FACTORS INFLUENCING SMALL CARNIVORE COMMUNITY STRUCTURE IN CHANDOLI NATIONAL PARK, NORTHERN WESTERN GHATS

Dissertation submitted to the
Saurashtra University Rajkot, Gujarat

In partial fulfillment of
Master's Degree in Wildlife Science

By
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Under the Supervision of

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Wildlife Institute of India

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CERTIFICATE

This is to certify that **Mr. Himanshu C. Lad** has carried out an original piece of research in partial fulfillment of Master's Degree in Wildlife Science of the Saurashtra University, Rajkot, Gujarat. The topic of his dissertation is **"Factors influencing small carnivore community structure in Chandoli National Park, Northern Western Ghats".** The study was carried out under our supervision from December 2018 to June 2019. We hereby certify that this work has not been submitted for any degree to any university

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DECLARATION

I, **Himanshu Lad**, hereby declare that the research work titled "**Factors influencing small carnivore community structure in Chandoli National Park, Northern Western Ghats**" carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University; Rajkot is an original piece of work. This study was carried out under the supervision of Dr. Gopi.G.V and Dr. Bilal Habib at the Wildlife Institute of India from December 2018 to June 2019. I also declare that this work has not been submitted for any other degree of any university.

Date: 30th June, 2019

Place: Dehradun

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'Some things should be better left incomplete; so you might get a better chance in the future to complete them.'

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Summary

The current study was conducted on small carnivores in Chandoli National Park of Sahyadri Tiger Reserve from December 2018 to April 2019. The main objective was to understand drivers of spatial distribution and temporal variations amongst sympatric small carnivores present in the study area. Camera trapping was conducted using CuddebackC1 camera trap model using grid-based sampling (grid size =0.5 km^2, n=72). Sign survey done to identify ideal camera trap locations and collect information on civet's diet resulted in identification of five commonly consumed fruits in the dry season (Jan-April) viz. *Gnetum ula, Diospyros sylvatica, Palaquium sp., Syzygium sp.,* and *Caryota urens.* Camera trapping resulted in photo-captures of 24 species of wild mammals including ten species of small carnivores including small cats (n=645 independent captures). Small carnivores recorded include three species of civets, three species of mongooses, one species of otter. Three species of small cats were also recorded for which time activity patterns was assessed. Habitat parameters collected for species-habitat relationship consisted of canopy cover, fruiting trees, average tree height, undergrowth type, habitat type, trail type, capture probabilities of predators. Endemic species like Brown palm civet were having limited distribution in the study area showing association with riparian habitats having high fruiting diversity and taller trees. Asian palm civet was recorded from open canopy forest, lateritic plateaus and semi-evergreen forest. Small Indian civet was photo-captured in relocated villages and open canopy forest. Time-activity patterns revealed nocturnal behaviour of all three civets with inter-species variation in activity peaks for Brown palm civet. Mongooses were strictly diurnal with Striped-necked mongoose being more active in early morning hours from 8am to 12pm. There was considerable degree of spatial overlap between all small carnivore species to large carnivore's presence. Activity overlap showed temporal segregation between small and large carnivores possibly to avoid intra-guild predation.

This study was the first extensive fine-scale study focused on small carnivores to be conducted in Western Ghats of Maharashtra using camera traps in 0.5Km^2 grid size. It further provided information on local small carnivore distribution, dietary patterns of palm civets and time-activity patterns of small carnivores in Chandoli national park.

1. Introduction

1.1 General introduction

With most of our attention focused towards conserving large sized charismatic carnivores, lesser known small carnivores who play an important ecological role in seed dispersal (Nakashima, Nakabayashi, & Sukor, 2013; Rabinowitz, 1991) stabilizing prey population (invertebrates, small mammals) and also acting as prey species for large-sized carnivores remain largely unstudied. Declining large carnivore population possibly provides opportunity for small carnivore and mid-sized carnivores to become over-abundant causing trophic cascades (Crooks & Soule, 2010). Information on endemic small carnivores and their ecology is still scarce, as studying them is often very difficult concerning their nocturnal, elusive habits and occurrence in areas that are not easily accessible (Jathanna, 2016; Schipper, Hoffmann, Duckworth, & Conroy, 2008). Understanding their habitat requirements and crucial role in trophic dynamics helps in management interventions to ensure proper functioning of forest ecosystem.

Small carnivores are subset of larger group of animals from the order Carnivora known to occur world-wide having 165 species from 9 families (Schipper et al 2008). India harbors about 32 species of small carnivores with North-east region and Western Ghats serving as the two hot-spots having higher endemism (Mudappa, 2013). Small carnivores show remarkable ability to adapt to their surroundings considering their omnivorous diet, nocturnal, elusive behavior and seasonal movement for resource utilization (Mudappa, 2013; Waser, 1980). Small carnivores are facing multiple threats including habitat loss, hunting (Farris et al., 2015), trade for body parts, pet trade, fragmentation (Crooks & Crooks, 2002; Mudappa, Noon, Kumar, & Chellam, 2007), road kills (Hatti & Mubeen, 2019), predation from feral dogs and diseases prevalence.

Habitat use studies of elusive and nocturnal small carnivores are usually done by assessing species presence and quantifying habitat parameters (Chen, Tewes, Pei, & Grassman, 2009; Chutipong, Steinmetz, Savini, & Gale, 2017). Some of the habitat parameters include structural composition of the habitat, which includes tree height and undergrowth category.

These parameters are important for small carnivores as they provide better roosting sites and cover to escape from predators. Tree height is an important habitat parameter for brown palm civet, as they require taller trees for their day roosting sites (Mudappa, 2006).

Many generalist species are known to adapt to human modified landscapes and thrive in plantations and agriculture fields (Jennings et al., 2015; Nakashima et al., 2013). Studies concerning effect of anthropogenic disturbance has revealed negative numerical response to disturbance with lower density and diversity in logged forests than in primary forests (Gerber, Karpanty, & Randrianantenaina, 2012; Heydon & Bulloh, 1996). Similar study on impact of fragmentation on small carnivore community also showed difference in relative abundance between small and large sized fragments (Mudappa et al., 2007).

1.2 Western Ghats and small carnivores

Western Ghats harbors 12 species of small carnivores including four species of mongooses i.e. Striped-necked mongoose, Ruddy mongoose, Grey mongoose, Brown mongoose; four species of civets i.e. Brown palm civet, Common palm civet, Malabar civet, Small Indian civet; three species of otter i.e. Small-clawed otter, Smooth-coated otter, Eurasian otter and Nilgiri marten. Small cats are also sometimes considered as small carnivores and include four species from Western Ghats which include Rusty spotted cat, Leopard cat, Jungle cat and Fishing cat. These species often occur sympatrically harboring a diverse community with different requirements of diet, habitat and roosting sites. Most information on small carnivores comes from opportunistic observations, anecdotal records and status surveys. It is often difficult to study small carnivores considering their low detectability; inability to distinguish between indirect signs; nocturnal behavior and their distribution in inhospitable terrain.

1.3 Using camera traps to study small carnivores

Camera traps provide easier means for monitoring wildlife and have been increasingly used for making species inventory, studying species response to habitat parameters, activity patterns, estimating abundance of carnivores and rare animals (Sollmann, 2018). Radio telemetry offers precise information on movement, home-range and behavior patterns of mammals. But to conduct such studies on endemic species like Striped-necked mongoose

and Brown palm civet requires familiarity with the undulating terrain and accessibility while tracking these elusive animals.

