restricted endemics in disturbed habitats. This study underlines the need for more in-depth rapid assessments in the Western Ghats for the poorly understood small mammals and the initiation of conservation programmes for endemics.

Keywords: Diversity, Eulipotyphla, Muridae, Platacanthomyidae, Rodentia, Scuridae, Soricidae, Western Ghats.

INTRODUCTION

Volant and non-volant small mammals constitute almost 75% (73%) of the world's mammalian diversity with just the non-volant small mammals contributing a little over 50% (52.5%) (Amori & Gippoliti 2000; Wilson & Reeder 2005). The composition is very similar in South Asia (Molur et al. 2002; Molur et al. 2005) and in the Western Ghats (Nameer et al. 2001). Their composition is usually not reflected in biodiversity inventories due to the lack of specific methods required to understand their diversity. Most instances of documentation are sporadic and opportunistic. Shanker (2003) provides a comprehensive overview of the studies on non-volant small mammals in India by various researchers.

The earliest inventory of small mammals in India was by the Bombay Natural History Society's Mammal Survey of India project, which included all groups, in the early 20th century. The Mammal Survey of India was a pioneering effort in documenting the mammalian fauna of the Indian Subcontinent including India, Bhutan, Myanmar and Sri Lanka. A total of 30 locations were surveyed throughout the subcontinent and as many reports were published. Ryley (1913) published the Coorg report (No. 11) based predominantly on the collections and field notes by G.C. Shortridge, who worked extensively for two months, December-January of 1912-13 in the small district of Western Ghats.

Much of Coorg's natural habitats lie restricted to the western and northern boundaries of the district, while much of the central, eastern and southern zones have been converted to plantations or agriculture. Barring Nagarhole National Park, which lies to the southeastern part of the district adjacent to Wyanad Wildlife Sanctuary of Kerala in the south, majority of Coorg's protected areas and reserve forests lie in the western and northern zones. Brahmagiri, Talakaveri and Pushpagiri wildlife sanctuaries along with many reserve forests interspersed between the protected areas form an extensive length of relatively undisturbed medium elevation evergreen forests.

The Nilgiri Biosphere Reserve extends from the Nagarhole National Park in the west to the Bandipur and Mudumalai National Parks in the east across the three states of Karnataka, Kerala and Tamil Nadu. The Brahmagiri Wildlife Sanctuary in the southwestern part of Coorg District is separated from the Nilgiris by a mere 30km,



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with towns such as Kutta and Srimangala occurring in the intervening area. The division being artificial, species occur commonly in the Nilgiri Biosphere Reserve and in the adjoining parts of Coorg.

In the last decade or two, there has been an increased focus on the ecological aspects of small mammals, which is reflected by several studies in southern India. All of these studies concentrated on small mammal composition and ecology in the forested areas of the Western Ghats (Chandrashekar 1989, Chandrashekar-Rao & Sunquist 1996 in the Anamalais; Venkataraman 1997, Venkataraman et al. 2005 in Mudumalai Wildlife Sanctuary; Prabhakar 1998 in Anamalai hills; Umapathy & Kumar 2000 in Anamalai hills; Shanker 1998, 2000a, 2000b, Shanker & Sukumar 1998, 1999, Shanker 2003 in upper Nilgiris; Mudappa et al. 2001 and Kumar et al. (2002) in the Anamalais and Kalakad-Mundanthurai Tiger Reserve). Earlier to these Bhat & Sujatha (1986) documented non-volant small mammals in Kerala.

The intention of this study to document the non-volant small mammal composition of the habitats of Coorg Western Ghats was to compare the species found currently to those recorded by Shortridge 1911-12 (Ryley 1913). Although Shortridge did not document the presence of non-volant small mammals quantitatively, his notes provide a very good background to the qualitative aspects of the habitats, the species and practices of land use in general. Further, other documents regarding human populations and practices are available from gazetteers published such as those by Richter (1857) and Sathyan (1965). There has been no subsequent study of small mammals in this region of Western Ghats, but the vegetation and land use have changed considerably since the early 1900s.

This study was to also understand the impacts of macro and micro changes on small mammal composition, and to understand the feasibility of rapid assessment of small mammal community, which could be emulated in other locations of Bombay Natural History Society's mammal surveys. Since very little systematic information on small mammals is available on modified habitats in India, this work is a first step in understanding the same in a fast changing landscape of the Western Ghats. This paper contains data and analysis on species natural history, species richness and diversity.

Given the changes that have taken place in Coorg over the last 150 years, especially in human population growth and thereby increased conversion of natural forests into plantations and agricultural lands (Elouard et al. 2000), and the increasing trends in hunting that have resulted in local extinctions or declines in large mammals (Kumara 2005), our knowledge of these impacts on small mammals is lacking. In initiating this project we assumed that small mammals are under as much pressure from changes in vegetation, loss of habitat quality and intensified cultivation practices over the last century and the use of pesticides and introduction of exotic shade in the last few decades. We expected changes in community structure in modified habitats of Coorg to impact endemics negatively and introduce competition from invading widespread species. This paper deals with a portion of the overall objective to present our findings on non-volant small mammal diversity and natural history currently in Coorg.

MATERIALS AND METHODS

Study area: The district of Coorg lies in the Western Ghats of southern Karnataka ($11^{\circ}56'-12^{\circ}52'N$ & $75^{\circ}25'-76^{\circ}14'E$) covering an area of nearly 4,106km²; the lowest elevation at 850m and the highest at 1745m. The eastern parts of the district extend into the Mysore plateau at 850m, while the western part is delimited by the high elevations peaks. The geographic features also influence rainfall pattern which decreases substantially eastwards. The district is divided into four prominent vegetation zones — wet evergreen forests (rainfall of 2000-5000+mm/yr), moist deciduous forests (rainfall of 1500-2000mm/yr), dry deciduous forests (rainfall of 800-1500mm/yr), and dry woodlands (rainfall of 800mm/yr). Two other factors that determine vegetation changes within Coorg Western Ghats are duration of rainfall and temperature gradient (Pascal & Meher-Homji 1986; Elouard 2000). The study was predominantly conducted in the medium elevation evergreen forests and in moist deciduous forests.

The forested areas of Brahmagiri, Talakaveri, Pushpagiri and Nagarahole protected areas and the adjoining reserve forests constitute roughly 30% of the area of Coorg, while coffee and cardamom plantations constitute 60%, paddy cultivation and open land uses constitute 8%, and sacred groves or small- to medium-sized forest fragments make up the remaining 2% (Bhagwat et al. 2005). Areas with dense forest cover were restricted to just over 16% (658.7km²) of the total land area in 1997. Much of the moist deciduous and dry deciduous forests have been converted into plantations with roughly 2% and 1.2% remaining respectively. Only low elevation, medium elevation and high elevation wet evergreen forests still retain dense growth amounting to approximately 13% of the total area (Elouard et al. 2000).

Study sites: We surveyed for small mammals in 11 locations in Coorg District (Image 1) in two vegetation zones – medium elevation evergreen forests and the moist deciduous forests; most of the locations were in plantations or man-modified habitats. Since official permission to conduct the study in protected areas and reserved forests was not available, we conducted the study in private properties consisting of plantations, agricultural fields, open areas and forests. Although we wished to set traps in the areas Shortridge had studied in 1911-12, due to unavailability of permissions from the estate owners, we set up trapping stations in estates close to the original estates (Table 1). The study was conducted sporadically from April 2004 to April 2008 based on the availability of time and permission from the estate owners as well as avoiding monsoons. The data gathered from this study were treated together without separating seasonal, annual and habitat variances.

Taxonomy: The taxa of the genus *Rattus*, viz. *Rattus rattus wroughtoni* and *Rattus rattus rufescens* are referred to as distinct taxa *Rattus wroughtoni* and *Rattus rufescens* in the paper rather than as subspecies. This is to eliminate confusion in reference to the two taxa with overlapping distribution in contradiction to the principles of subspecies delineation. Similarly, in light of lack of detailed taxonomic work on the endemic *Suncus* of the Western Ghats, the original description of *Suncus niger* is recognized and the synonymy of this taxon under *Suncus montanus*, a highland shrew of Sri Lanka, is ignored (Molur 2009). In all the other cases the taxonomy is after Carleton & Musser (2005) for rodents and Hutterer (2005) for insectivores.

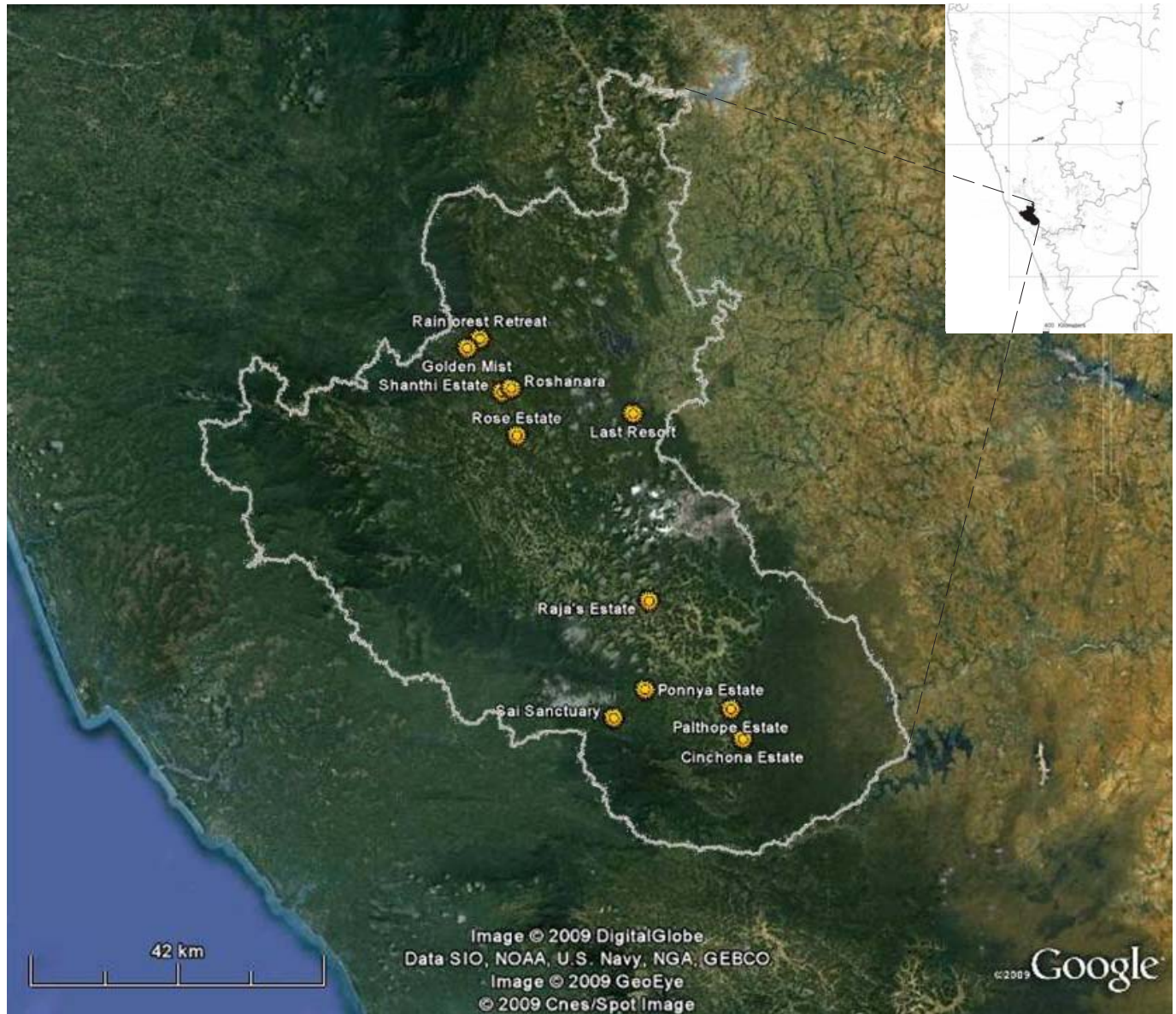


Image 1. Non-volant small mammal trapping sites in Coorg Western Ghats, Karnataka

