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Caption: Malabar Slender Loris *Loris lydekkerianus malabaricus* © Dileep Anthikkad.



The diel activity pattern of small carnivores of Western Ghats, India: a case study at Nelliampathies in Kerala, India

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Abstract: The diel activity pattern of small carnivores was studied using the camera trap technique at Nelliampathy Reserve Forest, Kerala, India. Six species of small carnivores were recorded during the study. These include Brown Palm Civet *Paradoxurus jerdoni*, Small Indian Civet *Viverricula indica*, Stripe-necked Mongoose *Herpestes vitticollis*, Brown Mongoose *Herpestes fuscus*, Nilgiri Marten *Martes gwatkinsii*, and Leopard Cat *Prionailurus bengalensis*. The maximum diel activity overlap was detected between the Brown Palm Civet and Small Indian Civet, while the activity overlap was minimal between the Stripe-necked Mongoose and Small Indian Civet.

Keywords: Activity overlap, camera traps, civet, endemism, marten, mongoose, otter, Palakkad district, small cat, southern India.

Malayalam: പശുവിമുഖമലനിരകളിലെ നെല്ലിയാമ്പതി വനമേഖലയിൽ ക്യാമറട്രാപ്പുകൾ ഉപയോഗിച്ച് ചെറിയ മാംസഭുക്കുകളെക്കുറിച്ചുള്ള ഒരു പഠനം നടത്തുകയുണ്ടായി. പ്രസ്തുത പഠനത്തിനിടയിൽ ആറ് ഇനം ചെറിയ മാംസഭുക്കുകളുടെ സാന്നിധ്യം നെല്ലിയാമ്പതി വനമേഖലയിൽനിന്നും രേഖപ്പെടുത്തിയിട്ടുണ്ട്. തവിടൻ വെരുക, പൂവെരുക, ചെങ്കീരി, തവിടൻ കീരി, മരനായ, പുലിപൂച്ച എന്നിവ ഇതിൽ ഉൾപ്പെടുന്നു.

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Author details: P.O. NAMEER is Professor and Head of Centre for Wildlife Studies, Kerala Agricultural University. His research interest include the taxonomy, biogeography and ecology of vertebrates of Western Ghats (except fishes). DEVIKA SANGHAMITHRA is the PhD scholar in the Department of Wildlife Sciences, Kerala Agricultural University, and this paper is an outcome of part of her PhD thesis.

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INTRODUCTION

Small carnivores are medium-sized mammals belonging to the order Carnivora. There are 195 species of small carnivores globally belonging to 10 families (Wilson & Mittermeier 2009). The Western Ghats has 14 species, out of which 13 are present in Kerala (Nameer 2015, 2020). Understanding the geographical and ecological distributions and abundance of each species is the foundation for effective management.

A study on the impact of various factors on habitat selection of Smooth-coated Otters *Lutrogale perspicillata* in Periyar Tiger Reserve (PTR) found that the otters showed affinity towards areas with less rocky and gently sloped banks with vegetation and adjoining streams (Anoop & Hussain 2004). The central part of the *L. perspicillata* diet in PTR was fishes (96%), among which tilapia was the primary food item during both lower and higher water levels in the lake (Anoop & Hussain 2005). While comparing the abundance of small carnivores between an intact rainforest and adjoining forest fragments, it was observed that the intact forests have a higher abundance of small carnivores than the fragmented landscapes (Mudappa et al. 2007). Pools in the streams, particularly the second-order streams, were preferred by the Asian Small-clawed Otter *Aonyx cinereus* in the mountainous forests of Eravikulam National Park (Perincherry et al. 2011). Small carnivores of Mudumalai Tiger Reserve showed a negative relationship to the distance from the villages. Indian Grey Mongoose *Herpestes edwardsii* showed an affinity towards degraded forests, whereas Stripe-necked Mongoose *H. vitticollis* preferred subtropical evergreen and dry deciduous forests. Jungle Cat *Felis chaus* and Common Palm Civet *Paradoxurus hermaphroditus* preferred dry thorny and dry deciduous forests of the reserve. Open dry forests with moderate canopy were chosen by Ruddy Mongoose *H. smithii* and Small Indian Civet (Kalle et al. 2013a). The niche of Brown Mongoose *H. fuscus fuscus* was greatly influenced by temperature, rain and topography (Raman et al. 2020).