Camera traps have provided valuable information on small carnivore distribution usually using the by-catch data obtained from studies focused on large-carnivores. Initial studies in our country that used camera traps exclusively for small carnivores were conducted in Western Ghats (Kumar et al., 2002; Mudappa, 1998). Since then numerous species inventories have been created in our country for different protected areas (Kumara and Singh, 2007; Kumara *et al.*, 2014; Sreehari and Nameer, 2016; Bashir *et al.*, 2018; Sanghamitra and Nameer, 2018). Long term studies using camera traps for small carnivores to understand their ecology include Gupta (2011), Jathanna (2014) and Kalle (2013) from protected areas in Rajasthan, Karnataka and Tamil Nadu respectively. These studies examined their diet, density, spatial distribution, predictive modeling and time-activity patterns. Most of these studies were conducted using grid size of 1-2 Km^2. A crucial trade-off comes with logistics considering number of camera traps available while considering camera trapping to study small carnivores. Further batteries, memory cards and other costs are also included. Depending on the objective, one can use fewer camera traps for longer duration at each site or use multiple cameras for shorter durations at various locations.

Studies from Western Ghats part of Maharashtra on small carnivores are largely restricted to observational records. The lack of information on small carnivores from northern Western Ghats encourages further research to better understand their distribution, habitat requirements, community organization and response to anthropogenic pressure. This study attempts to understand small carnivore assemblage using camera traps looking at factors influencing their spatial use in Chandoli National park, northern Western Ghats.

1.4 Objectives

The objectives of this study would be to

1) Determine small carnivore species richness and its distribution in the study area
2) Understand factors influencing small carnivore's presence in Chandoli National Park

3) Investigate inter-species variation in time activity patterns among sympatric small carnivores

Research Questions

- How is small carnivore diversity and distribution affected by habitat structure and predator presence?
- How species sharing similar guild are temporally segregated?
- Do predator activity patterns influence small carnivore activity patterns?

2. Study area

2.1. Western Ghats

The current study area lies in the bio-geographic zone 5B consisting of the Western Ghats - a long stretch of mountain ranges running parallel to India's western coast for approximately 160,000 km^2 extending from Gujarat to Kerala. These mountain ranges are older than the Himalayas and its topography promotes habitat heterogeneity, isolated fragments, speciation and unique biodiversity of endemic flora and fauna gaining the status as 'biodiversity hotspot'(Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000).

The Western Ghats are divided into four phytogeographical regions, viz. 1) the region extending from river Tapi to Goa is known as the northern Western Ghats or 'Sahyadri' ranges, 2) Western Ghats from Kali nadi to Coorg, 3) the Nilgiri and the 4) Anamalai, Palni and Cardamom hills. (Subramanyam & Nayar, 1974)

Mountain chains of the Northern Western Ghats have steep escarpments on the windward side (western) and more gently sloping towards the leeward side. The vegetation of the Northern Western Ghats can be differentiated into altitudinal zones - scrub and semi-deciduous type vegetation at elevations between 200–500 m and dry deciduous forests to semi-evergreen forests at elevations between 500–1100 m.

Basalt rock of volcanic origin, lateritic plateaus, steep slopes, fragmented patches of stunted semi-evergreen forests and heavy rainfall are the typical characteristics of the northern Western Ghats that shape its biodiversity.

2.2 Chandoli National Park

Chandoli National Park lies at the junction of four districts – Kolhapur, Satara, Sangli, and Ratnagiri in Maharashtra. It was notified as a national park in 2004. The terrain is hilly and undulating. Sahyadri Tiger Reserve is formed by bringing together Chandoli National Park, Koyna Wildlife Sanctuary (to north of Chandoli), and Radhanagari Wildlife Sanctuary (to its south). The total area of the national park is 317.67 Km^2 with the Vasantsagar reservoir in the middle (also known as the Chandoli dam). A large part of the national park remains

inaccessible due to cliffs and gorges. Agriculture fields (during winter; wheat and gram), sugarcane cultivation, Acacia and Teak plantation surround the protected area on the eastern side. The western side of the National park includes steep escarpments followed by privately owned uncultivated land.

Seasonality: The dry season starts from December until May and includes the temperature ranging from minimum 5° Celsius in winter to more than 40° Celsius in summer. The region receives heavy rainfall for four months from July till October with precipitation more than 5000mm in some areas.

2.3. Intensive study area

Camera trapping and sign survey was conducted in two blocks covering an area of 70 km^2. The description of which is given in Table no.1

	Helwak Range	**Chandoli Range**
No. of cameras placed	40	32
Beats surveyed	Rundiv north & south, Ambole, Siddheshwar, Chandoli Khurd	Gothane, Chandel, Dhakale, Sonarli and Nivale
Dominant habitat type	Semi-evergreen forest	Grassland
Livestock presence	Absent in surveyed area except Chandoli Khurd	Present in surveyed area (300+ approx.)
Villages in Helwak range(core)	Present (Male, Kolne, Patharpunj)	Absent
Relocated villages (about 15-20 years ago)	Jawali (Ambole), Rundiv, and Chandoli Khurd	Sonarli, Nivale, Gothane and Chandel
Tourism	Active till Bhairavgad Fort	Not active in surveyed area, Wildlife tourism in other parts of the range till Jholambi

Historical monuments	Bhairavgad Fort, Prachitgad Fort	
Other information	Bhairavgad 'jatra' (local religious fair) celebrated in April attracting 500+ visitors	*Acacia nilotica* and *Eucalyptus sp.* plantation done by Forest dept.

Table 1 Comparative account of sampled blocks in Chandoli National Park

The habitat was categorised into five types for this study namely grassland, forest, riparian, relocated village, plateau(sada):

1. **Lateritic plateaus (Sada)-** It can be described as flat hilltops at an elevation of 800-1000m with negligible or sparse vegetation consisting of lateritic boulders and rocky substrate. These areas are formed due to extreme geological events and are rich in iron content. During monsoons, they support a diverse assemblage of endemic ephemerals like *Aponogeton sp.* and *Ceropegia sp.*

2. **Forest**- This habitat type includes both the deciduous as well as semi-evergreen tracts of forest. The dominant trees are dwarfish and include *Memecylon umbellatum* and *Syzygium sp.* Understory dominated by *Strobilanthes* (locally called as 'Karvi') and 'Dhad-dhada'. Fruiting tree diversity is high but lower when compared to riparian areas. Fruiting trees include *Diospyros sylvatica* and *Olea paniculata.* Ground cover dominated by leaf litter and fallen logs.

3. **Scrub/Grassland** – Large tracts of grass-covered areas having open scrub forest consisting trees of *Acacia sp., Actinodaphne hookeri, Terminalia paniculata, Memecylon umbellatum, Vangueria spinosa* and *Syzygium sp.* Fruiting trees includes *Zizyphus sp., Syzygium sp., Aegles marmalosa, Ficus racemosa* etc.

