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Distribution, Abundance, Activity Patterns and Habitat Characteristics Associated with Family Herpestidae (Mammalia: Carnivora) in Three Protected Areas Representing Three Main Bioclimatic Regions of Sri Lanka

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ABSTRACT

Four species of mongooses; Brown mongoose (Herpestes fuscus), Grey mongoose (H. edwardsii), Black-tipped/Ruddy mongoose (H. smithii) and Stripe-necked/Badger mongoose (H. vitticollis) belonging to the family Herpestidae are found in Sri Lanka. The distribution, abundance, activity and habitat characteristics of family Herpestidae was studied using camera traps in three protected areas (Horton Plains National Park-HPNP, MaduruOya National Park-MONP and Sinharaja Forest Reserve-SFR) that represent three of the six main bioclimatic regions of the island. Ruddy mongoose had the highest trap success (9.58, a measure of relative abundance) at MONP which was also the highest among all the species considered for any given study site. Interestingly, Stripe-necked mongoose was the most abundant in SFR with a trap success of 2.95. At each study site, there was a prominent species with a higher trap success followed by the remaining species with lower trap success rates. With a total of 143 mongoose sightings, MONP can be considered to be providing the suitable habitats for these animals with optimum conditions when compared to HPNP and SFR. Ruddy mongoose preferred habitats with higher rock availability while Stripe-necked mongoose preferred aquatic habitats. High leaf litter cover, litter depth and forested habitats with canopy cover were identified as important habitat characteristics that are associated with three observed Herpestids at MONP. Grey mongoose was absent in all camera trap records which suggests that habitat requirements of this species are not met within the study sites of focus. Data generated through this study can be incorporated for effective conservation and management measures in the future.

KEYWORDS:*Camera trapping, Mongooses, Meso-mammals, Relative abundance, Bioclimatic zones*

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1 INTRODUCTION

Sri Lanka harbours 141 species of mammals (24.5% of the South Asian total) which include both terrestrial (land) and oceanic mammalian species (MoMD&E, 2016). Family Herpestidae of the island is represented by four species of mongooses (*Herpestes fuscus, Herpestes edwardsii, Herpestes smithii* and *Herpestes vitticollis*) that all belong to the same genus Herpestes. Mongooses in Sri Lanka are medium-sized (meso), long-bodied, short-legged, terrestrial mammals (Corbet and Hill, 1992; Santiapillai *et al*., 2000) of order Carnivora. *H.vitticollis* (Stripe-necked/Badger mongoose) and *H. smithii* (Ruddy mongoose) are closely related and are considered to be sister species emerging from a common ancestor while *H. fuscus* (Indian brown mongoose) and *H. edwardsii* (Indian grey mongoose) are also sister species (Yapa and Ratnavira, 2013). Mongooses (Herpestids) are distributed throughout the island from the coastal plains to the central hills. This study was conducted in three protected areas (MaduruOya National Park, Horton Plains National Park and Sinharaja Forest Reserve), representing three (low and mid country wet zone, dry zone and montane wet zone) of the six different bioclimatic zones of the island (Wijesinghe *et al*., 1993; MoMD&E, 2016).

Much of what is known about the biology and ecology of meso-mammal carnivores in Sri Lanka is still derived from the observations of Eisenberg and Lockhart (1972), and Phillips (1935). General descriptions about mongooses in Sri Lanka are given in some recent publications by Kotagama (2004) and Yapa and Ratnavira (2013). No quantitative ecological studies are available regarding Herpestids of the island except for the study carried out in Ruhuna National Park by Santiapillai *et al*., (2000) evaluating diversity, abundance and activity of mongooses. However, mongooses are a common feature in the wildlife seen in the National Parks of Sri Lanka (Santiapillai *et al*., 2000) and their diurnal activity makes them easier to be observed. Despite being common, their habitat occupancy and habitat usage are some of the areas that have not been investigated in a serious manner. More knowledge regarding these factors may aid in future conservation assessments and habitat management programs.