Brown Palm Civet *P. jerdoni* was believed to have distribution ranges from Kalakkad Mundanthurai Tiger Reserve, Tamil Nadu, to Bhagvan Mahaveer Wildlife Sanctuary in Goa. However, the distribution of Brown Palm Civet has extended further north of Goa up to Satara district of Maharashtra (Bhosale et al. 2013; Sayyed et al. 2019). Punjabi et al. (2014) have reported the northern extension of Stripe-necked Mongoose distribution from Maharashtra and Goa. Recent records of Brown Mongoose from Bilgiri Rangaswamy Temple Tiger Reserve points towards the southeast extension of the distribution of the

species from its known range (Suthar et al. 2020).

Studies on the species richness of small carnivores from the Western Ghats reported varying species from the different regions. Kumara & Singh (2006) and Kumara et al. (2014) reported 11 species of small carnivores from the forests of Karnataka. Parambikulam Tiger Reserve reported 11 species, with Small Indian Civet and Common Palm Civet as the common ones (Sreehari & Nameer 2016). The drier tracts of Wayanad Wildlife Sanctuary reported nine species, and similar to Parambikulam Tiger Reserve, Small Indian Civet was the most frequently sighted species at Wayanad WS. (Sreekumar & Nameer 2018). The high-altitude landscape in Eravikulam National Park recorded nine species, and Jungle Cat and Leopard Cat were the common small carnivores (Nikhil & Nameer 2017). The rain forest landscape of Silent Valley National Park recorded only seven species. The Small Indian Civet was the most common small carnivore in the rainforest habitat (Sanghamithra & Nameer 2018). Anil et al. (2018) reported on the social behaviour, feeding habits, and activity pattern of *Martes gwatkinsii* from the Pampadum Shola NP.

Diel activity pattern is one of the critical factors which determines the ecological niche of a species. It is also an essential tool for the co-living of the species (Gerber et al. 2012). Interspecific competition is reduced by the chronological separation between the species (Selvan et al. 2019). Variation in activity peaks was observed among sympatric species with similar activity (Su & Sale 2007; Chen et al. 2009).

All the three species of the civets recorded from Wayanad Wildlife Sanctuary in the Western Ghats were nocturnal with varying temporal activities, while the mongooses were diurnal (Sreekumar & Nameer 2018). In Sumatra, a study on the activity pattern of the small carnivores found that all the six species of viverrids in the study area were nocturnal with temporal variations in the activity peaks in an oil palm plantation. At the same time, the Yellow-throated Marten *Martes flavigula* was diurnal (Solina et al. 2018), the Nilgiri Marten of Pampadum Shola NP in the Western Ghats was also diurnal in habit (Anil et al. 2018). The nocturnal nature of the Small Indian Civets was proved in other studies from the Western Ghats, too (Pillay 2009; Chen et al. 2019; Kalle et al. 2013b). However, Selvan et al. (2019), in a study in the Villupuram district of Tamil Nadu, observed that Small Indian Civets were active during daytime hours.

The present study is expected to gather additional information on the diel activity pattern of the small carnivores of Western Ghats.

STUDY AREA AND METHODS

Study Area

The study was conducted at Nelliampathy Reserve Forests (NRF), in the Anamalai Hills, southern Western Ghats, India (Figure 1). The Nelliampathy reserve forest lies between 10.374–10.686 °N latitudes and 76.518–76.752 °E longitudes in the Palakkad district, Kerala, and has an extent of 206 km². The altitude varies from 40 m to 1,530 m, and the primary vegetation type is west coast tropical evergreen forest. The dominant trees are *Cinnamomum malabattrum*, *Drypetes roxburghii*, *Holigarna arnottiana*, *Mesua ferrea*, *Palaquim ellipticum*, *Schleichera oleosa*, *Syzygium cumini*, and *Vateria indica*. The average temperature ranges 21–41 °C during summer, and the temperature can be as low as 10°C during the winter in the upper reaches of the Nelliampathies. The mean annual rainfall is 2,500mm (Varghese 2015).