Table 1. Study area of non-volant small mammals in Coorg

Area	Location	Coordinates	Altitude (m)	Vegetation (forest) type (Pascal & Meher-Homji 1968)
Madikeri	Shanthi Estate	12°24'28.1"N, 75°44'24.2"E	935	Medium elevation evergreen
Madikeri	Roshanara	12°24'47.06"N, 75°45'05.36"E	1000	Medium elevation evergreen
Kallur	Rainforest Retreat	12°28'32.1"N, 75°42'38.7"E	1060	Medium elevation evergreen
Galibeedu	Golden Mist	12°27'53.6"N, 75°41'41.3"E	1110	Medium elevation evergreen
Theralu	SAI Sanctuary	11°59'49.7"N, 75°53'08.8"E	815	Medium elevation evergreen
Kushalnagara	Last Resort	12°22'54.8"N, 75°54'31.2"E	650	Moist deciduous
Birunani	Ponnya Estate	12°01'53"N, 75°56'06"E	800	Medium elevation evergreen
Hakkathur	Rose Estate	12°21'17.8"N, 75°45'28.6"E	950	Medium elevation evergreen
Ponnampet	Raja's Estate	12°08'38.5"N, 75°55'52.3"E	830	Moist deciduous
Kutta	Palthope Estate	12°0'25.6N, 76°02'15.7"E	915	Moist deciduous
Kutta	Cinchona Estate	11°58'07.9"N, 76°03'13"E	905	Moist deciduous

Trapping methods: Small mammals can be trapped using different methods such as snap traps (Prakash et al. 1995), pitfall traps (Canova & Fasola 1991), multi traps (Laurance 1994), and Sherman traps (Chandrashekhar-Rao & Sunquist 1996; Shanker 1998; Prabhakar 1998; Kumar et al. 2002; Venkatraman et al. 2005). For the needs of this study, we decided not to use snap traps as it is a violent method and not useful for mark-recapture techniques; the wire mesh multi traps are too cumbersome and difficult to transport; and pitfall traps are labour intensive and time consuming. We chose to use the more practical and widely used Sherman traps of 22 x 9 x 7 cm for its ease to carry in the field, ease of placement and handling trapped animals.

Rodents and insectivores were live trapped in 12 broad habitat types in 11 locations in Coorg District. Traps were placed in 0.50ha plots at a distance of 10m in habitats that were big enough to support 50 traps in a grid. In smaller habitats the grids were suitably modified in the number of traps to accommodate maximum numbers, keeping the inter-trap distance of 10m constant. The 0.50ha plots consisted of 50 Sherman traps in a rectangular grid of 10 rows x 5 columns configuration. Traps were set at 10m intervals taking into account ground and vegetation features such as runways, rocks, fallen logs, trees and buttresses.

We used a mixture of home-made peanut butter (without salt) with a variety of grains and pulses rolled into small balls and placed in the trap as bait. We checked the traps twice daily, between 0630 and 0830 hr, and 1530 and 1730 hr for trapped animals and to replenish bait, if needed. We laid the traps for five consecutive nights, usually placed in the afternoon of the first day and removed in the morning of the sixth day. In some instances when trap mortalities were noticed to occur more frequently, we reduced the trapping sessions to four or sometimes even three nights. Animals were measured, ear tagged and released in the same area.

Data analyses: Taxa richness is the number of taxa in an area. In this instance taxa richness is only of small mammals trapped. Taxa known to occur in an area through direct or indirect evidence are excluded from analysis in this paper.

The diversity of non-volant small mammals is analysed using the following indices as per Magurran (2004).

- Captures (C) is the total number of unique individuals captured on the grid.
- Recaptures (R) is the total number of individuals recaptured on a grid during one trapping session.
- Total captures (TC) is the total number of all captures on a grid during one trapping session.
- Species richness (S) is the total number of species captured.
- Individuals (N), is the total number of individuals of all species trapped in a habitat.
- Biomass (B) is the average estimate of biomass per species.
- Margalef's richness index (DMg) is estimated using the formula $DMg = S - 1 / \ln N$
- Shannon-Weiner diversity index (H') is estimated using the formula $H' = -\sum P_i \ln P_i$, where P_i is the proportion of total individuals belonging to the i th species in the sample.
- Pielou's index of evenness (J) is estimated using the formula $J = H' / \ln S$, where H' is the Shannon-Weiner diversity index and S is the species richness.
- Simpson's diversity index (D) is estimated using the formula $D = 1 / \sum (n_i / N)^2$.
- Berger-Parker index is estimated using the formula $Dominance = N_{max} / N$
- Jaccard's Index of Similarity (C_j) on presence/absence of species is estimated using the formula $C_j = a / a + b + c$, where a = the total number of species present in both samples; b = the number of species present only in sample 1; and c = the number of species present only in sample 2.
- Morisita-Horn Index of Similarity (C_{MH}) on abundance of different species in habitats is given by $C_{MH} = 2 \sum (a_i \times b_i) / (d_a + d_b) (N_a \times N_b)$, where N_a = the total number of individuals at site A; N_b = the total number of individuals at site B; a_i = the number of individuals in the i th species in A; b_i = the number of individuals in the i th species in B; and d_a (and d_b) are calculated as $d_a = \sum a_i^2 / N_a$ and $d_b = \sum b_i^2 / N_b$
- Goodness of fit (G) is estimated using the formula $G = 2 \sum Ob \times \ln(Ob/Ex)$, where Ob is the observed number of individuals and Ex is the expected number of individuals.
- Principal Component Analysis (PCA) of non-volant small mammal diversity profile against habitats.
- Correspondence Analysis (CA) depicting the dependence of presence and abundance of non-volant small mammal species on habitat types.

RESULTS

In an overall trapping effort of 11060 trap nights across all habitats and plantations in Coorg, 14 species of rodents and insectivores were trapped totaling 569 overall captures (5.7%) and 412 individuals (3.79%). *Rattus wroughtoni*, or the Common White-bellied Rat was the most common taxon trapped constituting 26.2% of individuals, a distinctly higher proportion compared to all other rodents (murids, sciurids and platanthomyid), followed by the two insectivores *Suncus murinus* or the Grey Musk Shrew (16.3% of individuals) and *Suncus niger* or the Nilgiri Highland Shrew (16.3% of individuals). Details of overall and individual percentages of all small mammals trapped in Coorg are provided in Figure 1. Other rodents that were sighted, but not trapped include the Dusky-striped Squirrel *Funambulus sublineatus* and the Indian Giant Squirrel *Ratufa indica* in undisturbed forests.

Of the 412 individuals trapped during the study 276 (67%) were rodents, and 33% insectivores. The Order Rodentia consisted of 239 (86.6%) individuals from the family Muridae, 35 (12.7%) individuals from the family Sciuridae, and two individuals (0.7%) from the family Platanthomyidae. Overall, murids represented by nine species formed 58% of the total traps, sciurid with one species formed 8.5%, and platanthomyid by one species represented 0.5%. The insectivore Order Eulipotyphla represented by three soricid species contributed to 33% of the trap catches.

Captures and recaptures: During the period, out of the 412 individuals captured, 157 individuals were recaptured during the 3- to 5-night trapping exercise in each grid. The capture rates followed classical decrease in new individuals captured on subsequent nights. The first three nights showed maximum captures, which dropped on the last two nights rather sharply. Figure 2a shows the average proportions of captures across five nights.

The number of trapping nights was evaluated against mortalities and any indication of increased mortalities in both

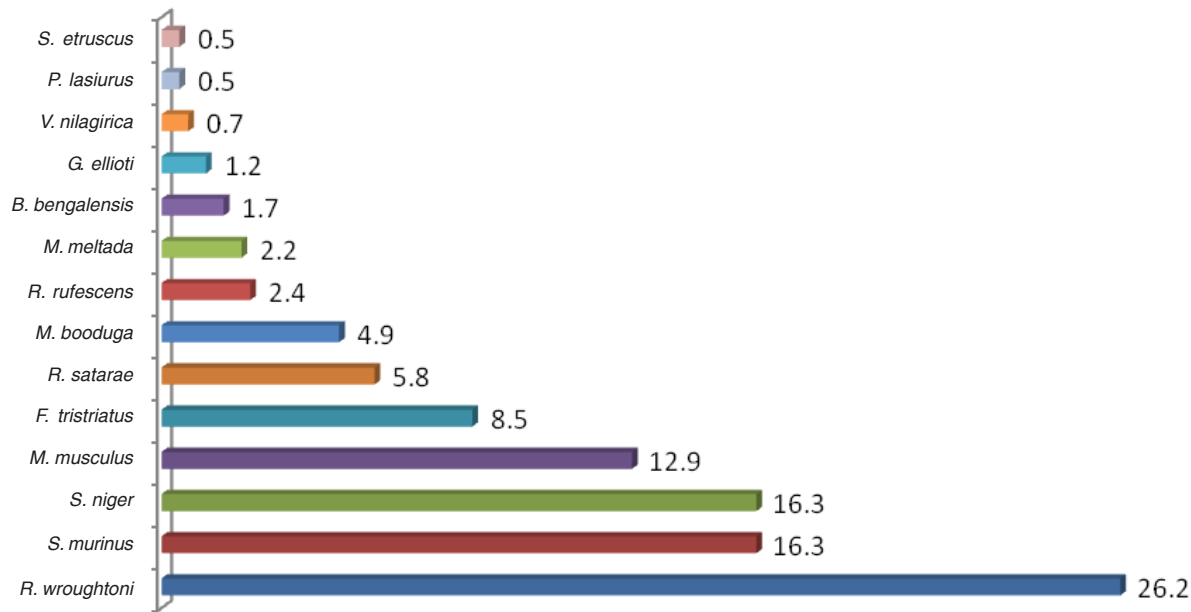


Figure 1. Proportions of individuals of small mammals trapped in Coorg

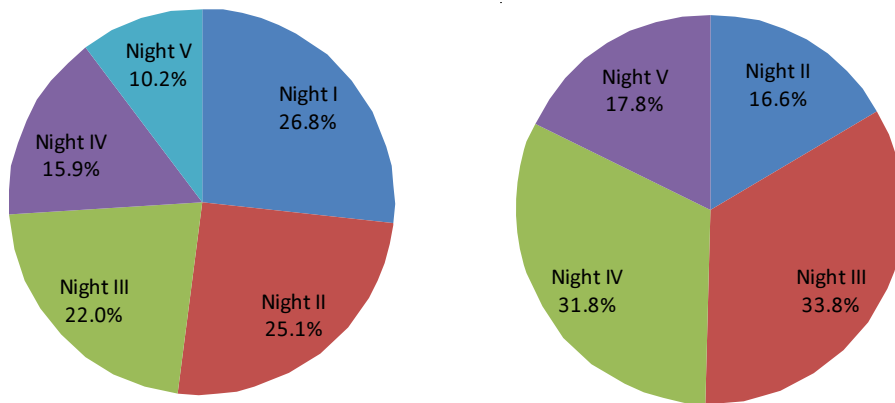


Figure 2. (a) Proportion of new individuals captured per night; (b) Proportion of recaptures

new captures and recaptures was noticed, trapping was discontinued. Factors such as weather, temperature and ants were taken into account in deciding whether to continue trapping efforts or not. Overall, the first three nights yielded up to 75% of the total captures of new individuals. Recaptures were very high on the third and fourth nights contributing to more than 65% of all individuals recaptured during the subsequent four nights (Fig. 2b).