Use of camera traps for wildlife studies has increased significantly over the last decade (De Bondi *et al*., 2010). Camera-trapping surveys of small and medium terrestrial mammals provide a new and cost-effective technique for surveying terrestrial mammals. This is particularly the case when presence data are the main requirement of the survey, with no requirement to capture and tag animals. There is potential to use this approach to increase the level of replication and spatial coverage of mammal surveys. Therefore, camera traps were used in this study which helps data collection with minimum disturbance to the wildlife. This study focused on investigating the distribution of mongooses in three selected areas of the island and to assess their abundance, activity patterns and

habitat usage as an effort to aid the conservation of these species and effective management of their habitats. According to the current conservation status, Stripe-necked mongoose is listed as vulnerable nationally (MOE, 2012) and all four species are of least concern in the global scale (Iucnredlist.org. 2020).

2 MATERIALS AND METHODS

2.1 Study Sites

Maduru Oya National Park (MONP) lies in the districts of Ampara and Polonnaruwa representing areas of the dry zone. The park acts as a catchment for Maduru Oya Reservoir. The climax plant community of the area is tropical dry mixed evergreen forests. However, large tracts of forests within the park had been severely exploited for shifting cultivation. This has effected in secondary forests and vast stretches of open plains dominated by grasses. The park area experiences a mean annual temperature of 27°C and the total annual precipitation in the area is approximately 1650mm (IUCN, 1990). For the purposes of the present study, forest (FR), shrubland (SL), grasslands (GL) and aquatic habitats were considered as main habitat types in MONP.

Sinharaja Forest Reserve (SFR) is situated in the south-west lowland and mid-country wet zone of Sri Lanka, within Sabaragamuwa and Southern provinces. Over the last 60 years, the mean annual rainfall in the area has ranged from 3614 mm to 5006 mm and temperatures from 19°C to 34°C (Zoysa and Raheem, 1987). Sinharaja is the last extensive primary lowland tropical rain forest in Sri Lanka. Primary forest (PF), secondary forest (SF) and aquatic habitats were the main habitat types considered in SFR.

Horton Plains National Park (HPNP) is located on the highest southern plateau of the central highlands of Sri Lanka in the montane wet zone. The vegetation in natural habitats comprises of upper montane rainforests (cloud forests) and wet 'patana' grasslands (Gunatilleke and Gunatilleke, 1986). Some forest die-back areas can also be seen within the park. This area experiences a subtropical monsoon climate. The mean annual temperature is 15°C and the regional mean annual rainfall is 2150 mm (DWC, 2007). Cloud forest (CF), cloud forest die-back (CFD), grasslands (GL) and aquatic habitats were considered as main habitat types in HPNP.

2.2 Camera Trapping

The study was conducted from December 2018 to June 2019. Browning Dark Ops (Browning, USA), Browning 850 Pro (Browning, USA) and Bushnell Trophy Cam Aggressor (Bushnell, USA) IR night vision camera straps were used for camera trapping. All cameras were equipped with IR motion and heat sensor triggered low/no glow flash which generates minimal disturbance to the animals. A total of 25, 40 and 35 camera trap stations, selected proportional to the park area, were deployed in HPNP, MONP and SFR yielding 900, 1200 and 1050 trap nights respectively. Camera trap locations

were arranged in a systematic random method. Each study site was divided into 1 km^2 plots using Arc GIS grid maps. Sampling plots were selected to cover at least 30% of the available habitat types. Within each selected plot a minimum of three camera traps was deployed. Cameras were placed at 25 cm above the ground attached to a tree (Plate 1). Logs were used when large trunked trees were not available in the habitat. Camera traps were operating 24 h day^{-1} with a 30-second delay for 30 consecutive days at each station. Multiple photographs/videos of single individuals within a 30-min period were recorded as one effective photograph/video following the method of Chen *et al*. (2009).

2.3 Activity Patterns

Time prints recorded on photographs/videos were used to categorize the captures into hour intervals. Total number of captures for each species was obtained for hourly time intervals.