Methods

A total of 30 camera trapping stations were selected in the NRF based on indirect evidence such as scats, pugmarks, and scratches of the small carnivores. We de-

ployed camera traps (Cuddeback attack model C1: digital scout cameras with passive infra-red sensors for heat and motion detection) at these locations during January 2019 at the height of 30 cm from the ground, and two cameras were placed at least 250 m from each other (Mudappa et al. 2007; Sreehari & Nameer 2016; Nikhil & Nameer 2017; Sanghamithra & Nameer 2018; Sreekumar & Nameer 2018). The cameras were set up in default settings. The time delay between the pictures during the day was set as fast as possible, and during the night, it was set with a time delay of five seconds. Garmin GPS etrex 30 was used to mark the camera trap stations. The cameras were kept open for 24 hours a day for 28 days at each location. Thus, 840 camera trap days, monitoring for 20,160 hours of trap effort, were carried out in NRF during the study period.

Camera trap success rate

The camera trap success rate is the ratio of independent photo events to the whole camera trap days and the value multiplied by 100 (Rovero & Marshall 2009). The number of independent images of small carnivore camera trapped from NRF was used to calculate the camera trap success rate.

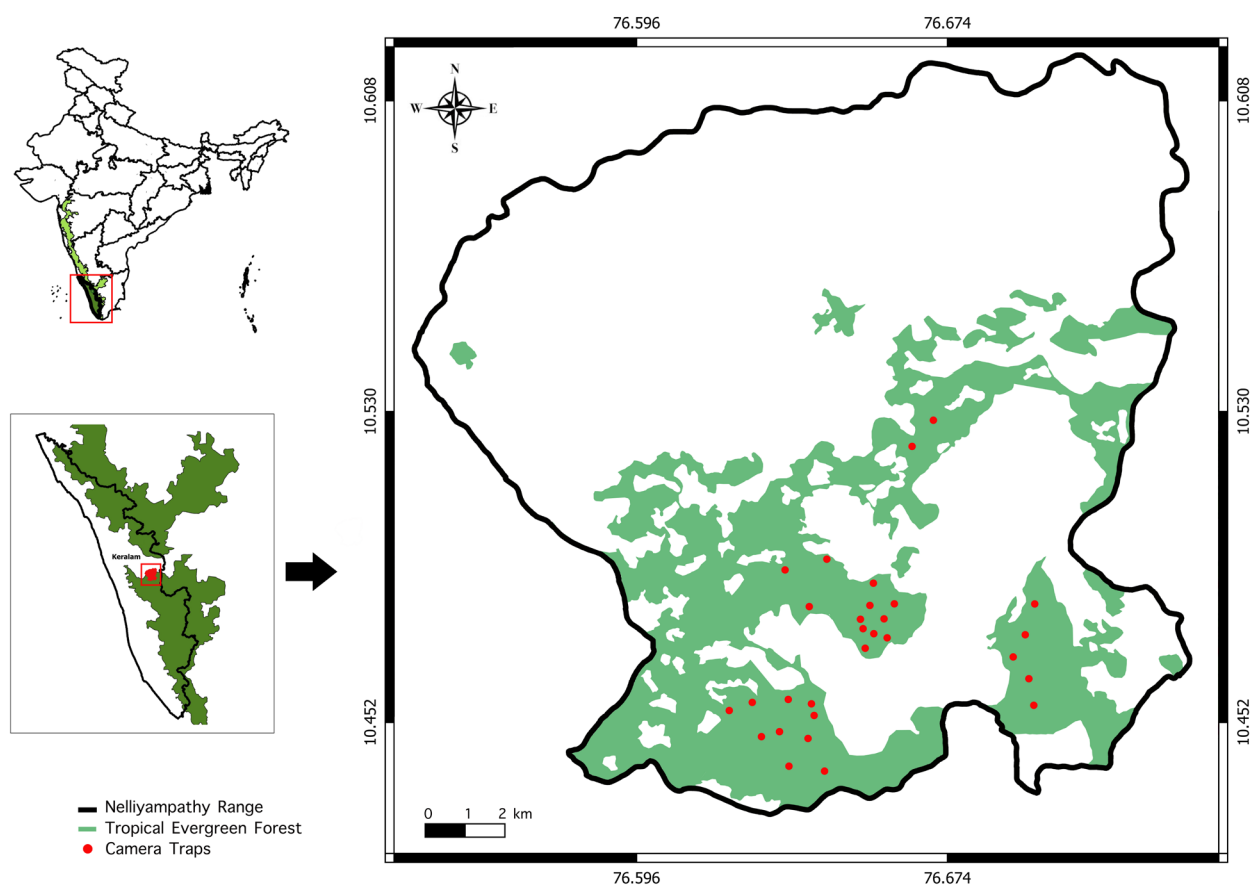


Figure 1. Camera trap locations at Nelliampathy Reserved Forest, Western Ghats, southern India.

Line transect survey for indirect evidence

The transects were done on the existing trails, forest roads, and streams, searching for indirect evidence of small carnivores. A total of 104km was walked through the various trails in search of indirect evidences of small carnivores. The scats were identified to the family level of small carnivores or the species level (Silveria et al. 2003; Sridhar et al. 2008; Mudappa et al. 2010; Perincherry et al. 2011).

Analysis of diel activity

We recorded species of small carnivores, date, time, and geocoordinates of the trap location for every camera trap image captured. To ensure the independence of the capture, we have defined successive images of the same species at the same camera trap station within a recess of ≤ 30 minutes as a single event (Linkie & Ridout 2011; Mukherjee et al. 2019; Selvan et al. 2019). However, if more than one individual of similar or