The common Grey Musk Shrew *Suncus murinus* was the most commonly trapped species of non-volant small mammal in Coorg, trapped in 11 of 12 habitats, followed by the Common House Mouse *Mus musculus* trapped in 10 of 12 habitats. The Nilgiri Highland Shrew *Suncus niger* was captured in eight of the 12 habitats. Although *Rattus wroughtoni* was the most commonly trapped species, it was trapped in only seven of the 12 habitat types, as was the Western Ghats Striped Squirrel *Funambulus tristriatus* (Table 2). Agriculture, coffee and open areas yielded the maximum number of species (9 species each) followed by cardamom (7), bamboo (6), banana, forest and human habitation (5 each), tea (3), orange and pineapple (2 each) and vanilla (1) (Table 2). Jaccard's Index of similarity

shows clustering between habitats such as forest, habitation, coffee, cardamom, bamboo, open and agriculture, and between pineapple, vanilla, orange, tea and banana based on species richness (Fig. 3).

Trap success: The overall effort of captures during the study yielded maximum captures in open areas (26.2%), coffee plantations (25.2%) followed by forests (12.4%), agriculture (10%), cardamom (9%), bamboo (7.5%), human habitation (5.3%), banana (1.9%) and other plantations (tea, orange, pineapple and vanilla) combined (2.4%). Trap success calculated for unique individuals caught indicated bamboo to have the highest (12.1%) followed by forests (7%) and habitats with the highest individuals caught showed lower overall trap success around the average of trap success of the entire exercise (3.8%). Figure 4 indicates distinctly higher abundances in bamboo and forests.

Trap success or abundance of species varied widely in different habitats. The most commonly occurring small mammal, *Suncus murinus*, in 11 of 12 habitats with 67 individuals captured showed a high variation in captures between habitats, the average trap success being 0.77 (SD 1.12; Table 3). *Suncus*

Table 2. Small mammals trapped in different habitats in Coorg

Taxon	Agri	Bamb	Bana	Card	Coff	Fore	Habi	Open	Oran	Tea	Vani
Rodentia: Muridae											
<i>Bandicota bengalensis</i>	+	+			+		+				
<i>Golunda ellioti</i>	+							+			
<i>Millardia meltada</i>	+				+						
<i>Mus booduga</i>	+			+	+			+			
<i>Mus musculus</i>	+	+	+	+	+			+	+	+	+
<i>Rattus rufescens</i>	+				+			+			
<i>Rattus satarae</i>				+		+					
<i>Rattus wroughtoni</i>	+	+		+	+		+	+			
<i>Vandeleuria nilagirica</i>			+								
Rodentia: Sciuridae											
<i>Funambulus tristriatus</i>		+	+	+	+	+	+	+			
Rodentia: Platacanthomyidae											
<i>Platacanthomys lasiurus</i>						+					
Eulipotyphla: Soricidae											
<i>Suncus etruscus</i>							+	+			
<i>Suncus murinus</i>	+	+	+	+	+	+	+	+	+	+	
<i>Suncus niger</i>	+	+	+	+	+			+		+	

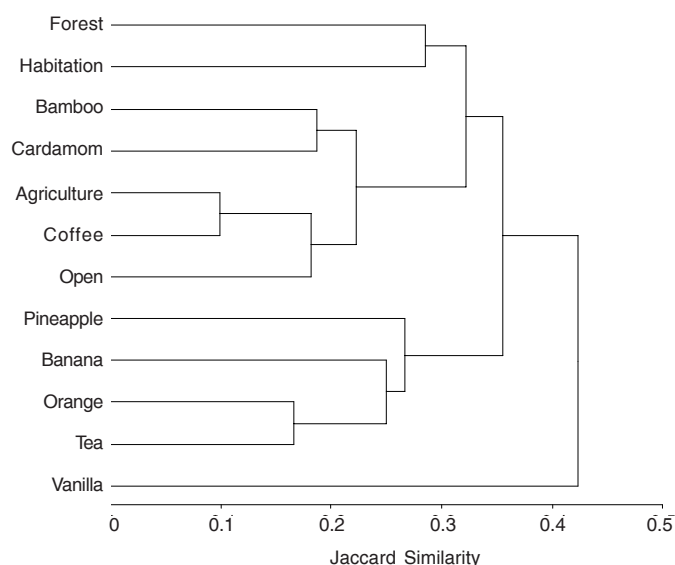


Figure 3. Single linkage clustering of species richness of non-volant small mammals across habitats using Jaccard's Index of Similarity

niger trapped in eight habitats with 67 individuals captured in all showed a higher average abundance of 0.84 (SD 0.75) and lower variation compared to *S. murinus*. The species with relatively high overall average abundance were *Rattus wroughtoni* (1.74±1.57) and *R. satarae* with (1.65±2.19); the latter being mostly trapped in forests, but the one individual trapped in the contiguous canopy of an organic cardamom plot adjacent to a forest fragment, and one degraded forest fragment supporting none increasing the variation. Among rodents the common House Mouse with the second highest captures across nine habitats showed an average abundance of 0.54 (SD 0.2). Other species with high variations in abundance between habitats were the Jungle Squirrel, Metad and the Indian Field Mouse (Table 3). *S. etruscus* abundance was not estimated as the two individuals captured were incidental.

Habitat association: In our trapping exercise, three species indicated strong habitat associations (Fig. 5) – *P. lasiurus* in forests, *V. nilagirica* in banana, although indirect evidence of this species in coffee plantations were noticed even though it was not trapped in those grids, and *R. satarae* with 96% of the

Table 3. Average trap success of non-volant small mammals in Coorg

Species	Total captures	Habitats	Average (SD)
<i>B. bengalensis</i>	7	4	0.25 (0.13)
<i>F. tristriatus</i>	35	7	0.57 (0.57)
<i>G. ellioti</i>	5	2	0.2 (0.14)
<i>M. meltada</i>	9	2	0.35 (0.35)
<i>M. booduga</i>	20	4	0.32 (0.32)
<i>M. musculus</i>	53	9	0.54 (0.2)
<i>P. lasiurus</i>	2	1	0.3 (0)
<i>R. rufescens</i>	10	3	0.13 (0.05)
<i>R. satarae</i>	24	2	1.65 (2.19)
<i>R. wroughtoni</i>	108	7	1.74 (1.57)
<i>S. etruscus</i>	2	2	*
<i>S. murinus</i>	67	11	0.77 (1.12)
<i>S. niger</i>	67	8	0.84 (0.75)
<i>V. nilagirica</i>	3	1	0.5 (0)
Total	412		3.79 (3.39)

captures in undisturbed forests and only one individual in an organic cardamom plantation with contiguous canopy with an adjacent forest fragment. *Golunda ellioti* and *M. meltada* showed strong affiliation to open habitats as is evident from their traps in ginger fields; while we trapped the former in fallow grasslands, the latter was found on occasion in an open and a year-old coffee-areca nut plantation. These species were not trapped in any other habitat. We found a relatively even distribution of trap success amongst small mammals in the open and in coffee plantation than compared to any other type of habitat (Fig. 6).

Our trapping success of small mammals in habitats distributed across two broad vegetation zones in Coorg showed a significant bias towards higher trap success in the moist deciduous forest zone than in the medium elevation evergreen forest zone (Goodness of fit $\chi^2 = 30.6$, df = 1, $p < 0.0001$; Table 4). The abundance of small mammals in the habitats of moist deciduous forest zone of Coorg (predominantly southern part of the district) was significantly higher.

In a similar exercise the goodness of fit test showed a significant difference in small mammal abundances in different habitats across Coorg ($\chi^2 = 92.88$, df = 10, $p < 0.0001$) with bamboo, forest and open habitats showing very high abundance followed by habitation, and the rest of the habitats being negatively related, with coffee and cardamom showing the

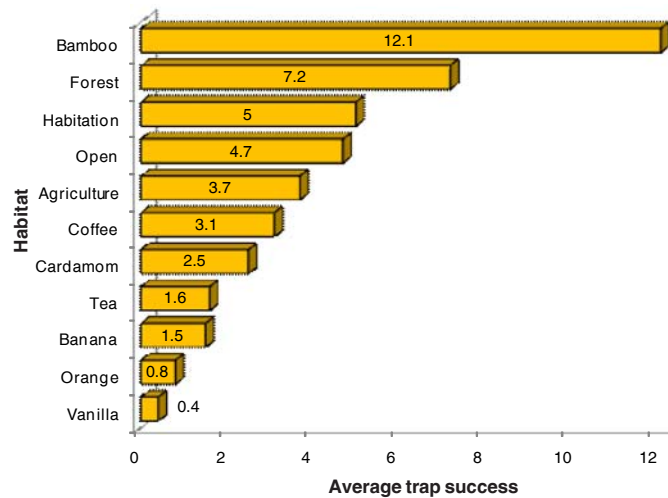


Figure 4. Average trap success of non-volant small mammals in broad habitats in Coorg

Table 4. Goodness of fit test for small mammal abundance in vegetation zones in Coorg

Vegetation zone	Area (ha)	Individuals trapped (Ob)	Expected individuals (Ex)	G
MEEF	18.99	292	338.11	-42.81
MDF	4.15	120	73.89	58.19
Total	23.14	412	412	30.76

MEEF – Medium elevation evergreen forest; MDF – Moist deciduous forest; G – Goodness of fit

Table 5. Goodness of fit test for small mammal abundance in different habitats in Coorg

Habitat	Area (ha)	Individuals trapped (Ob)	Expected individuals (Ex)	G
Agriculture	2.5	44	44.51	-0.51
Bamboo	0.55	31	9.79	35.72
Banana	1.2	8	21.37	-7.86
Cardamom	3	37	53.41	-13.58
Coffee	7	104	124.63	-18.82
Forest	1.6	51	28.49	29.70
Habitation	0.95	22	16.91	5.78
Open	4.84	108	86.17	24.38
Orange	0.5	2	8.90	-2.99
Tea	0.5	4	8.90	-3.20
Vanilla	0.5	1	8.90	-2.19
Total	23.14	412	412	92.88

Table 6. Diversity indices of non-volant small mammals in 12 habitats in Coorg

	S	N	DMg	H'	E	D	Dominance
Agriculture	9	41	2.15	2.00	0.91	0.85	0.22
Bamboo	6	31	1.46	1.45	0.81	0.72	0.35
Banana	5	8	1.92	1.49	0.93	0.75	0.37
Cardamom	7	37	1.66	1.56	0.80	0.75	0.35
Coffee	9	104	1.72	1.90	0.87	0.82	0.32
Forest	5	51	1.02	1.25	0.78	0.67	0.45
Habitation	5	22	1.29	1.03	0.64	0.50	0.68
Open	9	108	1.71	1.76	0.80	0.80	0.28
Orange	2	2	1.44	0.69	1.00	0.50	0.50
Pineapple	2	3	0.91	0.64	0.92	0.44	0.67
Tea	3	4	1.44	1.04	0.95	0.62	0.50
Vanilla	1	1	0	0	0	0	1.00

S – species richness; N – no. of individuals; DMg – Margalef Richness Index; H' – Shannon-Weiner Diversity Index; E – Pielou's Evenness Index; D – Simpson's Diversity index; Dominance – Berger-Parker Index