4. **Relocated villages** – This habitat category includes village relocated areas and consists of grassland habitats with edible fruiting trees like *Ficus racemosa, Syzygium sp.*, Mango, Guava and *Artocarpus heterophyllus.* The villages were relocated 10-15 years ago. Grass cover is dominated by *Aristida sp.* and *Heteropogon sp.* Shrub species present in this habitat includes *Colebrookea oppositifolia.*

5. **Riparian areas-** This habitat type includes both dry and active streams, forest patches having dense canopy (>80%), high liana density, taller mature trees (some having buttresses). Fruiting tree diversity includes trees like *Caryota urens, Terminalia chebula, Diospyros sp., Palaquium ellipticum, 'Biba', Syzygium cumini* and many others. The understory is dominated by lianas and 'dhad-dhada' (grid scale) and ferns around the streams (camera trap location). Most of the riparian areas sampled were dried while some had small pools of water.

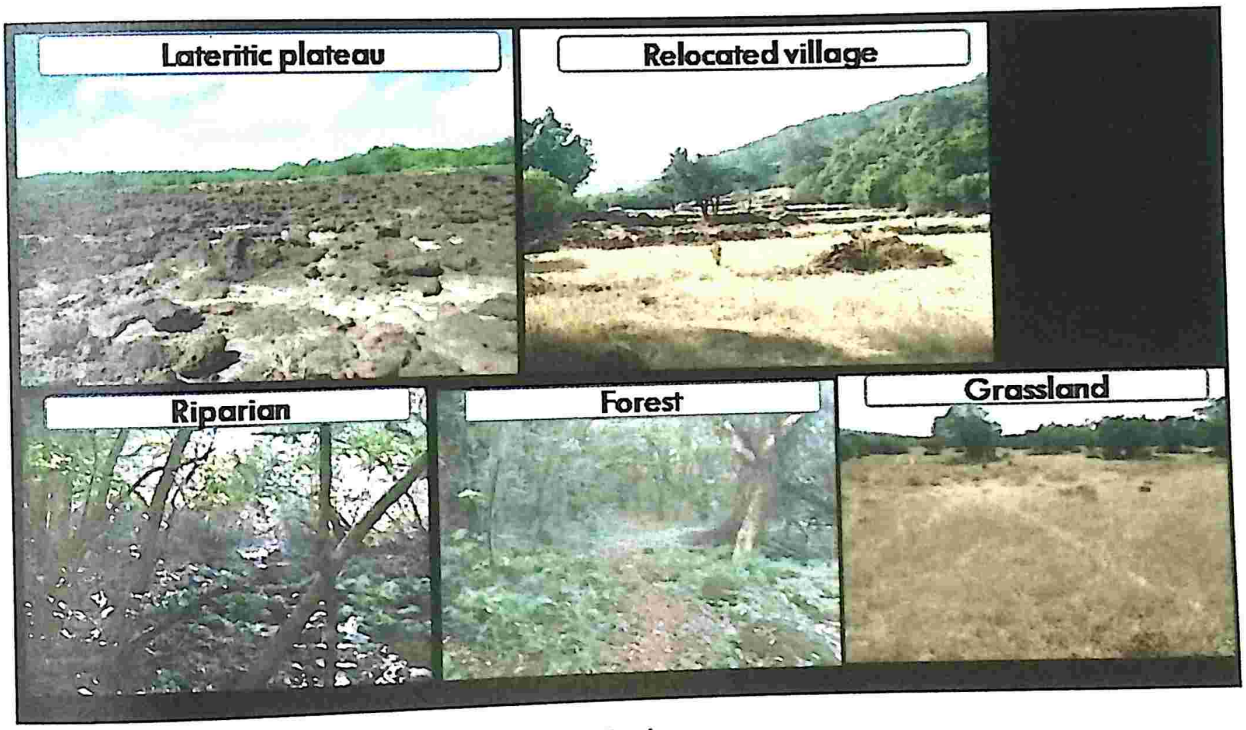

Figure 1 Habitat types in Chandoli National Park

3. Study Area Map:

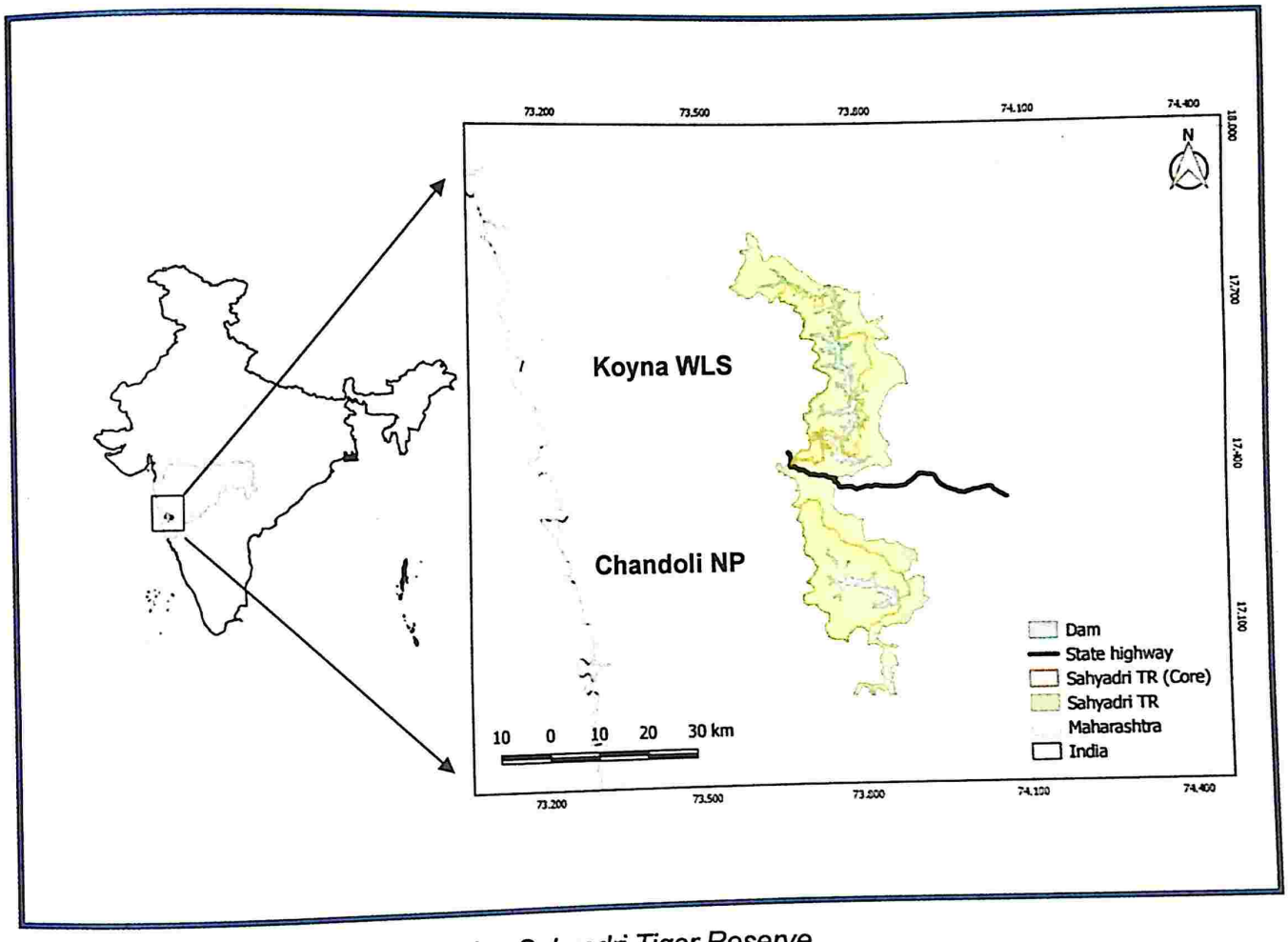

Figure 2 Study area map showing Sahyadri Tiger Reserve

Intensive Study Area

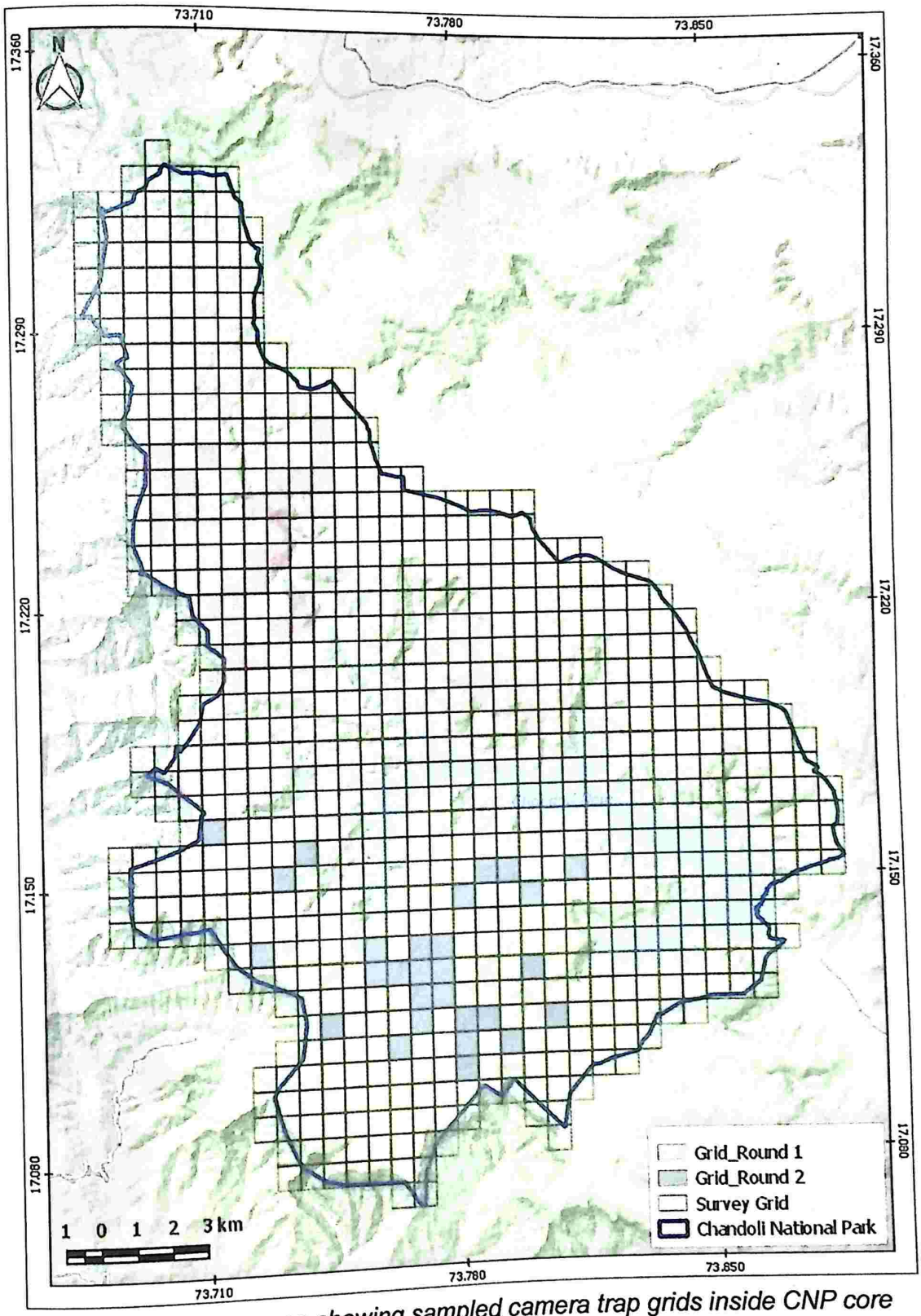

Figure 3 Study area map showing sampled camera trap grids inside CNP core area

4. Methods

4.1 Field Methods:

To determine the species richness of small carnivores in the study area

4.1 a. Camera trapping

A reconnaissance survey was conducted from December 2018 – January 2019 in the study area in which accessible trails were walked looking for indirect signs including scats, pugmarks to decide ideal camera trap locations. Accessible grids and ideal camera trap locations were recorded using handheld GPS *eTrex20*. *Cuddeback* C1 model (both flash and infrared) was used for camera trapping. Camera traps (N=72) were placed strategically (at height of 30-45cm) to maximize photo-captures of small carnivores on nature trails, forest roads and trails near streams (riparian areas). The cameras were active for mean 43 days during the month of Feb-April 2019. Camera traps were placed inside the core area of the national park to avoid theft and damage.

The interval was set to FAP setting (Fast as Possible, ¼ sec trigger speed, active for 24hrs/day) so as to avoid missing any captures of fast-moving individuals. The STRB power that takes into account the flash intensity in the white flash camera was kept at a minimum (mode: CLOSE). In areas devoid of human presence, cameras were scraped using leaves from the adjoining tree to reduce leaving olfactory cues for the animal. The inter-camera distance was kept between 250-400m. Baits or lures were avoided at any location so as to not interfere with the movement pattern of small carnivores.

Camera trapping was done in two blocks taking into account the habitat heterogeneity and accessibility. Cameras were placed in a grid size of 0.5km^2 (700m*700m) with one camera trap per grid. The grid size was selected to encompass the maximum daily movements of species like mongoose and civet based on their known home ranges from published literature. (Refer to table no. 2)

4.1 b. Sign Survey

Trails of varying length (5-10km) were walked in every forest beat as part of the reconnaissance survey. Places like fallen logs, boulders in dried streams, leaf litter and animal trails were searched for scats. The location, substrate, habitat and dominant food material were recorded using photographs.