different species were captured in a single image, each individual was considered a discrete incident (Mukherjee et al. 2019). The timings of dawn and dusk in the study area were recorded during the study period. Sunrise and sunset were at about 0645 h and 1815 h local time (GMT+5), respectively (IMD 2019). Based on dawn and dusk, the day was divided into three periods, 0745–1715 as day, 1915–0545 as night, and 0545–0745 (dawn) & 1715–1915 (dusk) as crepuscular (Gerber et al. 2012; Selvan et al. 2019).

The diel activity of species was categorized as diurnal ($<10\%$ of records at night), nocturnal ($>90\%$ of records at night), primarily diurnal ($10\text{--}29\%$ of records at night), mostly nocturnal ($70\text{--}89\%$ of records at night) or cathemeral ($30\text{--}69\%$ of records at night) (Gomez et al. 2005; Azevedo et al. 2018; Selvan et al. 2019).

The diel activity pattern and activity overlapping were determined using a non-parametric circular Kernal density method. Smoothing parameter of 0.8 (sample size <50)

was used to generate coefficient of overlap (Δ) (Ridout & Linkie 2009). The range of coefficient of activity overlap varies from 0 (zero overlaps) to 1 (100% overlap) (Ridout & Linkie 2009). R-package 'OVERLAP' was used to analyze activity patterns of single species and coefficient of overlapping between two species (Meredith & Ridout 2018). To obtain a bias-corrected percentile, we estimated the 95 % confidence interval of Δ with 1,000 bootstrap (Meredith & Ridout 2018).

RESULTS AND DISCUSSION

Diversity of small carnivores at Nelliampathy Reserve Forests, Western Ghats

We recorded six species of small carnivores from NRF representing four families. This comprises two species each of herpestids and viverrids and one species each of felids and mustelids (Table 1). A total of 677 images of 24 species of mammals were obtained during the study period. Two-hundred-and-thirty-one images were of carnivores, out of which 199 (86.15 %) were of small carnivores (Figure 2). The small carnivores recorded from NRF include Brown Palm Civet *P. jerdoni* (43.65 %) (Image 1), Stripe-necked Mongoose *H. vitticollis* (26.39 %) (Image 2), Brown Mongoose *H. fuscus* (13.19 %) (Image 3), Small Indian Civet *V. indica* (13 %) (Image 4), Nilgiri Marten *M. gwatkinsii* (3 %) (Image 5), and Leopard Cat *Prionailurus bengalensis* (1 %) (Image 6) (Figure 3).