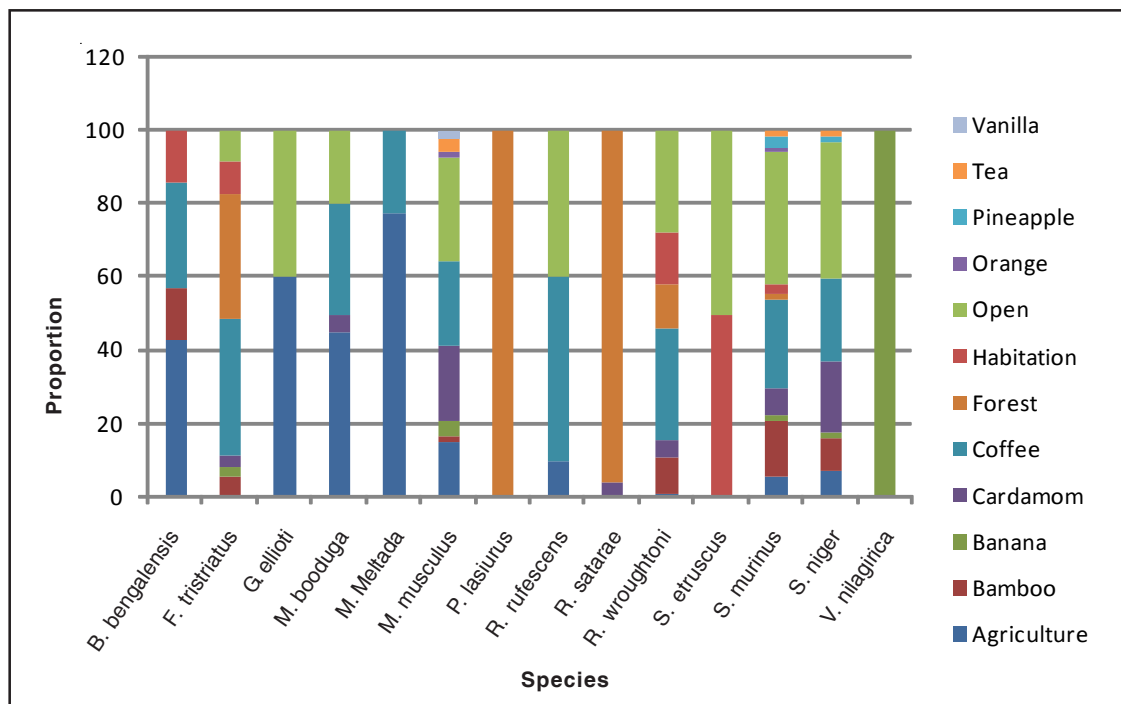


Figure 5. Affiliations to habitats by species.

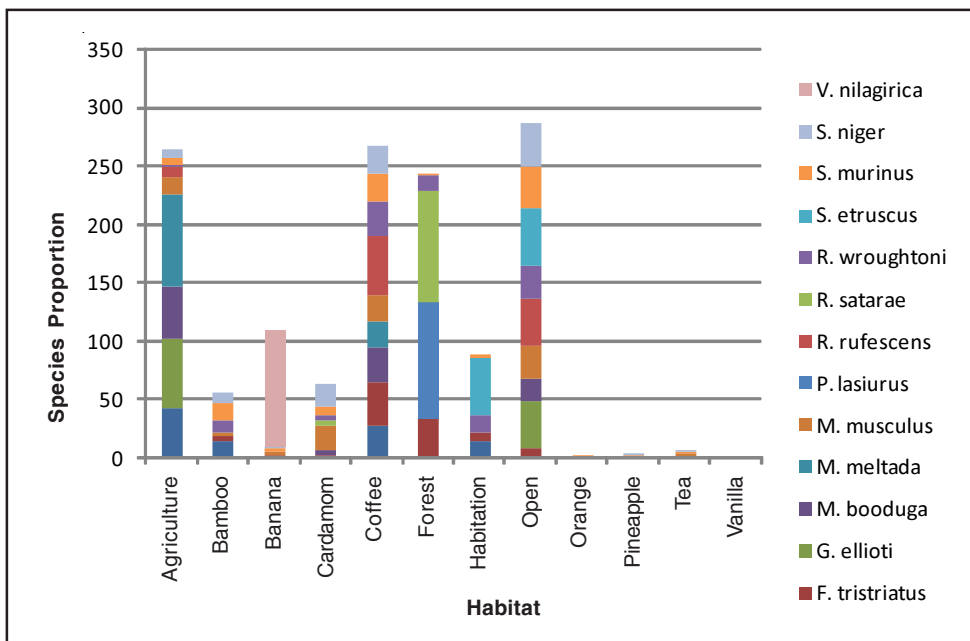


Figure 6. Habitats occupied by non-volant small mammals in proportions (stacked).

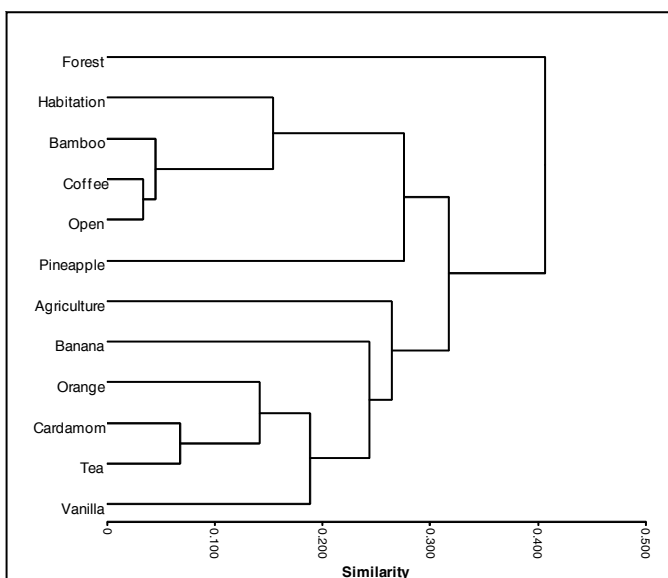


Figure 7. Single linkage clustering of abundances of non-volant small mammals across habitats using Morisita-Horn Index of Similarity

lowest abundance (Table 5). The observed abundance of small mammals in bamboos was significantly higher as compared to the expected trap success, of about three times.

Diversity: Our studies indicated variations in the indices of non-volant small mammal community structure between habitats (Table 6). Shannon-Wiener Diversity Index H' , Simpson's Diversity Index D and Margalef's Species Richness Index DMg were the highest in agriculture and the lowest in vanilla. Orange showed maximum evenness followed closely by tea, banana, pineapple and agriculture. *Rattus wroughtoni* was the most abundant and dominant species in human habitation reflected in the highest dominance calculated on Berger-Parker Index (Table 6). Similarity in species abundances across habitats calculated by the Morisita-Horn

Index revealed a tight grouping between open, coffee, bamboo, habitation and pineapple, while cardamom, tea, orange, vanilla, banana and agriculture showed greater similarities. Forest stood out separately from the two habitat clades with respect to species composition and abundance (Fig. 7).

To find out whether the Shannon diversity index is significantly different between two sites we used a modified version of t-test by Hutcheson (1970) and Magurran (1988). The p values for the t values at given df are given in the Table 7. The p values are for two tail tests. At alpha = 0.05, p values highlighted in yellow in Table 7 are significant. Since the analysis has 66 comparisons, we used the Bonferroni correction (corrected alpha = alpha/number of tests = 0.05/66 = 0.000758). Values which are significant after Bonferroni correction are indicated in Table 7 with an asterisk (p < 0.000758).

Correspondence Analysis (CA) suggested that the dependence of species abundance on habitats in Coorg is significant ($\chi^2 = 586.145$, p < 0.0001). CA extracted four significant factors with eigen values more than one. While the first factor explained 38.51% of the total variation in the data, the second explained 26.75% of the total variation (Fig. 8).

There is a good relationship between habitat types and the non-volant small mammal species trapped. *P. lasiurus* and *R. satarae* are more abundant in undisturbed forests but are absent in habitation, open and plantations. *V. nilagirica* is abundant in banana plantation. *M. meltada*, *G. ellioti*, *M. booduga* and *B. bengalensis* are more abundant in agricultural lands. *S. niger* and *S. murinus* are abundant in pineapple, cardamom plantation and open habitats. *R. wroughtoni* is mainly associated with human habitations as also in bamboo and coffee although it was trapped in lower numbers in several different habitats, *R. rufescens* in coffee and bamboo, and *M. musculus* is abundant in vanilla, tea and orange plantations; suggesting that small mammals show habitat preferences.

A principal component analysis (PCA) of the non-volant small mammal data was carried out to understand diversity

Table 7. Significant variance in Shannon-Wiener Diversity index between habitats using modified t-test by Hutcheson (1970).

	Agri	Bamb	Bana	Card	Coff	Fore	Habi	Open	Oran	Pine	Tea	Vani
Agri		0.1669	0.3766	0.2697	0.7820	0.0344	0.0213	0.4944	<.0001*	0.0014	0.0770	<.0001*
Bamb			0.9337	0.7570	0.1569	0.5291	0.2773	0.3118	0.0054	0.0285	0.4023	<.0001*
Bana				0.9011	0.4341	0.6384	0.4106	0.6003	0.1219	0.1269	0.4676	0.0128
Card					0.2846	0.3215	0.1680	0.5144	0.0015	0.0144	0.2914	<.0001*
Coff						0.0114	0.0126	0.5810	<.0001*	0.0016	0.0894	<.0001*
Fore							0.5067	0.0375	0.0020	0.0564	0.6326	<.0001*
Habi								0.0308	0.2251	0.2779	0.9871	0.0013
Open									<.0001*	0.0034	0.1358	<.0001*
Oran										0.8063	0.4110	1.0000
Pine											0.3950	0.0592
Tea												0.0538
Vani												

Highlighted cells show significant differences between H' between habitats, while those marked with asterisk show significance after Bonferroni correction.

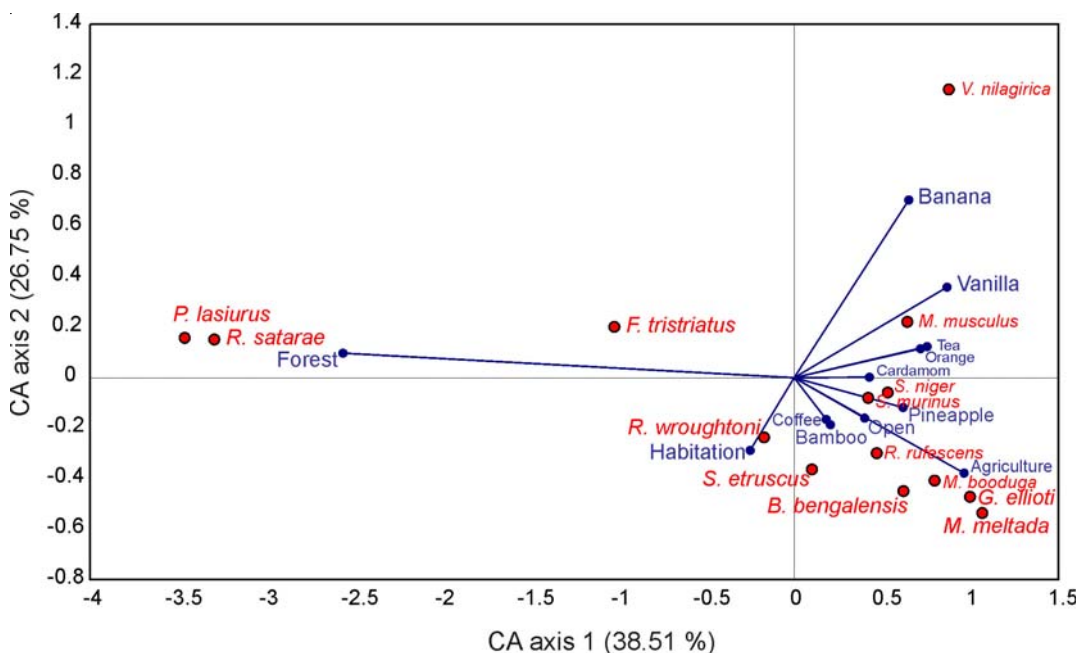


Figure 8. Correspondence Analysis of non-volant small mammals depicting the dependence of presence and abundance of species on habitat types. Numbers in parenthesis are percent variation explained by each correspondence axis. Factor loading for banana and *V. nilagirica* are divided by 10 before plotting to avoid scale problem.

profiles amongst habitats. The PCA extracted two significant factors with eigen value of more than one. The first factor explained 78.26% of the total variation in the data and the second factor explained 16.33% of the total variation. On the first factor Simpson’s diversity index showed maximum factor loading followed by Shannon index and Margalef’s richness index. Berger-Parker index had high magnitude on the negative axis of first factor. Number of individuals had maximum factor loading on the second factor followed by number of species. Evenness index had maximum magnitude on the negative axis of second factor (Fig. 9).