2.4 Habitat Usage

Habitat type of each camera station was recorded. Habitat variables of each camera trap station were recorded. The variables used for the analysis included Ambient temperature (Ta), Canopy cover (CC), Sunlight availability (SA), Stem density 1(SD1), Stem density 2(SD2), Ground vegetation (GV), Litter cover (LC), Litter depth (LD), Small rock availability (SRA), Large rock availability (LRA) and Vertical vegetation cover (VV). Ambient temperature was obtained from the temperature recording of the camera at each capture. Spherical densiometer was used to measure the canopy cover and it was recorded as a percentage. Sunlight availability was categorized as full sunlight, dappled sunlight and shade with respective scores of 3, 2 and 1allocated for each effective capture. Stem density was measured by the modified Point Centered Quarter (PCQ) method given by Chen *et al*. (2009) from the original method of Higgins *et al*., (1996). Distance to the nearest woody plant (<10 cm from the camera-trap) with a diameter at breast height - DBH between 1-10 cm within each of the four quadrats was measured for SD1, whereas SD2 included plants with a DBH >10 cm. Stem density was calculated as 1/mean area $[distance]^2$. Ground vegetation cover was estimated by averaging the percent herbaceous cover (<0.5 m height) within four 1×1 m plots situated 5 m north, south, east, and west of the camera trap (Chen *et al*., 2009). Litter cover was measured using the same quadrats and the percentage was averaged. A metal ruler was used to measure the litter depth. Small rock and large rock availability were measured ascertaining a score of 1-10 by counting the rocks in 10 random quadrats of 2×2 m within a radius of 10 m around the camera trap. Small rocks were defined as rocks with a maximum length of <50 cm, whereas rocks >50 cm in length were defined as large rocks. The vertical vegetation cover was measured as a percentage by holding a 1×1 m cloth from a distance of 10m from the camera trap in four directions. Four photographs were taken from the point of camera trap and they were computer analysed to get the

average vegetation that covers the 1×1 m cloth.

3 RESULTS & DISCUSSION

Highest trap success was recorded for Brown mongoose (1.73) in HPNP located in the upcountry wet zone (Table 1). Grey mongoose was not recorded from camera traps at any of the protected areas. Ruddy mongoose (Plate 2b) had the highest trap success (9.58) at MONP, and this was also the highest among all the species considered for any given study site. Interestingly, Stripe-necked mongoose (Plate 2a) was the most abundant in SFR with a trap success of 2.95. At each study site, there was a prominent species with a higher trap success followed by the remaining species with lower trap success rates. Moreover, the most abundant species with higher trap success differed between the three protected areas considered. With 143 total mongoose sightings and three of the four species present, MONP can be considered to be providing adequate habitats with suitable conditions for these animals when compared to HPNP and SFR where the number of total sightings was 19 and 43 respectively. Interestingly, Grey mongoose which is a common species in the dry zone was not observed inside the MONP despite being observed in the human-modified peripheral areas of the park. A possible reason for this surprising observation could be the fires set by poachers which are common during the dry season. These man-made fires burn through extensive areas of the parks shrublands and grasslands threatening many faunal species that inhabit them. According to the results, Ruddy mongoose can be considered as the species that is more associated to the dry zone while Stripe-necked mongoose and Brown mongoose (Plate 2c) can be considered favoring the wet zones of South West and Montane region of the island.

3.1 Habitat Occupancy

Of the 115 Ruddy mongoose sightings at MONP, 109 were recorded from the dry mixed evergreen forest habitat, whilst the remaining were captured in the adjacent shrublands. The second abundant mongoose species of MONP, Stripe-necked mongoose was recorded in the dry mixed evergreen forest habitat (17 sightings) and aquatic habitat (6 sightings), specifically near the stream banks. Brown mongoose was recorded only in the forest areas (5 individuals).

In HPNP, the most abundant Brown mongoose was sighted in all habitats but the aquatic habitats (CF-6, CFD-4, GL-3). The remaining species observed in HPNP, Stripe-necked mongoose was recorded only in the CF.

Stripe-necked mongoose was highly associated with the SFR aquatic habitats (riverine) (25 sightings), whereas only four and two sightings were recorded in PF and SF habitats. The only other mongoose species sighted in SFR was Brown mongoose (two sightings) in SF habitat. However, Ruddy mongoose was sighted in the villages adjacent to the

reserve. The present study results conform with those of Santiapillai *et al*., (2000) where they have mentioned that Stripe-necked mongoose prefers riverine habitats since they feed on frogs and crabs. Therefore, the presence of small streams is an important factor for Stripe-necked mongoose. All three protected areas fulfil this requirement in different levels with SFR providing the optimum conditions, resulting in its highest abundance (capture probability) between the three sites. However, the association of other mongooses with water was not observed contradicting the observations by Santiapillai *et al*. (2000).