The small carnivore camera trap success rate from the evergreen forests of NRF was 22.14 per 100 trap nights. The camera trap success rate of NRF is much higher than earlier camera trap studies from various locations in the Western Ghats. For example, the camera trap success rate of Silent Valley National Park was 10.90 per 100 camera trap nights (Sanghamithra & Nameer 2018), Parambikulam Tiger Reserve was 4.40 (Sreehari & Nameer 2016),

Table 1. Small carnivores of Nelliampathy Reserve Forest, Western Ghats, southern India.

Common name	Scientific name	Family	IUCN Red List status	CT	IE
Brown Palm Civet	<i>Paradoxurus jerdoni</i>	Viverridae	LC	*	*
Small Indian Civet	<i>Viverricula indica</i>	Viverridae	LC	*	
Brown Mongoose	<i>Herpestes fuscus</i>	Herpestidae	LC	*	
Stripe-necked Mongoose	<i>Herpestes vitticollis</i>	Herpestidae	LC	*	
Nilgiri Marten	<i>Martes gwatkinsii</i>	Mustelidae	VU	*	
Asian Small-clawed Otter	<i>Aonyx cinereus</i>	Mustelidae	VU		*
Leopard Cat	<i>Prionailurus bengalensis</i>	Felidae	LC	*	

CT—Camera trap | IE—Indirect evidence.

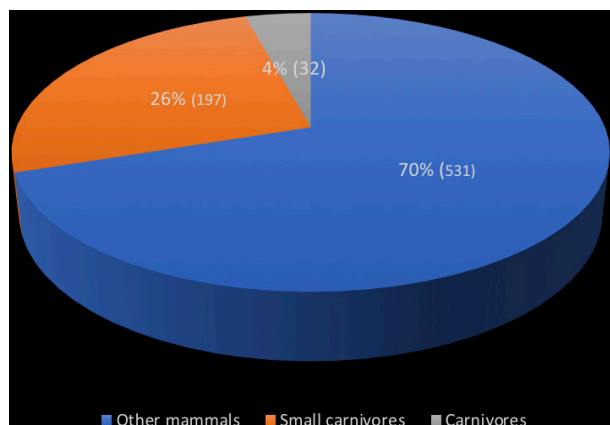


Figure 2. Relative abundance of mammals captured in the camera traps in Nelliampathy Reserve Forest, Western Ghats, southern India.

and Eravikulam National Park was 2.10 (Nikhil & Nameer 2017). However, a higher camera trap success rate 41.10 per 100 trap nights was recorded from Kalakkad Mundanthurai Tiger Reserve (Mudappa et al. 2007).

Diel activity of small carnivores at Nelliampathy Reserve Forests, Western Ghats

The maximum diel activity overlap was detected between Brown Palm Civet and Small Indian Civet with Δ of 0.81 (0.66–0.92) (Fig. 4a), followed by Brown Mongoose and Small Indian Civet (Δ = 0.76, 0.58–0.91) (Figure 4b), and then Brown Mongoose and Brown Palm Civet (Δ = 0.70, 0.53–0.83) (Figure 4c). Whereas, the minimal diel activity overlap was observed between Stripe-necked Mongoose and Small Indian Civet (Δ = 0.08, 0.01–0.18) (Figure 4f), Stripe-necked Mongoose and Brown Palm Civet (Δ = 0.13, 0.06–0.21) (Figure 4e), and between Stripe-necked Mongoose and Brown Mongoose (Δ = 0.20, 0.08–0.33) (Figure 4d).

The most significant diel activity overlap was between Brown Palm Civet and Small Indian Civet. Even though they are similar in size and activity, the competition for resources may be minimized by the dissimilarity in their dietary preferences. Brown Palm Civet is primarily frugivorous (Rajamani et al. 2002; Mudappa et al. 2010), whereas Small Indian Civet is a generalist and omnivorous (Mudappa et al. 2007).