Habitats such as vanilla, pineapple, tea, orange and habitation exhibit low diversity and organisms with higher Berger-Parker dominance index, i.e. few taxa with high abundance. The habitats also show higher evenness despite a few taxa dominating, due to very few individuals and species present in them. Agriculture and banana have higher evenness index. Open and coffee habitats have higher individuals, greater species richness and relatively less evenness. Forest

has high number of individuals and species, however, it also exhibits lower diversity due to less evenness as some species are more abundant than others.

We trapped eleven species of rodents and three species of shrews in all during the study. We report new distribution records for the forest rat *Rattus satarae* in Coorg, earlier known only from the type locality of Satara and the Nilgiris (Hinton 1918; Verneau et al. 1997; Musser & Carleton 2005). Similarly, we report range extension for *Vandeleuria nilagirica* in central and northern Coorg; the earlier records were from the Nilgiris and Kutta in southern Coorg (Corbet & Hill 1992).

Species account:

Funambulus tristriatus (Waterhouse, 1837) [Western Ghats Striped Squirrel, Jungle Palm Squirrel] (Image 2).

We found this species to be quite shy in the northern wet evergreen forests than in the southern moist deciduous forests of Coorg. The squirrels were also more visible in the southern plantations and were either shier or less abundant as one went

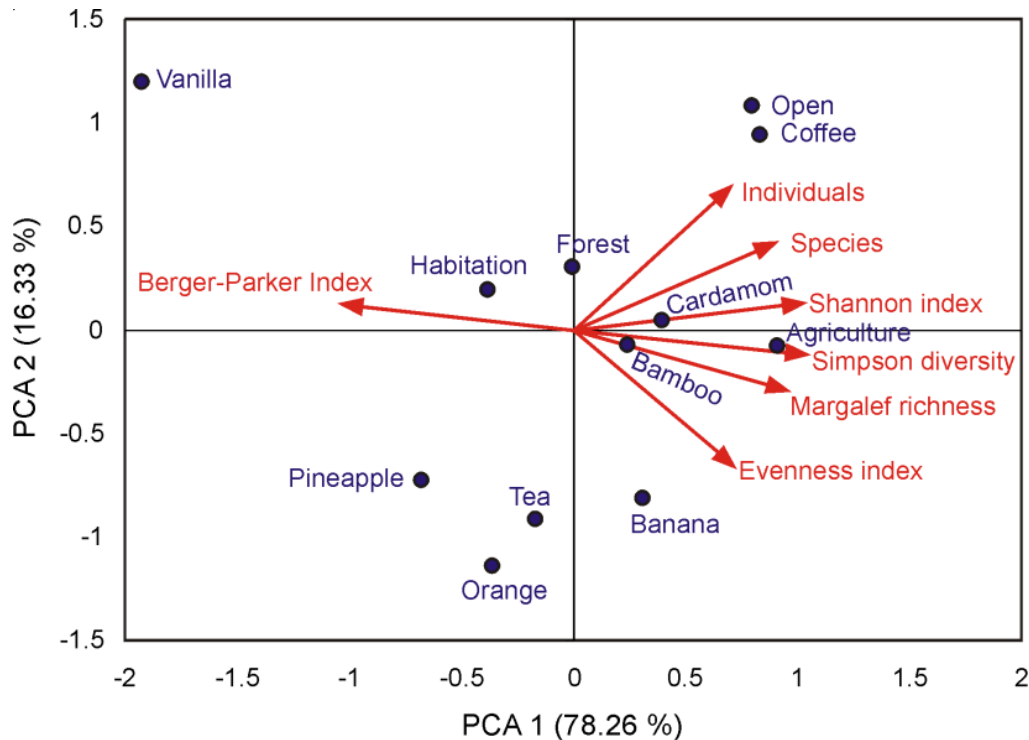


Figure 9. Principal Component Analysis of non-volant small mammal data depicting diversity profiles among habitats. Numbers in parenthesis are percent variation explained by each principal component.

north. Although we did not set traps specifically for this squirrel, they seemed more willing to be trapped in southern Coorg. We also found the specimens from the south to be harder than those in the north; their reaction to being trapped and being handled distinctly different and more tolerant in the southern parts. The 35 individuals contributed to 8.5% of the total, and 12.7% of all rodents trapped during the study. The species does not like being trapped as is evident from the very low percent (5.7%) of recaptures. During the summer of 2007 we observed several specimens in an area suffering from a disease, which seemed to have had spread through much of the population (>90% of individuals affected).

Bandicota bengalensis (Gray, 1835) [Lesser Bandicoot Rat, Indian Mole Rat] (Image 3)

We trapped this species in an organic paddy field close to the Brahmagiri Wildlife Sanctuary, southern Coorg, and in a newly converted (9-10 year old) forest patch to coffee-arecanut plantation 3km south of Madikeri town in northern Coorg. In both the cases the traps were about 50m from the nearest forest fragment. Indications of the existence of species in other places were meager, with no serious complaints from planters or workers about their destructive role to plantations. This species contributed to 1.7% of the total captures, 2.5% of rodents, and 2.9% of murids captured during the study. Only one of the seven individuals was recaptured.

Golunda ellioti Gray, 1837 [Indian Bush Rat] (Image 4)

We trapped this species from one location in northern Coorg and one in the plains of eastern Coorg; the former in the fallow grasslands of a discontinued paddy field in a freshly converted ginger field at about 1000m, and the latter in a ginger



Image 2. *Funambulus tristriatus* (Waterhouse, 1837)

plantation (850m) on the banks of river Cauvery. The species was never captured in plantations or forests. Surveys amongst plantation owners and labourers indicated no berry predation by rodents, and complete ignorance to the presence of this species, probably an indication of its non-destructive role at least in coffee plantations. Although very common in peninsular India, we did not find this species to be common in Coorg basing on trap success and informal surveys with locals and agricultural labourers. *G. ellioti* contributed to only 1.2% of all the captures, 1.8% of rodents, and 2.1% of all murids captured during the study. There were no recaptures.

Millardia meltada Gray, 1837 [Soft-furred Field Rat, Metad]

(Image 5)

We recorded this metad in only one location at about 850m, in a ginger field on the banks of river Cauvery at Kushalnagar. It was distinctly absent from all other locations including forests, plantations, fallow grasslands, and agricultural patches of the hilly Coorg terrain. The species formed a very small proportion (2.2%) of the small mammals, 3.2% of rodents and 3.8% of all murids trapped in Coorg. The Metad showed the highest rate of recapture (89%) with 75% of the animals recaptured more than once. In an interesting episode, one individual that was captured on the first trap night had been ear tagged and kept in captivity for observation. On the fifth day of the session, while we were photographing the animal, the metad escaped. The next morning on checking the traps of the fifth night, the individual was trapped in the exact same trap as in the first instance on night one. The animal had escaped nearly 1km away from the trapping grid, but had returned to the grid within 12 hours (he escaped around 18.30hr) crossing coffee and bamboo plantations, a elephant trench and a pond.

Mus booduga Gray, 1837 [Little Indian Field Mouse, Indian Pygmy Field Mouse] (Image 6)

In our study, it was a common grassland species trapped in four habitats, especially close to water bodies, but not as frequently as *M. musculus*. It occurred usually along with *Mus musculus*, a species with which it is easy to confuse with. The adults of this species are small compared to *M. musculus*, but unless several individuals are handled and measured, it is difficult to distinguish the two. *M. booduga* is more docile compared to *M. musculus*, and is very sensitive to handling compared to *M. musculus*. The species constituted nearly 5% of the total small mammals trapped, 7.2% of all the rodents (n=277), and 27.4% of the *Mus* spp. (n=73) trapped during the study. Only one of the 20 individuals trapped was recaptured. In two instances two individuals were trapped together in a Sherman trap; in both the cases we found an adult male-female pair.

Mus musculus Linnaeus, 1758 [House Mouse] (Image 7)

This was trapped more often than *Mus booduga*. Although confusing, in the juvenile age class, to distinguish the two species, adult *Mus musculus* are distinctly larger and heavier than adult *Mus booduga*. It was trapped in 10 of the 12 habitats; most surprisingly, it was not trapped in and around human habitation. 12.9% of the total captures were of *M. musculus*, 19.2% of all rodents, 22.2% of murids and 76.2% of the *Mus* spp. trapped. During the study the highest proportion were trapped in coffee plantations (22.6%) followed by cardamom and grass (20.8% each).

Rattus rufescens (Gray, 1837) [Buff-bellied Rat]

Recognised as a subspecies of *Rattus rattus*, this taxon occurs along with another subspecies *R. r. wroughtoni* in some areas, especially in coffee plantations (50% of the catches), grass and agriculture. It was not very commonly trapped compared to the other two rats. It formed 2.4% of the total captures, 3.6% of rodent captures, 4.2% of murid captures and 7% of the total rats captured during the study. Compared to *R. wroughtoni*, this taxon exhibited relative calmness in the trap, while being handled and when released. The snout is not as long as in *R. wroughtoni*, and the skull seems more robust on the exterior

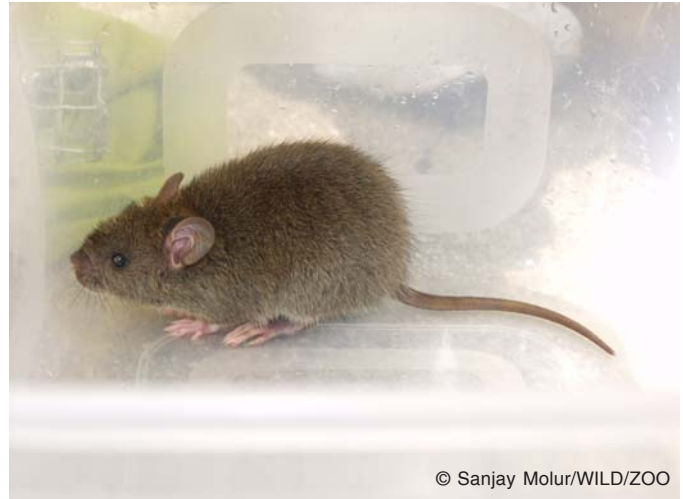


Image 3. *Bandicota bengalensis* (Gray, 1835)



Image 4. *Golunda ellioti* Gray, 1837



Image 5. *Millardia meltada* Gray, 1837

compared to the former. Morphometric data revealed a distinct difference from the other two rats, indicating the need for recognising this rodent as a species rather than a subspecies within the *Rattus rattus* complex. From our study it is clear that this taxon is still extremely rare compared to the other two white-bellied rat taxa and not confirming to Shortridge's prediction, it has not replaced the white-bellied rats anywhere in our study sites in Coorg.