3.2 Habitat Usage

Most of the habitat variables associated with the most abundant species were significantly different among the three protected areas (Table 2). Those variables included ambient temperature, canopy cover, sunlight availability, stem density 2 (woody plants >10 cm DBH), ground vegetation, small/large rock availability and vertical vegetation. Therefore, the results indicate the ability of family Herpestidae to inhabit a variety of habitats in a broad range from dry forests to the moist montane forests. However, the difference in the abundance (as a measure of capture probability) clearly shows that the prominent species differ from one location to another. Furthermore, the absence of a significant difference in the litter cover and the litter depth can be attributed to the high tendency of family Herpestidae as a whole shown towards preferring high amounts of litter. Presence of leaf litter indirectly indicates the high availability of insects, other invertebrates, frogs, lizards and snakes which are prominent food items of mongooses (Phillips, 1984; Santiapillai *et al*., 2000).

According to the principal component analysis results (Figure 1) there was a discrimination between the habitat characteristics associated with the two most abundant mongoose species (Ruddy mongoose and Stripe-necked mongoose) in MONP. PC1 scores were 0.417 and 0.443 for small rock and large rock availability respectively. This indicates that Ruddy mongoosefavors the habitats with higher rock assemblages while -0.449 and -0.458 PC2 scores for ground vegetation and vertical vegetation reflects the affinity of Stripe-necked mongoose for more forested habitats with moisture and leaf litter. PCA analysis was only performed comparing Ruddy mongoose and Stripe-necked mongoose in MONP since the abundances were lower in the other two locations for comparative analysis.

Activity patterns

All the captured data were pooled together to represent each species. All three mongoose species recorded were observed to be diurnal (A list of all mammalian species recorded in camera traps is given in Annexure I). The activity level gradually increased towards 12 noon where the peak in activity was recorded between 1200 and 1400 hours (Figure 3). This was a common feature for Ruddy mongoose and Stripe-necked mongoose. Despite showing the highest peak in activity from 1200-1300, *H. fuscus* was observed to be having a relatively lower activity level in the morning. The colder

and moist conditions in HPNP where it was most abundant would have led to this behavior. Its activity peaks only when enough sunlight falls to trigger the activity of its prey most of which are cold-blooded. However, this observation is different from that of Santiapillai *et al*. (2000) where they mention that peak activity levels fall in the morning time period and later in the evening in a study conducted in Ruhuna (Yala) National Park. This could be due to the comparatively drier conditions and high heat during mid-day that prevail in Yala. Both HPNP and SFR are situated in the wet zone, while MONP despite being situated in the dry zone provide forest areas with better canopy cover where most of the mongoose captures were present. The absence of Grey mongoose (more abundant in Yala) which prefers less wooded areas may have also influenced these results.

Table 1: Trapping success and total capture events for different mongoose species in the three protected areas considered

Protected Area	Trap Success/TCE	Species		
		Brown mongoose *H. fuscus*	Ruddy mongoose *H. smithii*	Stripe-necked mongoose *H. vitticollis*
HPNP (3,160 ha)	Trap Success	1.73	0.27	0.53
	TCE[b]	13	2	4
MONP (58,850 ha)	Trap Success	0.42	9.58	1.92
	TCE	5	115	23
SFR (11190 ha)	Trap Success	0.19	-	2.95
	TCE	2	-	31

[a]A measure of relative abundance for all camera-trap stations was calculated as (total capture events / total trap nights) × 100. Number of trap nights was defined as the total number of complete 24-hour periods during which cameras were functioning.

[b]Total Capture Events. All photographs taken within a 30-minute period were considered one capture event

Table 2**: Habitat variables associated with the most abundant mongoose species in each of the three protected areas**