Table 2 Small carnivore home ranges from published literature

Species	Habitat	n	Home range (estimation method may vary)	Citation
Herpestes edwardsii	Thorn scrub, open deciduous	1	0.034- 0.049 km^2	(Umapathy & Kumar, 1999)
Paradoxurus hermaphroditus	Mixed deciduous, dry dipterocarp and dry evergreen forest	5	0.72km^2 average monthly range	(Rabinowitz, 1991)
Paradoxurus hermaphroditus	Deciduous Forest	4	0.141 km^2	(Joshi, David Smith, & Cuthbert, 1995)
Herpestes auropunctatus	Coastal forest and grassland		0.39km^2 (male) 0.22km^2 (female)	(Gorman 1978)
Herpestes fuscus	Evergreen forest	1	0.171 km^2	(Jathanna 2016)
Paradoxurus jerdonii	Evergreen forest	7	0.06 -0.57 km^2	(Mudappa 1999)

Habitat parameters collected for determining species-habitat relationship

4.1 c. Habitat Survey

Habitat variables including canopy cover, average tree height, fruiting tree species, undergrowth category, habitat and trail type were recorded for the area within the proximity of camera trap location. Habitat type was divided into five categories, which included grassland, forest, riparian, relocated village and plateau. Trail type was divided into three categories based on usage: animal (used by animals but not by humans, trail width usually less than 1.5m), human (used by both humans and animals) and forest road (used by vehicles). The average tree height was recorded based on ocular estimation using a 1m stick for reference. Canopy cover was sub-divided into four categories: open (0-40%), moderate (40-60%), dense (60-80%) and very dense (80-100%). The undergrowth was categorised into five categories based on the dominant vegetation cover near the camera trap location. These categories were i) liana (including climbers like *Grewia sp., Gnetum sp.*etc), ii) *Strobilanthes callosus (locally called as' karvi')*, iii) Dhad-dhada, iv) Grass and v) Rocks (including boulders and lateritic plateaus).

4.1 d. Predator presence

Capture probabilities of Wild dog (*Cuon alpinus*) and Leopard (*Panthera pardus*) were used as a surrogate of relative predator presence in respective camera trap location. Although cameras were placed to optimize detections of small carnivores, leopards were noticed using all type of trails.

Capture Probability = (Number of independent record of a species)/ active Number of days of the respective camera

(*independence decided by a difference of ≥ minute between two consecutive captures)

4.2 Analytical Methods

4.2 a. Determining time-activity patterns and temporal overlap

Camera trap data was sorted into species-wise folders and further analysis conducted using package '*camtrapR*' in software R version 3.6.0.(Niedballa, Sollmann, Courtiol, & Wilting, 2016) Inter-species variation of time-activity pattern between species was estimated using 'activityOverlap' command (Rowcliffe *et al* 2014). Statistical analysis was done in *Rstudio* and *Microsoft Excel*. Oriana software was used to prepare graphs for time activity patterns.

4.2 b. Assessing the determinants of small carnivore's presence

To understand the factors influencing small carnivores' distribution kernel density heat maps were created using arcGIS 10.2 software. Further comparison between capture rates and habitat parameters was done using the species-habitat matrix.

5. Results

5.1 a. Camera trapping summary

Camera trapping was active for mean 43 days leading to 2900 trap nights which resulted in photo-captures of 24 different species of wild mammals (refer annexure) including 10 species of small carnivores (considering otters and small cats) in 2900 trap nights. A total of 645 independent captures were recorded for small carnivores in the study area (independence defined by time difference ≥60 seconds between successive photo captures of same species at a location). Tiger (*Panthera tigris*) known to occur in the study area was not photo-captured during the sampling duration. Golden Jackal was also absent from the intensive study area but was present at lower elevations near villages around Chiplun-Karad state highway.

Species distribution was examined for six species of small carnivores including three species of civets (Asian palm civet, Brown palm civet, and Small Indian civet), three species of mongooses (Ruddy mongoose, Indian grey mongoose and Striped-necked mongoose).

Apart from small carnivores, other rare species photo-captured in camera trap included Indian Pangolin (*Manis crassicaudata)* and Four Horned Antelope (*Tetracerus quadricornis,* locally called as '*Malsanda*')

Table 3 Small carnivores recorded from study area

Common name	**Scientific name**	**IUCN Status**	**Locations Captured (67)**	**Number of independent records**
Ruddy mongoose	*Herpestes smithii*	Least Concern	25	175
Small indian civet	*Viverricula indica*	Least Concern	31	164
Striped-necked mongoose	*Herpestes vitticollis*	Least Concern	15	31
Small-clawed otter	*Aonyx cinerea*	Vulnerable	3	12

Jungle cat	*Felis chaus*	Least Concern	13	57
Grey mongoose	*Herpestes edwardsii*	Least Concern	13	50
Common palm civet	*Paradoxurus hermaphrodites*	Least Concern	24	104
Brown palm civet	*Paradoxurus jerdoni*	Least Concern	10	42
Rusty-spotted cat	*Prionailurus rubiginosus*	Near Threatened	3	4
Leopard cat	*Prionailurus bengalensis*	Least Concern	5	6
				645

5.1 b. Sign survey results

A total of N=134 scats were identified as small carnivore's scat based on their size and structure. Out of these, palm civets' scat could be easily distinguished due to the presence of a large number of seeds. Civet scats observed (N=109) showed monthly variation in seeds eaten (figure 3) and consisted largely 5 species viz. *Gnetum ula, Diospyros sylvatica, Syzygium sp., Grewia sp., Caryota urens* (Plate 2).

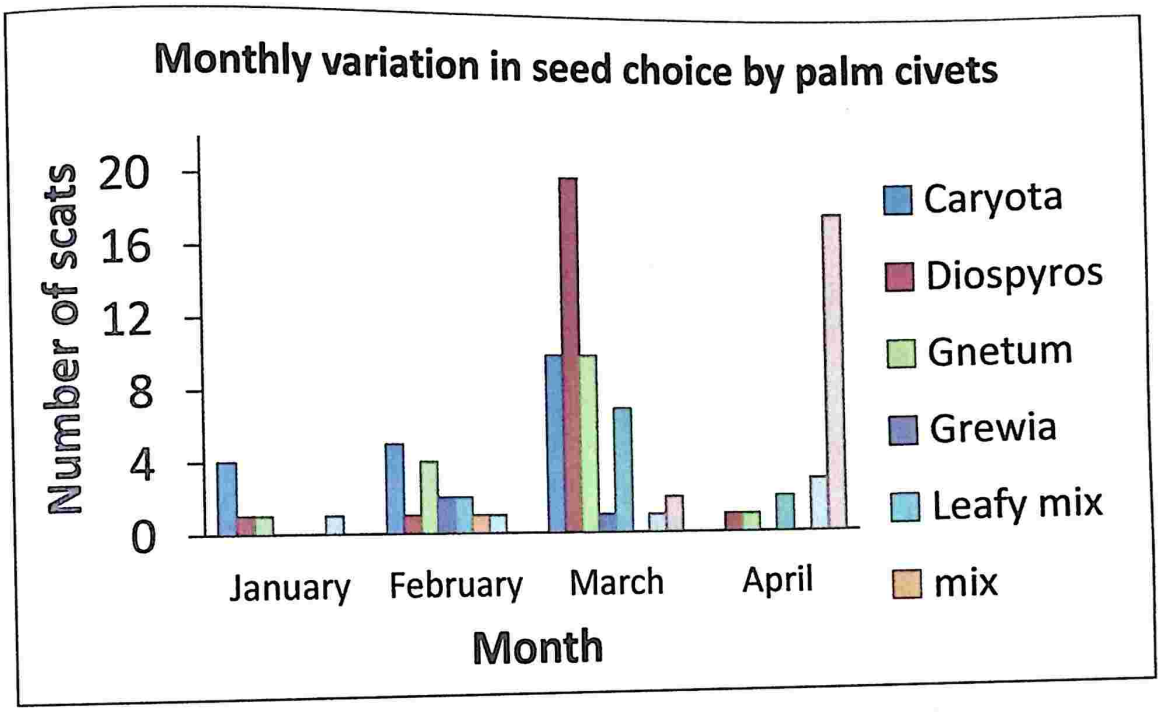

Figure 4 Monthly variations in major seed consumed by palm civets

Boulders in riparian habitats (usually dried streams) were extensively used as a substrate by palm civets for defecation along with bare ground and fallen logs. Two civet scats were recorded from watchtower and culvert having *Gnetum ula* seeds. Nine otter spraints were also recorded in hilly streams (elevation more than 850m) consisting entirely of crab shells (Hussain, Gupta, & Silva, 2011) indicating them to be of Small-clawed Otter. The spraints were observed on rocky substrate, usually boulders in riparian habitat.