Rattus wroughtoni (Hinton, 1919) [White-bellied Rat, Common House Rat, Black Rat]

This species was the most commonly caught taxon during the trapping effort; it contributed to 26.2% of the total. A rather skittish rat compared to the other two, when handled it 'yelps' in a high squeak, hops excitedly in the bag and is rarely still. The underside is grey or white unlike *R. rufescens*, which is buff coloured, the morphological characteristics of this taxon separates from the other two rats. Although there are slight overlaps in the range of its morphometrics with the other two rats, the head-body to tail ratio in this taxon falls in between the ratios of the other two taxa (*rufescens* < *wroughtoni* < *satarae*), so are the head-body and tail lengths (again, *rufescens* < *wroughtoni* < *satarae*) (Molur et al. in prep.). Caught in eight habitats, the highest trap rate was in coffee followed by grass. It constituted 39.1% of rodents, 45.2% of murids, and 76.1% of the three rats trapped in Coorg.

Rattus satarae (Hinton, 1918) [Western Ghats Forest Canopy Rat, Sahyadri Forest Rat] (Image 8)

In our study, this highly restricted species was found mainly in habitats such as undisturbed forest fragments and in one instance in an undisturbed, organic cardamom plantation with native vegetation, closed canopy and next to an undisturbed forest patch. Mainly caught in traps set on vines and tree trunks, this species was very docile, almost wanting to be handled, very curious and unafraid, although shy. All of the trapped individuals, without exception, stayed calm within the trap even when the trap walls were collapsed, and cooperated during handling and measurements. When released, the animals examined the surroundings patiently, as did they examine us and reluctantly scampered away towards the nearest tree or vine and climbed up. In all cases where the animal was released close to the forest it was trapped from, the released animal assessed the surroundings and moved in the direction of the forest fragment. 96% of the species were caught in forests; it contributed to 5.8% of the total traps, 8.7% of rodents, 10% of murids, and 16.9% of all rats.

Vandeleuria nilagirica Jerdon, 1867 [Nilgiri Pencil-tailed Tree Mouse] (Image 9)

The specimens of *Vandeleuria nilagirica* we caught in the banana plantation had longer tails and grayish-white underparts and differed from specimens we had examined from Alibagh in Maharashtra and Anaikatty in Coimbatore (both *V. oleracea* and in the Western Ghats). We also observed their nests in a coffee estate in northern Coorg (Halari Estate, Halari, 1000m), in only one small part of the area. The nests had been constructed that season, used during the previous breeding and development stage between October and March, and abandoned. This assessment was also supported by an old plantation worker with a keen interest in natural history, who



Image 6. *Mus booduga* Gray, 1837



Image 7. *Mus musculus* Linnaeus, 1758



Image 8. *Rattus satarae* (Hinton, 1918)

has been observing their behaviours for over 50 years. We counted 20 nests and estimating an adult pair in each nest with two or three young, the number of individuals in that patch was estimated at between 80 and 100. On another occasion we noticed the presence of this species in a coffee plantation at about 950m and based on the characteristic mint-smelling droppings in and around the traps (see Molur et al. in prep.), we deduced that the species had managed to steal the bait by using its long prehensile tail for hanging from a branch overhead or from the trap roof to enter and eat the bait, and leaving its scat as evidence. The species contributed to a very meager proportion of the entire trapping exercise of just 0.7%, 1.1% of all rodents, and 1.3% of all murids.

Platacanthomys lasiurus Blyth, 1859 [Spiny Tree Mouse, Malabar Spiny Tree Mouse] (Image 10)

This unique species, a spiny tree mouse, was trapped only on two occasions in a private undisturbed riverine forest adjacent to the Brahmagiri Wildlife Sanctuary at about 850m. Of the six forest fragments we surveyed in Coorg, the species was present in only this patch, showing a preference to forest contiguity and nondisturbance. Of the two individuals caught, one was recaptured on the third and fourth nights. The proportion of catches were 0.5% of the total, and 0.7% of all rodents. This species is considered a pest of pepper based on very limited observations (Jason 2006), but in all our surveys of pepper growers in Coorg, not one estate owner or labourer complained about pepper crop damage from any rodent; and that they had never seen a rodent like *P. lasiurus* in their estates or anywhere else. The only damage to pepper in Coorg was due to fungal attacks.

Suncus etruscus (Savi, 1822) [Pygmy Shrew, Etruscan Shrew] (Image 11)

A rather cryptic species, we found it once in open and around human habitation habitats each as incidental catch. We initially confused the individuals, a male and a female, for baby *Suncus* sp., but on further examination realized they were adults of *S. etruscus*. The female weighed a mere 1.5g, while the male was about 2g.

Suncus murinus Linnaeus, 1758 [Grey Musk Shrew, Asian House Shrew] (Image 12)

The commonest of shrews in India, the taxon found in Coorg closely resembles *S. murinus*, but has to be genetically examined for its affinities. The species is much smaller than the northern Indian *S. murinus*, but is distinctly different from the conspecific *S. niger*. *S. murinus* is grayish overall, with whitish patches under the neck and distinct pink muzzle, hands, feet, tail and ears. The animal exhibited behavioural differences from *S. niger* in being very restless and squeaking when handled, and producing the characteristic musk odour. The most widely adapted species; we trapped this species in 11 of the 12 habitats in Coorg, with the highest proportion of traps in grass followed by coffee plantations. It constituted 16.3% of the total non-volant small mammals, and 49.3% of all shrews trapped.

Suncus niger Horsfield, 1851 [Nilgiri Highland Shrew] (Image 13)

This taxon is distinct in morphological and behavioural characters compared to *S. murinus* and we trapped it in eight of



Image 9. *Vandeleuria nilagirica* Jerdon, 1867



Image 10. *Platacanthomys lasiurus* Blyth, 1859



Image 11. *Suncus etruscus* (Savi, 1822)

the habitats in Coorg along with *S. murinus*. Similar to *S. murinus*, *S. niger* constituted 16.3% of the total non-volant small mammals, and 49.3% of all shrews trapped. Like *S. murinus*, *S. niger* was trapped most in grass followed by coffee plantations. However, unlike *S. murinus*, *S. niger* is black overall with no greyish tinge under the neck; the hands, feet, tail, ears and muzzle are black or distinctly dark. The tail is black, slender and angular with short black hairs compared to *S. murinus*'s tail which is thick, pink and has long white vibrosae. Trapped individuals of *S. niger* were more docile, cooperative during handling and measuring, non-squeaky and did not leave any

musky odour. The inguinal mammae arrangement in *S. niger* is distinctly different from those of *S. murinus* with the first two closer in *S. niger*, while all three separated equally from each other in *S. murinus*. In the males, the penis head of *S. niger* is red, while it is white in *S. murinus*.

During the study, we observed the presence of a few non-volant small mammals occurring in certain habitats, mostly prominent ones such as giant squirrels, gliding squirrel and the common Indian bandicoot. We observed the Indian Giant Squirrel *Ratufa indica* in the forests of Brahmagiri, Pushpagiri and Talakaveri wildlife sanctuaries, Nagarhole National Park and in reserve forests of northern and western Coorg. Local knowledge revealed their presence in three of the six forest fragments we surveyed, indicating a strong preference to less disturbed fragments as well as closeness to larger forest areas. Of the two gliding squirrels, we observed only the Large Brown Gliding Squirrel *Petaurista philippensis* in three locations – all three forest patches. There were occasional reports of these squirrels by estate owners who reported that their frequency had declined drastically in plantations over the years. We did not observe the endemic smaller Travancore Gliding Squirrel *Petinomys fuscocapillus* nor did we gather any evidence of their existence from the locals, who very distinctly remember the gliding squirrels to be fairly big in size leading us to assume they were *P. philippensis* and not *P. fuscocapillus*. During the four years of our survey we did not observe a single Greater Bandicoot Rat *Bandicota indica* in any location throughout Coorg. However, we did come across several burrows in different locations, mainly in and around human habitations, cow sheds, granaries, coffee drying yards and kitchen gardens in estates close to townships. Estate owners also complained of the ‘nuisance value’ of these bandicoots to their vegetable patches. We did not observe burrows of this species in any forested area, fragments or in plantations. Although species such as the Dusky-striped Squirrel *Funambulus sublineatus*, White-tailed Wood Rat *Madromys blanfordi*, Brown Spiny Mice *Mus platythrix* and *M. saxicola*, and *Petinomys fuscocapillus* have been reported in Coorg or adjacent areas such as Wynaad before (Ryley 1913; Nandini Rajamani pers. comm., P.O. Nameer pers. comm.), we did not trap or observe these species throughout the four years of study in Coorg. We did not observe or trap in Coorg endemic species that occur in the neighbouring Nilgiri Biosphere Reserve such as Bonhote’s Mouse *Mus famulus* and Day’s Shrew *Suncus dayi*. Surprisingly, our efforts of 11060 trap nights did not yield a single specimen of the widely distributed and commonly occurring Indian Gerbil *Tatera indica*.

DISCUSSION

India has around 110 species of rodents and shrews and about 30 species in the Western Ghats (Molur et al. 2005), but when the different studies on non-volant small mammals over the last two decades are analysed, only a few species have been recorded in each study, viz., five in Anamalais (Chandrasekar-Rao & Sunquist 1996), seven in Mudumalai Wildlife Sanctuary (Venkatraman et al. 2005), six in Kalakad-Mundanthurai Wildlife Sanctuary (Mudappa et al. 2001; Kumar et al. 2002), five in the Anamalais (Mudappa et al. 2001; Kumar et al. 2002), eight in the Anamalais (Prabhakar 1998), eleven in the Nilgiris (Shanker 2003). Our study revealed 11 species of rodents and



Image 12. *Suncus murinus* Linnaeus, 1758



Image 13. *Suncus niger* Horsfield, 1851

three species of shrews in various habitats of Coorg. Species composition in Coorg differed from the earlier studies in that three species recorded in some areas, *Tatera indica*, *Madromys blanfordi* and *Mus platythrix* were not trapped during our studies anywhere in Coorg. Species richness in different habitats of Coorg is much higher than those of other studies until now.

Funambulus tristriatus (Waterhouse, 1837) [Western Ghats Striped Squirrel, Jungle Palm Squirrel] (Image 2).

This is an endemic Western Ghats species distinct from the plains *Funambulus palmarum* in being bigger and darker in colour. A rather shy creature, this species was trapped more often in the southern parts of the district (moist deciduous forests) than in wet evergreen forests of the northern parts. Ryley (1913) identified this species as *Funambulus wroughtoni*, however, Thorington & Hoffmann (2005) consider *F. wroughtoni* as a synonym of *Funambulus tristriatus*. Shortridge (in Ryley 1913) commented that *F. wroughtoni* were locally plentiful in Coorg and distinctly uncommon in some places. He noticed this species to be conspecific with *F. tristriatus* and *F. palmarum* in many parts of southern India, and presumed they experienced local die-offs due to epidemics such as bubonic

plague. He commented on the existence of many variations in the marking and colouration of these squirrels in Coorg.

The species' wide distribution in the Western Ghats with relatively few threats makes it a species of Least Concern (Molur et al. 2005) as per the 2009 IUCN Red List of Threatened Species (Molur & Nameer 2008a).

Bandicota bengalensis (Gray, 1835) [Lesser Bandicoot-Rat, Indian Mole Rat] (Image 3)

This species of bandicoot rat is so different looking from its congeners, Wroughton (1908) placed it under a separate genus *Gunomys*. Several workers have indicated its difference and suggest that it does not belong to the genus *Bandicota* due to morphological, genetic and chromosomal variations (Pradhan et al. 2005; Sharma & Raman, 1971, 1973). However, due to lack of any systematic study, it is still placed under the genus *Bandicota* (Musser & Carleton 2005). G.C. Shortridge in Ryley (1913) recorded the presence of *Gunomys kok* in Coorg, which at the present moment is considered a synonym under *Bandicota bengalensis* until further systematic investigations are carried out. *B. bengalensis* is widely distributed in India and also occurs in its immediate neighbouring countries of Nepal, Pakistan, Bangladesh and Sri Lanka (Molur et al. 2005). Since it has a very wide distribution in the region and not impacted by threats, it is categorized as Least Concern by Molur et al. (2005) and the 2009 IUCN Red List of Threatened Species (Aplin et al. 2008a).