Brown Palm Civet, Small Indian Civet, and Brown Mongoose displayed nocturnal activity patterns, and they have the most significant overlap in the diel activity. However, they all showed varying activity peaks, probably to reduce the competition. Activity peaks of Brown Palm Civet were just before dawn (0400–0600 h) and just after dusk (1800–2000 h), whereas Small Indian Civet had activity peaks were during midnight hours (0000–0100 h)

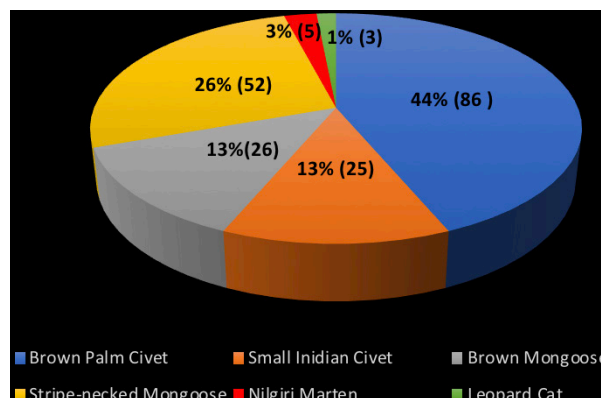


Figure 3. Relative abundance of small carnivores captured in the camera traps in Nelliampathy Reserve Forest, Western Ghats, southern India.

and soon after sunset (1900–2030 h). Brown Mongoose showed peak activity during the midnight hours from 2300 to 0100 h. Similar activity patterns and overlap were observed among the Small Indian Civet and Brown Palm Civet in Wayanad Wildlife Sanctuary (Sreekumar & Nameer 2018). The diel overlap between Common Palm Civet and Small Indian Civet both showed nocturnal activity but varying activity peaks (Su & Sale 2007).

The activity pattern not only depends on factors like limited resources and competition but also on seasonal changes (Ikeda et al. 2016), changes in diurnal temperatures (Fuller et al. 2016) prey-predator interactions (Harmse et al. 2011; Linkie & Ridout 2011) and human interventions and human activity (Cruz et al. 2018). It needs to be further investigated to understand how the sympatric species with overlapping diel activity perform the resource partitioning.

CONCLUSION

Depending on the time of the activity of a species, the small carnivores are generally grouped into two, nocturnal and diurnal. Species within the same temporal group have a more significant overlap in their activity. Maximum overlap was observed between two nocturnal small carnivores, Brown Palm Civet and Small Indian Civet. At the same time, the lowest overlap in activity was observed between Stripe-necked Mongoose and Small Indian Civet.

Diel activity patterns are a vital feature of animal behaviour with important implications for a wide range of ecological and physiological processes. Diel activity patterns are an adaptation to environmental variability throughout the day. They reflect a complex compromise