Table 4 Major seed type-habitat association showing number of scats recorded for palm civets

Row Labels	Caryota	Diospyros	Gnetum	Grewia	Leafy Mix	Palaquium	Syzygium
Forest	12	12	5	2	3	2	8
Grassland	-	3	-	-	4	2	7
Other	-	2	-	-	-	-	1
Riparian	7	1	10	-	2	2	1
Sada (LP)	-	5	1	1	2	-	3

Figure 5 Major scat types of palm civets observed in the dry season

5.2 Factors influencing small carnivore species presence in the study area

5.2 a. Herpestids distribution in Chandoli National Park

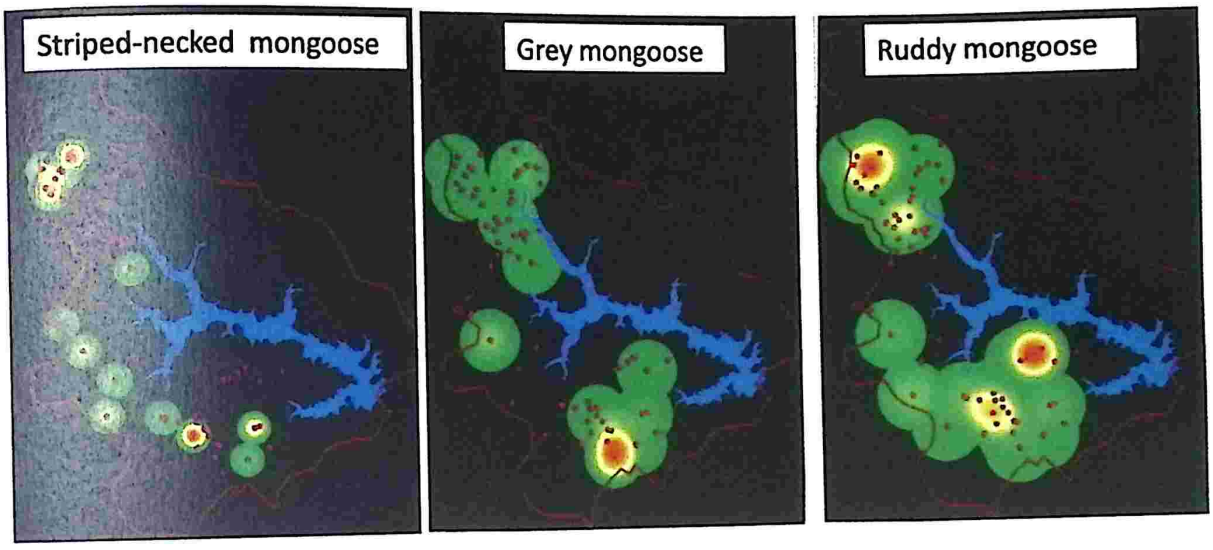

Figure 6 Heat map showing mongoose distribution in sampled area

Ruddy mongoose was independently captured in 25 locations (n=175). It showed association with riparian patches and lateritic plateaus (70% of captures from all camera trap locations). It was widely distributed and present in both the sampled blocks.

Indian Grey mongoose was recorded from 13 camera trap locations (n= 50 independent records). It was found mainly in open-scrub forest (76% of all captures) with undergrowth of grass or *Strobilanthes callosus* (86% of all grey mongoose captures). It was relatively more common in Chandoli range. The species was recorded in elevation range 850-1000m.

Striped-necked mongoose was photo-captured from 15 camera trap locations (n=31). It was recorded largely from camera-traps located near streams (80% of all captures). It showed spatial overlap primarily with Ruddy mongoose.

5.2 b. Viverrids distribution in Chandoli National Park

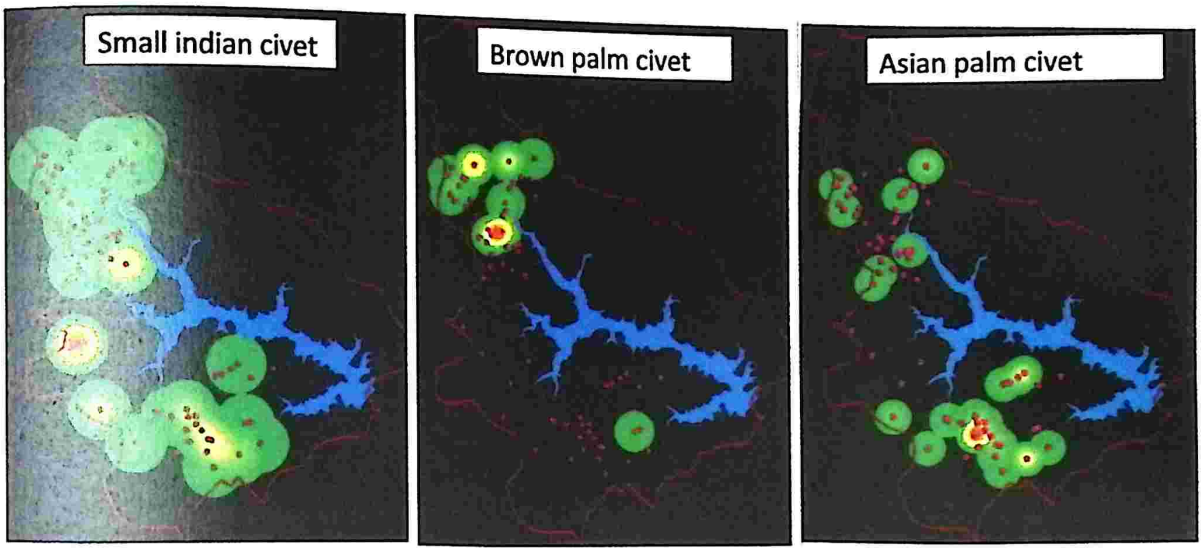

Figure 7 Heat maps showing civets distribution in sampled area

Small Indian civet had the highest number of photo-captures amongst viverrids (n=164) which can be attributed to its widespread distribution and terrestrial habit compared to other two palm civets. It was mostly recorded from relocated villages and habitat edges of lateritic plateaus and forest. The undergrowth type where Small Indian civet was recorded primarily included grass and rock.

Asian palm civet had 104 independent photo captures from 24 camera trap locations. Brown palm civet was more restricted to semi-evergreen patches in Helwak range while Asian palm civet was distributed mainly in open scrub forest of Chandoli range. It was photo-captured along with brown palm civets at two locations indicating some degree of spatial overlap between both the species. The undergrowth types found to influence Asian palm civet included three types- grass, other and rocks. Asian palm civet was observed using all habitat types from grassland, lateritic plateaus, and relocated villages to semi-evergreen forest. Its presence in areas having shorter trees (tree height 4-6m) and open scrub or lateritic plateaus with sparsely distributed trees is indicative of more terrestrial movement between two contiguous forest patches and better adaptability than Brown palm civet.