This rat is distinguished from *Bandicota indica* in being smaller in size and having a smaller skull. Behaviourally, this species is calmer and relatively less aggressive compared to *B. indica*. In Coorg, we observed burrows of this species (distinctly smaller than those of *B. indica*) close to wooded areas and very rarely in agricultural areas, grasslands or fallow lands. Morphological measurements of the different populations in India indicates a wide variation in Head-body length of 130-260mm, Tail length of 99-162mm, and Hind foot length of 27-48mm (Agrawal 2000). The rat is grayish-brown to black in dorsal colouration; specimens in Coorg with slightly more reddish tinge. Ventral colouration is light to dark gray, and the tail more uniformly darkly coloured.

G.C. Shortridge in Ryley (1913) estimated this species to be plentiful in deciduous and evergreen forests and around cultivation in Coorg. He collected specimens of this species only from southern Coorg in Wotekolli, Makutta, Virajpet and Srimangala. He mentions the destructive role of this species on young rubber plants, their tubers being eaten by this rodent. Due to their subterranean habit, he says, they are difficult to exterminate.

Golunda ellioti Gray, 1837 [Indian Bush Rat] (Image 4)

This is a monotypic genus with a fairly wide distribution in India and the neighbouring countries of Nepal, Pakistan and Sri Lanka (Molur et al. 2005) and extending only a little into southeastern Iran (Musser & Carleton 2005). While Ellerman (1961) listed seven subspecies, Agrawal (2000) does not find any geographic variation in this species. It is found in varied habitats of dry deciduous, scrub and grass; ventures into cultivated lands, orchards and grasslands close to streams. It builds nests in thick bush and is found in an elevation range of 100-1300m in India (Molur et al. 2005). G.C. Shortridge (in Ryley 1913) describes it as "probably plentiful", and although

seen in coffee estates, does not inflict sufficient damage to the berries and do not appear to be sufficiently numerous. Molur et al. (2005) and the 2009 IUCN Red List of Threatened Species (Molur & Nameer 2008b) categorize this species as Least Concern due to its wide distribution and no major threats affecting its population.

G.C. Shortridge (in Ryley 1913) commented on the species being probably plentiful in coffee plantations. They moved around in lantana thickets or other undergrowth and he presumed they fed on coffee berries. He trapped four specimens from three locations in southern Coorg, namely, Wotekolli, Virajpet and Kutta.

Millardia meltada Gray, 1837 [Soft-furred Field Rat, Metad] (Image 5)

The Soft-furred Metad is quite common in its distribution in India and neighbouring countries of Sri Lanka, Pakistan and Nepal (Molur et al. 2005). Although it bears close resemblance to *Golunda ellioti*, it can be easily recognized for its characteristic softer fur, five plantar pads and lack of a groove on its incisors. Ellerman (1961) recognized subspecies, but Agrawal (2000) does not recognize subspecies as he did not find any geographic variations. It commonly occurs in grasslands, cultivated lands, irrigated lands, embankments and rocky hills; found from sea level up to 2670m in India (Molur et al. 2005). G.C. Shortridge (in Ryley 1913) trapped this species in Huvinakadu estate in southern Coorg in a thick scrub patch close to a deciduous forest (apprx. 900m) and was surprised to see it since its affinity is to treeless environs in agricultural patches in Deccan India.

While Chandrashekar-Rao & Sunquist (1996) and Prabhakar (1998) do not report trapping this species from the Indira Gandhi Wildlife Sanctuary between 1000-1700m in the Anaimalai hills, Jayson (2006) reports it being trapped only in Chimmony Wildlife Sanctuary at an altitude of 450m in Kerala. North of the Palghat gap, Shankar & Sukumar (1999) trapped *M. meltada* occasionally in the periphery of sholas in the Nilgiris between 1800-2500m.

Molur et al. (2005) and the 2009 IUCN Red List of Threatened Species (Molur & Nameer 2008c) categorize this species as Least Concern due to its wide distribution and no major threats affecting its population.

Mus booduga Gray, 1837 [Little Indian Field Mouse, Indian Pygmy Field Mouse] (Image 6)

This mouse is sometimes difficult to distinguish in the field from *Mus musculus*. It has a wide distribution in India and the neighbouring countries of Nepal, Bangladesh, Pakistan and Sri Lanka, found at elevations from sea level up to 4000m (Molur et al. 2005). Marshall (1977) recognized *Mus dunni* to be very different from *Mus booduga* due to incompatible chromosomes and differences in molar shape and body colour; but Agrawal (2000) treated both *Mus dunni* and *Mus terricolor* as synonyms under *Mus booduga*. It occurs in agricultural fields, grasslands, scrub jungles, near water bodies and occasionally in plantations (Molur et al. 2005). G.C. Shortridge (in Ryley 1913) noted that the species lives underground or under stones and observed a round grass nest with young of this species in Nagarahole.

This species is considered the smallest *Mus* in the Indian subcontinent with head-body length ranging from 50-87mm,

tail length of 51–72mm, and hind foot length of 13–17mm (Agrawal, 2000). Shortridge (in Ryley 1913) reported trapping this species in six locations. Although Chandrashekar-Rao & Sunquist (1996) and Shanker & Sukumar (1999) do not report this species in their trapping efforts, Prabhakar (1998) trapped them in seven forest fragments of Anaimalai hills.

It is categorized as Least Concern by Molur et al. (2005) and the 2009 IUCN Red List of Threatened Species (Aplin et al. 2008b) due to its wide distribution and no apparent major threats.

Mus musculus Linnaeus, 1758 [House Mouse] (Image 7)

This rodent is the commonest mouse in the world with a very wide distribution all across except in the Antarctic, thanks to its association with humans and their movements across the globe (Ellerman & Morrison-Scott 1951; Musser & Carleton 2005). Agrawal (2000) recognized three subspecies in India. G.C. Shortridge (in Ryley 1913) reported *Mus manei* in three locations in Coorg “very abundant around houses”. The taxon in Coorg is not usually found inside houses and therefore does not fall under *Mus musculus castaneus*, one of the three subspecies recognized by Agrawal (2000) as an indoor mouse occurring all over India. The other two recognized subspecies do not occur in the south. It is slightly larger than *Mus booduga*, but sometimes difficult to tell apart in the field. Geographical variation in size is very obvious in this species. As it is widespread and is not threatened with any risk of extinction, it has been categorized as Least Concern by Molur et al. (2005) in India and by Musser et al. (2008) globally in the 2009 IUCN Red List of Threatened Species.

Rattus rufescens (Gray, 1837) [Buff-bellied Rat]

This is one of the several recognized subspecies of *Rattus rattus* (Linnaeus, 1758) in India. It is distinct from the other common Indian subspecies *R. rattus wroughtoni* in having a reddish dorsal fur and buff coloured ventral fur. This is a widely distributed subspecies occurring in the western and southern parts of India and in neighbouring Pakistan (Ellerman 1947). G.C. Shortridge (in Ryley 1913) refers to individuals with both grey and white underparts as *Epimys rufescens* saying the darker bellied form is quite rare and alien and could replace the native white-bellied form by interbreeding. He may have referred to either *Rattus satarae* or *R. rattus wroughtoni* as the white-bellied forms.

Rattus wroughtoni (Hinton, 1919) [White-bellied Rat, Common House Rat, Black Rat]

This is the most common Indian rat distributed almost all over the country; at least this is the name given to all the white-bellied rats around the country by several workers. This is distinctly smaller than *Rattus satarae* with the tail being less than 115% of head-body length (Ellerman 1947). This taxon occurs in all types of habitats, rarely preferring undisturbed forests; occupies any habitat that is influenced by human action. It is likely that the taxon has replaced other native forms as and when humans have moved into wilderness areas.

Rattus rattus as a species is categorized as Least Concern in India by Molur et al. (2005) and by Amori et al. (2008) in the 2008 IUCN Red List of Threatened Species. As the taxa in this complex such as *R. rattus rufescens* and *R. rattus wroughtoni* are to be taxonomically worked out, we have for purposes of

clarity and ease used *Rattus rufescens* and *Rattus wroughtoni* as species rather than subspecies. By definition, two subspecies cannot occupy the same location, which in the case of our work in Coorg indicates this in some of the habitats.

Rattus satarae (Hinton, 1918) [Western Ghats Forest Canopy Rat, Sahyadri Forest Rat] (Image 8)

This unique canopy rat has been elevated to a full species by Musser & Carleton (2005) based on Gordon Corbet’s comments that the subspecies identified by Hinton (1918) has a karyotype $2n = 42$ as against the *Rattus rattus wroughtoni* subspecies, which has $2n = 38$. This forest rat is morphologically distinct from *Rattus rattus wroughtoni*, which is usually what this species is confused with by several researchers. The tail length to head-body ratio is much larger than that of *R.r. wroughtoni* (Musser & Carleton 2005). The species has a disjunct distribution in Satara, Coorg and the Nilgiris, mainly due to lack of any systematic collections and proper identification. It is suspected to occur in all Western Ghats forests throughout the chain ranging in elevation from 700 to 2150m. It occurs in pristine or undisturbed forest habitats, usually restricted to the canopy of tall trees and vines, occasionally coming down to the ground. It is primarily an insectivore also eating fruits during season (Molur & Nameer 2008d). Presently, this species has been categorised, based on available information, distribution, range and threats, as Vulnerable by Molur & Nameer (2008d) in the 2009 IUCN Red List of Threatened Species.

Vandeleuria nilagirica Jerdon, 1867 [Nilgiri Pencil-tailed Tree Mouse] (Image 9)

This species had been either synonymised under *Vandeleuria oleracea* (Ellerman 1961; Agrawal 2000) or kept as a separate species (Corbet & Hill 1992; Musser & Carleton 2005). It had earlier been recorded only from the Nilgiris, but Molur & Nameer (2008e) provide additional information about its distribution in Coorg Western Ghats. It occurs from 900 to 2100m, usually found in moist deciduous forests, coffee, cardamom and banana plantations in Coorg, preferring native tree canopies (Molur & Nameer 2008e). It differs from a closely resembling species *Vandeleuria oleracea* in having a darker and slightly bigger body, and longer tail. Unlike *V. oleracea*, *V. nilagirica* is rarely seen indoors. Based on restricted and fragmented distribution, and threats to its habitat, it is categorized as Endangered by Molur & Nameer (2008e) in the 2009 IUCN Red List of Threatened Species.

V. nilagirica is different from *V. oleracea* in having a longer tail and grayish-white underparts (Musser & Carleton 2005). The specimens we caught in the banana plantation matched these characters and differed from specimens we had examined from Alibagh in Maharashtra and Anaikatty in Coimbatore (both *V. oleracea* and in the Western Ghats).

Family Platacanthomyidae:

This unique family is represented by only three species worldwide and only one species in India (Musser & Carleton 2005). The species of this family were earlier considered under the dormouse family Gliridae (Ellerman 1961). However, its affiliations to Muroidea were established by several workers (see Musser & Carleton 2005).