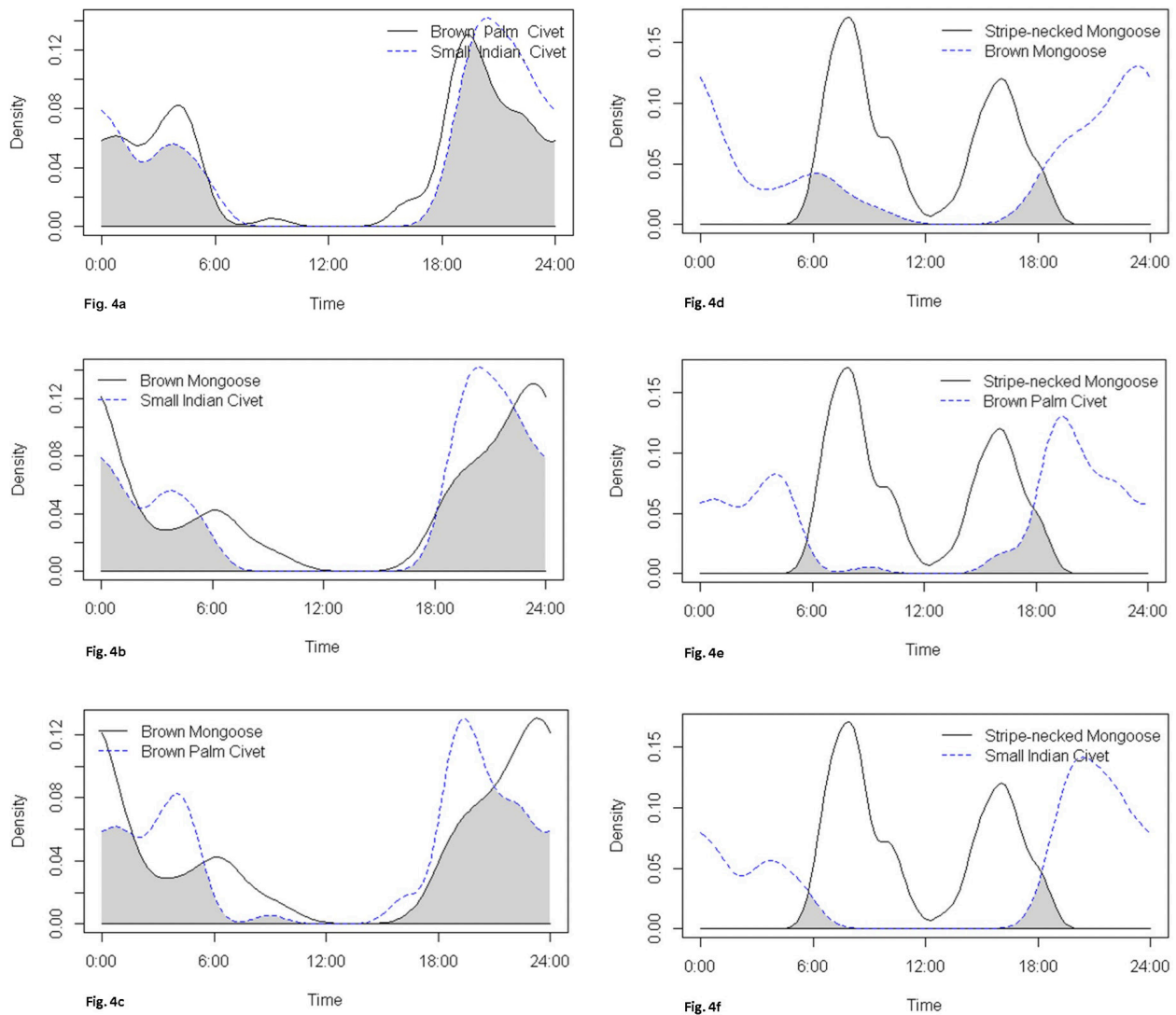


Figure 4. The activity pattern of small carnivores of Nelliampathy Reserve Forest, Western Ghats, southern India: a—Brown Palm Civet & Small Indian Civet | b—Brown Mongoose & Small Indian Civet | c—Brown Mongoose & Brown Palm Civet | d—Stripe-necked Mongoose & Brown Mongoose | e—Stripe-necked Mongoose & Brown Palm Civet | f—Stripe-necked Mongoose & Small Indian Civet.

between foraging, resting, predator avoidance, competition, social activities and environmental constraints determining fitness. Thus, the diel activity studies may enable us to perform more robust comparisons of activity patterns and levels across sites and species to better understand ecological and human drivers of these processes and thus have management and conservation significance.

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Image 1. Brown Palm Civet *Paradoxurus jerdoni* in Nelliampathy Reserve Forest, Western Ghats, southern India.



Image 2. Stripe-necked Mongoose *Herpestes vitticollis* in Nelliampathy Reserve Forest, Western Ghats, southern India.



Image 3. Brown Mongoose *Herpestes fuscus* in Nelliampathy Reserve Forest, Western Ghats, southern India.



Image 4. Small Indian Civet *Viverricula indica* in Nelliampathy Reserve Forest, Western Ghats, southern India.



Image 5. Nilgiri Marten *Martes gwatkinsii* in Nelliampathy Reserve Forest, Western Ghats, southern India.



Image 6. Leopard Cat *Prionailurus bengalensis* in Nelliampathy Reserve Forest, Western Ghats, southern India.

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