Protected area	MONP	HPNP	SFR

Habitat Variable	*H. smithii* (Mean + Minimum-Maximum)	*H. fuscus* (Mean + Minimum-Maximum)	*H. vitticollis* (Mean + Minimum-Maximum)	*p value* (Kruskal–Wallis test)
Temp (C^{o})	35.33 (31-41)	21.67 (17-24)	24.13 (20-22)	0.001
Canopy Cover (%)	34.17 (40-80)	47.22 (20-65)	59.13 (40-90)	0.001
Sunlight (score 1-3)	1.61 (2-3)	1.00 (1-1)	1.61 (1-2)	0.007
SD1(<10) (stems/m2)	1.56 (3.1-6.2)	0.5 (0.11-1)	0.51 (0.01-4)	0.327
SD2 (>10) (stems/m2)	0.176 (0.4-0.6)	0.179 (0-0.44)	0.528 (0.01-1.11)	0.008
Ground vegetation (%)	19.72 (0-60)	48.33 (30-60)	19.57 (0-35)	0.001
Small rocks (score 1-10)	1.5 (0-4)	0.00 (-)	2.35 (0-6)	0.006
Large rocks (score 1-10)	4.22 (0-9)	0.00 (-)	2.91 (0-6)	0.006
Litter cover %	52.5 (0-95)	57.78 (20-80)	59.57 (25-90)	0.764
Litter depth (cm)	1.75 (0-4)	1.78 (1-2.5)	2.35 (1-4)	0.175
Vertical vegetation (%)	48.89 (10-90)	74.44 (60-80)	35.00 (20-55)	0.000

Plate 1. A mounted camera trap with protective cover and lock

Plate 2. Camera trap captures of (a) *H. vitticollis* (b) *H. smithii* and (c) *H. fuscus*

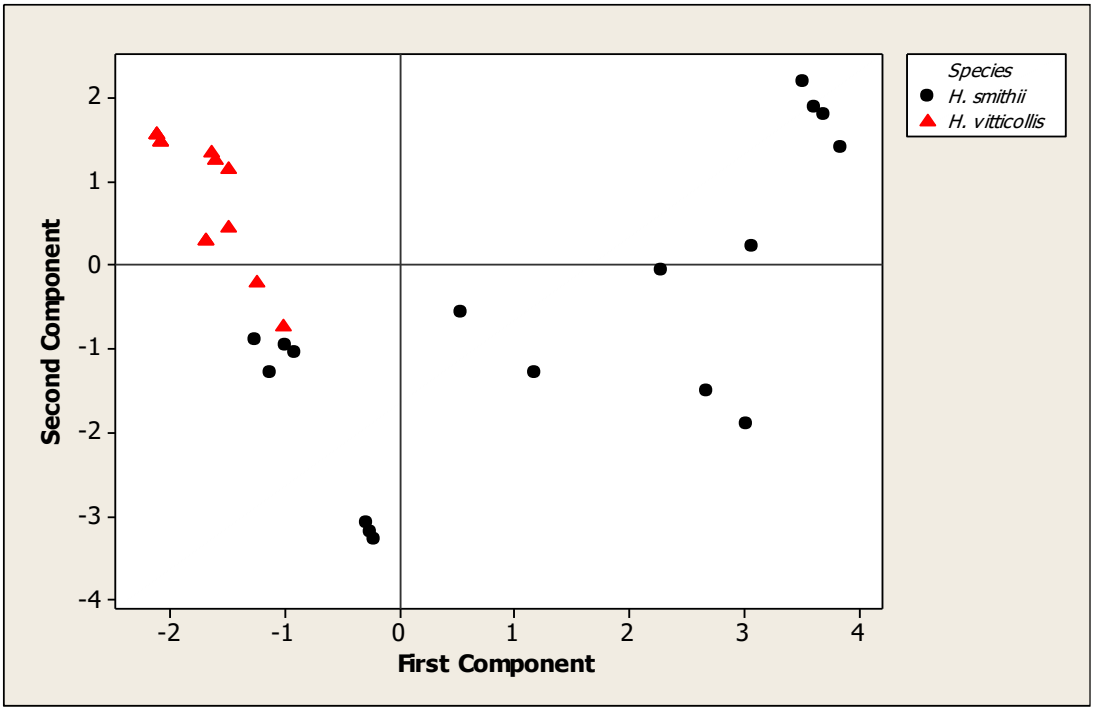

Figure 1: Scores plot of the first two principal components of habitat characteristics associated with *H. smithii* and *H. vitticollis*