Brown palm civet was photo-captured on 42 occasions at 10 different camera trap locations. It was photo-captured in locations having high diversity of fruiting tree species in semi-evergreen patches and was recorded mainly in riparian habitat type (9 of 10 locations). It was captured only once in the sampling block of Chandoli range and restricted to areas having tree height more than 8m near streams.

5.3 Temporal activity patterns of small carnivores in Chandoli National Park

5.3 a. Civets

Asian Palm civet (n=104) were strictly nocturnal showing bimodal activity peaks (3am-6am and 9pm-12am, histogram refer annexure). Direct opportunistic sightings of the same species were observed in the same time interval (8:35pm and 10:30pm).

Brown Palm civet (n=42) also showed bimodal activity peaks with activity peaks between 7pm-9pm and 12am-2am. Activity overlap coefficient (D-hat value) between Asian palm civet and Brown palm civet was 73 percent (Table below, Graph in annexure)

Small Indian civet (n=164) showed uni-modal activity peak showing maximum numbers of photo-captures from 12am-1am (n=35).

Table 5 Activity overlap between small carnivore species

Species 1	Number of records	Species 2	Number of records	Percentage overlap
Ruddy Mongoose	175	Grey Mongoose	50	0.86
Ruddy Mongoose	175	Striped-necked Mongoose	31	0.75
Grey Mongoose	50	Striped-necked Mongoose	31	0.81
Small Indian Civet	164	Asian Palm Civet	104	0.83
Small Indian Civet	164	Brown Palm Civet	42	0.83
Asian Palm Civet	104	Brown Palm Civet	42	0.73
Jungle Cat	57	Striped-necked Mongoose	31	0.36
Small clawed Otter	12	Striped-necked Mongoose	31	0.41
Brown Palm Civet	42	Striped-necked Mongoose	31	0.13

5.3 b. Mongoose:

Ruddy mongoose and Indian grey mongoose were diurnal with activity peaks in the afternoon hours. Striped-necked mongooses were found to be more active during morning hours (from 7-11am, n=31). The percentage activity overlap between Ruddy mongoose and Striped-necked mongoose was 75%. Grey mongoose activity overlap was found to be 81% with Striped-necked mongoose (Graph in annexure).

5.3 c. Small cats and Otters:

Jungle Cat was cathemeral having 57 independent captures. Leopard cat was captured on only six occasions, showing nocturnal behaviour. Rusty spotted cat was active at night during the interval 11pm to 4am (n=4). Asian small-clawed otter was captured from three locations and showed activity during the daytime (11am and 4pm) as well as night-time (12am until morning).

5.4 Activity overlap of small carnivores and predators

Small carnivores showed temporal segregation with respect to large carnivores while exhibiting spatial overlap. The degree of overlap in time-activity patterns was tested for various combinations of two species involving predators and small carnivores. Mongoose species had different activity periods when compared with leopards. Temporal segregation observed in small carnivores helps in avoiding predators while sharing same habitat. The lower value of percentage overlap signifies different time-activity periods.

Table 6 Activity overlap between small carnivores and large predators

Species 1	Number of records	Species 2	Number of records	Percentage overlap
Leopard	165	Ruddy Mongoose	175	0.44
Leopard	165	Grey Mongoose	50	0.42
Leopard	165	Brown Palm Civet	42	0.63
Leopard	165	Striped-necked Mongoose	31	0.42
Leopard	165	Small Indian Civet	164	0.61
Dhole	51	Small Indian Civet	164	0.36

Dhole	51	Jungle cat	57	0.45
Dhole	51	Ruddy Mongoose	175	0.40
Dhole	51	Striped-necked Mongoose	31	0.42
Dhole	51	Grey Mongoose	50	0.37

6. Discussion

The present study looked at the spatial and temporal patterns of small carnivore community structure in the northern Western Ghats. Fine-scale camera trapping was carried out in a grid size of 0.5 Km^2 to detect these elusive animals and understand their habitat associations. Camera trapping resulted in documenting ten species of small carnivores (including small cats). The habitat variables collected in the study included canopy cover, tree height, undergrowth type and habitat type.

Baits and lures were avoided in the current study as efficacy of baits and lures itself becomes one of the factors influencing species movement and behavior. For studying species distribution or habitat association, it will probably lead to skewed results. Incorporating bait efficacy and replacing baits accordingly at every trap location would help us to conduct large-scale study on rare and elusive animals (Mills 2019). This approach would increase detection probability and possibly lead to better understanding of rare animal distribution over larger area which can be prioritized for protection and further fine scale research.

Sign survey results provided better insights into the dietary patterns of palm civets in the dry season, which included various species of endemic fruiting trees of Western Ghats. The main component of diet varied from *Diospyros sylvatica* in February to *Syzygium cuminii* in April. Civet scats in riparian habitats showed frequent occurrence of the seeds of climber *Gnetum ula* and *Grewia sp.* These results depicts preference for fruits of trees and lianas than herbs or shrubs which is similar to the long-term study done on Brown palm civets in rainforest habitat of KMTR (Mudappa, Kumar, & Chellam, 2010). Indirect signs also help us to determine species presence in open scrub habitats or grasslands (in close proximity to forests) where trails are not evident enough to decide ideal camera trap locations.

Civets have shown seasonal variation in diet from previous long-term studies (Mudappa et al., 2010; Zhou et al., 2008) In the present study, a shift in fruit choice was observed from January to April. Knowing the main seed species helps us to further study the regeneration and dispersal processes of endemic tree species. Future studies exploring the seasonal variation in diet patterns of civet species would enhance the ecological knowledge of plant-animal association and help us in better conservation and management of remaining semi-evergreen forest tracts in northern Western Ghats.

The bias of sampling in areas with low or negligible human influence is evident and was done to avoid losing camera traps from villagers living closer to the forest. Sampling in disturbed habitats provides only a subset of complete diversity known to occur in an area. Protected areas provide good control sites for comparison between disturbed and undisturbed sites and help us better understand species tolerance and adaptability. Further research should be carried out outside protected areas using community participation and involvement. Human presence outside protected area is expected to show negative effect for habitat specialist species considering slash and burn practices, presence of dogs, absence of continuous tracts of forest (due to agriculture and sugarcane plantation). Sahyadri range lacks connectivity considering large continuous tracts of forests when compared with southern Western Ghats and declining population might lead to local extinctions of species having specialized habitat requirements.

Mountain streams having intact riparian habitats showed more photo-captures of endemic small carnivores' presence, which emphasizes the specialized habitat requirements of Brown palm civet and Striped-necked mongoose. These habitat associations can be explained by presence of intact forest patches having high fruiting tree diversity and large boulders present in these hilly streams providing suitable cover, substrate for defecating, availability of invertebrates.