Platacanthomys lasiurus Blyth, 1859 [Spiny Tree Mouse,

Malabar Spiny Tree Mouse] (Image 10)

Popularly known as the Malabar Spiny Dormouse, Musser & Carleton (2005) renamed it as Spiny Tree Mouse because of its affiliation to murids rather than glirids (dormice) so as to avoid perpetuating incorrect phylogeny. It is endemic to the Western Ghats in the states of Karnataka and Kerala, distributed between the elevations of 600 and 2000m. It prefers undisturbed deciduous and evergreen forests and riparian habitats. It is predominantly an arboreal species coming down to the ground on occasions. It prepares nests in tree holes (Molur et al. 2005; Jason 2006). It has been termed a pepper pest in Kerala and like the rest of the rats and mice is classified as a Vermin in the Indian Wildlife (Protection) Act of 1972. Due to restricted distribution, severe fragmentation and threats to its populations and habitat, it was categorized as Vulnerable by Molur et al. (2005) and Molur & Nameer (2008f) in the 2009 IUCN Red List of Threatened Species.

Order Eulipotyphla

This Order, until recently (Hutterer 2005), was called Soricomorpha and clubbed with other orders like Erinaceomorpha under Order Insectivora. It is now separated to include all shrews (IUCN 2009).

Family Soricidae:

The shrews in India placed under Family Soricidae are represented by 24 species of nine genera (Molur et al. 2005). Five taxa occur in southern India with one endemic to the Western Ghats. The Sri Lankan endemic, *Feroculus feroculus*, the long-clawed shrew was recently reported from the Nilgiris (Pradhan et al. 1997) in India. A systematic study is needed to determine if it is a subspecies or a new species.

Suncus etruscus (Savi, 1822) [Pygmy Shrew, Etruscan Shrew] (Image 11)

This is the smallest non-volant small mammal and occurs in Asia, Africa and Europe. Two subspecies in southern India have been tentatively recognized – *S. etruscus macrotis* and *S. etruscus nilgirica* (Hutterer 2005). G.C. Shortridge's (in Ryley 1913) collection of *Pachypus perrotteti* is synonymised under *Suncus etruscus nilgirica* (Anderson, 1877). Very few records of the shrew exist in India although it is presumed to have a wide distribution in the country and its neighbours. It occupies forested as well as rural landscapes and occurs from sea level up to 5000m (Molur et al. 2005). It is so small and light, one needs a highly sensitive Sherman trap to capture it. It is categorized as Least Concern in India (Molur et al. 2005) and globally (Aulagnier et al. 2008) in the 2008 IUCN Red List of Threatened Species.

Suncus murinus Linnaeus, 1758 [Grey Musk Shrew, Asian House Shrew] (Image 12)

This is the commonest shrew found widely distributed in India and the neighbouring countries of Pakistan, Bhutan, Bangladesh, Nepal and Sri Lanka (Molur et al. 2005). It lives in all kinds of habitats and also in human habitation. It occurs from sea level up to about 3700m altitude. There are several genetically distinct forms within this species complex (Hutterer 2005). The wide distribution of the species is primarily due to human movement and settlements (Hutterer 2005). It is a Least Concern species in India (Molur et al. 2005) and also globally

(Hutterer et al. 2008) according to the 2008 IUCN Red List of Threatened Species.

Suncus niger Horsfield, 1851 [Nilgiri Highland Shrew] (Image 13)

This shrew is endemic to the Western Ghats of India and is recognized as a subspecies of *Suncus montanus* by Hutterer (2005). *Suncus montanus* is a Sri Lankan highland shrew and the nominate subspecies is endemic to that country. *Suncus niger* closely resembles this species and for want of systematic studies, the two species have been synonymised. Based on geographical barriers, and the fact that the taxa have not bred naturally over many millennia, we consider the subspecies as a distinct species as was originally described by Horsfield in 1851. *Suncus montanus* occurs in evergreen, moist deciduous forests and grasslands between 900 and 2400m elevation. It has been assessed as Vulnerable by Molur et al. (2008) for the IUCN Red List of Threatened Species.

This taxon is distinct in morphological and behavioural characters compared to *S. murinus* and we trapped it in eight of the habitats in Coorg along with *S. murinus*. Similar to *S. murinus*, *S. niger* constituted 16.3% of the total non-volant small mammals, and 49.3% of all shrews trapped. Like *S. murinus*, *S. niger* was trapped most in grass followed by coffee plantations. However, unlike *S. murinus*, *S. niger* is black overall with no greyish tinge under the neck; the hands, feet, tail, ears and muzzle are black or distinctly dark. The tail is black, slender and angular with short black hairs compared to *S. murinus*'s tail which is thick, pink and has long white vibrosae. Trapped individuals of *S. niger* were more docile, cooperative during handling and measuring, non-squeaky and did not leave any musky odour. The inguinal mammae arrangement in *S. niger* is distinctly different from those of *S. murinus* with the first two closer in *S. niger*, while all three separated equally from each other in *S. murinus*. In the males, the penis head of *S. niger* is red, while it is white in *S. murinus*.

Rattus rattus is the most commonly prevalent rodent recorded in all the areas in the Western Ghats in previous studies. The white-bellied form, which is prevalent in the area seems to be composed to two distinct taxa, viz. *R. wroughtoni* and *R. satarae*, the latter just recently recognized as a distinct species. Apart from Shanker's (2003) comment on the white-bellied form in the Nilgiris could be of two taxa, all the studies assume the rat to be a single taxon. In our studies, the three taxa of rats, viz. *Rattus rufescens*, *R. satarae* and *R. wroughtoni*, were easily distinguishable by their morphology, morphometrics, habit and behaviours (Molur et al. in prep.). While *R. satarae* was the calmest and most cooperative of all three, it was also the only species caught on traps set on trees and on vines. On occasions this species was caught in traps on the ground, but most of the catches were of individuals captured for the second or third time. *R. rufescens* and *R. wroughtoni* were mostly caught in traps on the ground, but *R. wroughtoni* was also caught in traps on bamboos in that habitat. *R. rufescens* and *R. satarae* were never trapped in bamboo.

The non-volant small mammal trap success varied widely in our study in different habitats in Coorg. While 13 grids did not yield us a single animal, the highest trap success was 42% in one of the grids. The average trap successes across 70 grids, totaling 11060 trap nights and a total catch of 412 individuals, was 3.79%. This is one-third the trap success reported by

Shanker (1998, 2003; 10.6%) for small mammals in his work in the montane ecosystems of the Nilgiris. Venkatraman et al. (2003) reported a higher trap success in the tropical forest habitats of Mudumalai Wildlife Sanctuary in Tamil Nadu of 5.3%; Prabhakar (1998) reported an overall trap success of 5.4% in the tropical rainforests of the Anaimalai hills; Chandrashekar (1989) and Chandrashekar-Rao & Sunquist (1996) reported an average trap success of 5.6% (including recaptures; 2.5% excluding recaptures) in the habitats of Anaimalais; and Kumar et al. (2002) reported about 2.14% from the forests of Kalakkad-Mundanthurai Tiger Reserve, 3.5% from the forest fragments of Anamalais and 5.4% from the surrounding matrix in the Anamalais. In our study trap success in the forest grids was 7.2% higher than most trap successes from previous studies except in the Nilgiris by Shanker (2003); however, the average trap success in the rest of the man-modified habitats was only 3.5% in Coorg, a clear reversal of the situation reported by Kumar et al. (2002) in the Anamalais. While changes in habitat quality affect endemic species composition with commensals replacing them slowly, the undisturbed forest fragments support more abundance of endemics than man-modified habitats support commensals; perhaps an indication of depletion of resources for small mammals in general.

Correct identification of taxa is extremely important while understanding species compositions, richness, diversity indices, evenness, ecology and community structure. Small mammals are very poorly understood due to limited approaches to trapping methods. Much of our knowledge comes from morphological and morphometrics as studied earlier by taxonomists. Relative to location specimens show variations, which has prompted taxonomists to identify populations as unique taxa. While this may cause an increase in taxonomic units, clubbing ecologically distinct taxa does not serve the objectives of the study or purposes of understanding community ecology. It is therefore important to assign taxa unique identities and thereby the community ecology. Community studies with poorly identified taxa make them less applicable in the long run.

Behavioural observation is a key to taxonomic identification apart from morphology and morphometrics. In rodents and insectivores, conspecifics closely resemble which makes identification difficult — the three *Rattus* spp., the two *Mus* spp., the two *Suncus* spp. are case in point. Morphological characters help in initial identification, but we learnt in our trapping and identification efforts that observing individuals during handling and some individuals in captivity provided clues to better identification. Identification, behavioural observations, morphology and morphometrics of non-volant small mammals of Coorg from our study will soon be published separately (Molur et al. in prep.).

The dominance of the white-bellied form of *Rattus rattus* in the semi-evergreen forests of Mudumalai (Venkatraman et al. 2005), montane evergreen forests of Nilgiris (Shanker 2001, 2003), tropical rainforests of Anamalais (Prabhakar 1998), and middle elevation evergreen forests of the Anamalais (Chandrashekar-Rao & Sunquist 1996), while in our study the white-bellied form of *Rattus rattus* was dominant only in human habitations and bamboo. In one highly disturbed forest fragment near Ponnampet, with heavy logging and lopping of trees and higher density of bamboos, we recorded only the

white-bellied form. In all other forest fragments with no or little human interference, we trapped only the white-bellied endemic canopy rat, *R. satarae*. We trapped *P. lasiurus* only in an undisturbed riverine forest patch contiguous with the Brahmagiri Wildlife Sanctuary forests, while we did not catch a single individual in any of the other forest fragments and plantations with native and contiguous canopy. Our study supports Prabhakar's (1998) finding of *P. lasiurus* in only forest fragments larger than 16ha in the Anamalais suggesting the importance of large tracts of undisturbed forests for this species. Small islands of forests or sacred groves amidst plantations only support *R. satarae*, but not *P. lasiurus* or *Ratufa indica*, an indicator of the affects of changes in land use can have on endemic rodents in the Western Ghats.

A structural change to vegetation not only affects endemic species composition, but also tends to favour invasions by commensal species increasing competition (Kumar et al. 2002). The total displacement of *R. satarae* by *R. wroughtoni* in a disturbed sacred grove in southern Coorg suggests change in quality of habitat and canopy structure negatively affecting the endemic species. Similarly, displacement of the forest shrew *S. niger* by *S. murinus*, a widespread commensal in forest fragments is an indicator of structural changes on the forest floor affecting endemics. Coffee and cardamom plantations with native vegetation do not support such specialized endemics due to different practices such as trimming of canopy, lopping, clearing understory, clearing vines and the use of pesticides. Although species richness is high in modified landscapes of Coorg, the composition is dominated by commensals that do not occur in undisturbed forests.

Madromys blanfordi was reported in moist deciduous forests and teak plantations of the Anamalais by Chandrashekar-Rao & Sunquist (1996), in deciduous forests of Mudumalai by Venkatraman et al. (2005), in rainforest fragments of Indira Gandhi Wildlife Sanctuary by Prabhakar (1998), and in montane forest of the Nilgiris by Shanker (2003). However, we did not trap this species in any habitat in Coorg, perhaps an indication of the effects of changes in land use on the species. This study is a first step in understanding species composition of non-volant small mammals in an extremely fast changing landscape of Coorg in the Western Ghats. Since trends in plantation practices are in a constant flux, endemics of Coorg face greater threats and higher risks of extinction locally. Cardamom plantations which have the best available near natural vegetation with contiguous canopy are threatened from over use of pesticides and the changing mindset of planters to plant sun-loving varieties, which result in fauna in canopies getting affected as well as the loss of old growth trees, respectively. Continuous lopping of branches of shade trees and replacement of native shade trees with exotic trees such as casuarina and silver oak in coffee plantations cause grievous damage to faunal species composition. The recent trend in clear felling coffee plantations for ginger cultivation only encourages spread of commensals while effectively eliminating endemic small mammals. While conventional and systematic studies are needed to understand small mammal community structure, rapid assessments and immediate conservation action are required to stem the speed of loss of vegetation and changes in land use to help prevent local extinctions and the increase in risks to endemics in the Western Ghats.