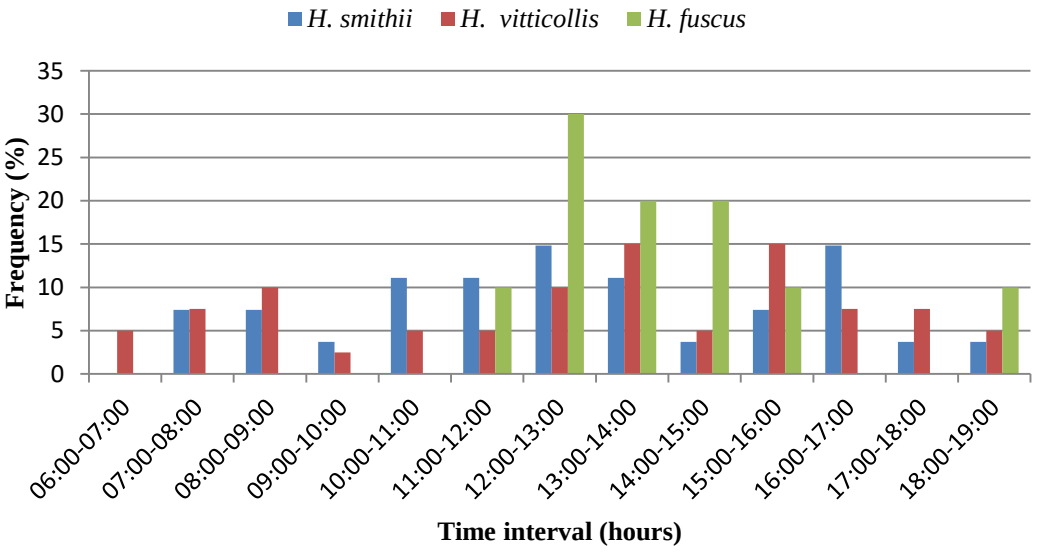

Figure 2: Diurnal activity patterns of *H. vitticollis*, *H. smithii* and *H. fuscus*

4 CONCLUSION

Family Herpestidae was observed in all three bioclimatic regions considered in the study displaying a broad distribution. The abundance of the three observed mongoose species differed between the three protected areas each having a unique most abundant species. Habitats with high leaf litter cover and litter depth were required by all three mongoose species that were recorded. Therefore, the conservation of areas with forest cover is highly important for the survival of family Herpestidae. Furthermore, Ruddy mongoose required rocky habitats, which are abundant in MONP making it a suitable location for this species. Stripe-necked mongoose prefers aquatic habitats (streams and other waterways) and the protection of those habitats is important for the conservation of the species. Brown mongoose and Grey mongoose were relatively rare and population studies are suggested for these two species to determine their status. HPNP acts as an important location for Brown mongoose. The results generated from this study can be incorporated into future conservation and management plans to protect the mongoose and their natural habitats.

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Annexture 01: List of other mammal species recorded during the study

Order	**Common Name**	**Scientific name**
Artiodactyla	White-spotted Mouse-Deer)	*Moschiola meminna*
	Sambhur deer	*Rusa unicolor unicolor*
	Spotted deer	*Axis axis*
	Wild Boar	*Sus scrofacristatus*
	Indian Buffulo	*Bubalus arnee*
Carnivora	Brown mongoose	*Herpestesfuscus*
	Ruddy mongoose	*Herpestes smithii*
	Stripe-necked mongoose	*Herpestes vitticollis*
	Golden Palm Civet	*Paradoxurus zeylonensis*
	Ring-tailed civet (Small Indian Civet)	*Viverricula indica*
	Dog	*Canis lupus familiaris*
	Sri Lankan golden jackal	*Canis aureus naria*
	Fishing Cat	*Prionailurus viverrinus*
	Rusty spotted cat	*Prionailurus rubiginosus*
	Sloth Bare	*Melursusursinus*
	Sri Lankan leopard	*Pantherapardus kotiya*
	Otter	*Lutra lutra*
Lagomorpha	Black-naped Hare (Indian hare)	*Lepus nigricollis*
Pholidota	Pangolin	*Manis crassicaudata*
Primates	Toque macaque	*Macaca sinica*
	Tufted graylangur	*Semnopithecus priamthersites*
Proboscidea	Elephant	*Elephas maximus maximus*
Rodentia	Indian porcupine	*Hystrix indica*
	Rodent (Mouse)	-
	Three-striped palm squirrel	*Funambulus palmarum*