Felids including Rusty spotted cat and Leopard cat were rarely photo-captured, the reason for this could possibly be associated with semi-arboreal habit, trap-shyness, restricted movement pattern along different trails or presence in low densities. Surprisingly, palm

civets also known to be semi-arboreal were captured in comparatively more locations. Otters being riverine species were excluded from the study design and were not the prime-focus but opportunistically photo-captured in first and second order hilly streams. Small-clawed otter are the smallest otter species in the world and have limited distribution requiring undisturbed streams and specialized diet of freshwater crabs (Hussain et al., 2011). New localities were found for small-clawed otter from current study that could help in better conservation by mapping distributions and avoiding management interventions like building check dams in these areas.

This study was conducted in the dry season and study area was limited due to logistics. Using relative abundance indices including species independent records (counts) or capture probabilities is not the best possible way considering different confounding variables involved. The confounding factors while using counts or independent records are difference in the detection zone in front of the camera, movement of study species near camera trap and bias while deciding trap locations. These confounding factors lead to false inferences while explaining the species-habitat relationships and should be better understood beforehand.

Relationship between sympatric carnivores

Temporal patterns pointed out considerable degree of temporal overlap between species like Ruddy mongoose and Indian grey mongoose. Small Indian Civet and Asian Palm civet also had higher temporal overlap. These being the generalist species differed in time activity patterns when compared with endemic species like Striped-necked mongoose and Brown palm civet. Brown palm civet exhibited localized distribution and limited spatial overlap with other civet species. Its activity pattern showed bimodal activity peaks between 7-9pm and 12-2am. There was less than 50% temporal overlap for mongooses and Leopard showing possible temporal segregation. Sympatric species sharing similar dietary and habitat requirements were expected to differ in their temporal activity patterns to avoid competition and improve foraging. Lunar cycles could also possibly influence carnivore activity patterns and needs to be further explored (Bhatt, Habib, Sarma, & L., 2018; Bischof,

Ali, Kabir, Hameed, & Nawaz, 2014). The activity peaks could possibly be restricted to dry season and needs post monsoon sampling to confirm similarity or differences between different seasons.

Conducting further long-term studies on small carnivores while incorporating seasonal variation and density estimation across the Western Ghats would help us better understand these lesser-known species which will facilitate their conservation ensuring proper functioning of trophic dynamics.

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Reference section prepared using Journal of Applied Ecology citation style both in text and bibliography

Annexure 1

Substrate-habitat association where civet scat was observed (n = 109)

	Habitat				Grand Total
Substrate	**Forest**	**Grassland**	**Plateau**	**Riparian**	
Fallen Log	6	-	-	-	6
Grass	-	13	-	-	13
Ground	14	14	1	-	29
Leaf Litter	14	-	-	1	15
Man made	1	-	1	-	2
Rock	7	2	5	30	44
Total	41	29	7	31	(109)

Other wild mammals photo-captured in Chandoli National Park

Common name	**Scientific Name**	**IUCN status**	**Locations Captured (70)**	**Number of independent records**
Barking deer	*Muntiacus muntjak*	Least Concern	47	241
Black-naped hare	*Lepus nigricollis*	Least Concern	23	227
Bonnet Macaque	*Macaca radiata*	Least Concern	1	3
Dhole	*Cuon alpinus*	Endangered	18	51
Four-horned antelope	*Tetracerus quadricornis*	Vulnerable	4	18
Gaur	*Bos gaurus*	Vulnerable	48	448
Hanuman Langur	*Semnopithecus sp.*	Least Concern	24	79
Leopard	*Panthera pardus*	Vulnerable	41	165
Mouse deer	*Moschiola indica*	Least Concern	26	118
Pangolin	*Manis crassicaudata*	Endangered	5	5

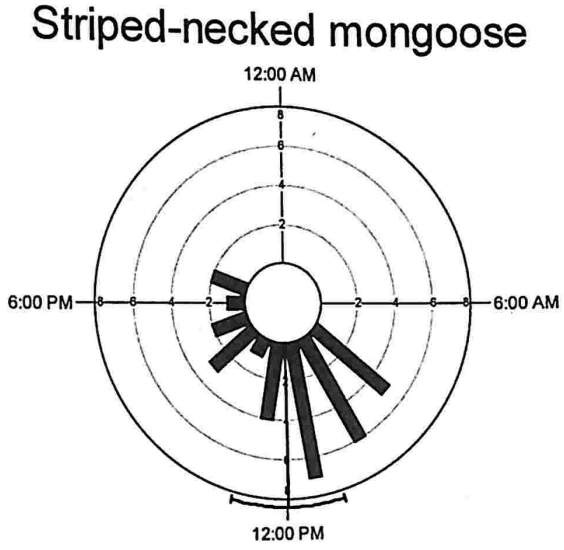
Porcupine	*Hystrix indica*	Least Concern	47	299
Sambar	*Rusa unicolor*	Vulnerable	28	92
Sloth bear	*Melursus ursinus*	Vulnerable	46	188
Wild Boar	*Sus scrofa*	Least Concern	53	406

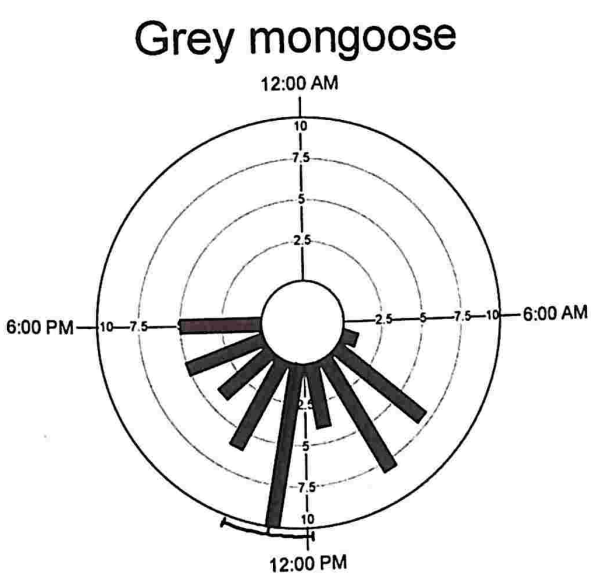
Small carnivores observed in the study area

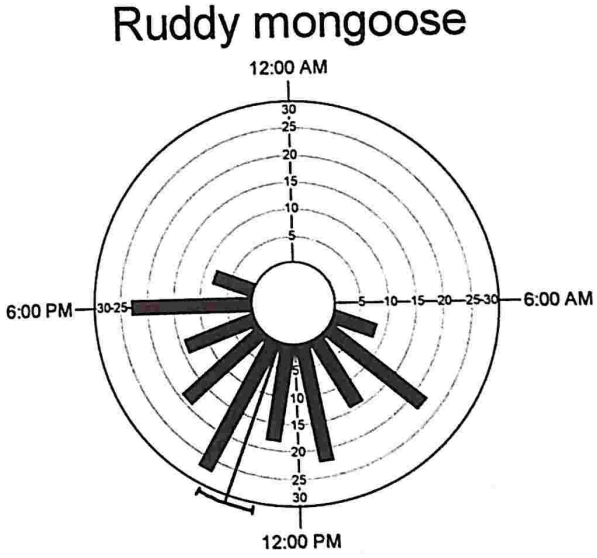
A: Rusty-spotted cat, B: Leopard cat, C: Jungle cat, D: Grey mongoose, E: Ruddy mongoose, F: Striped-necked mongoose, G: Common palm civet, H: Small Indian civet, I: Brown palm civet

Annexure 2

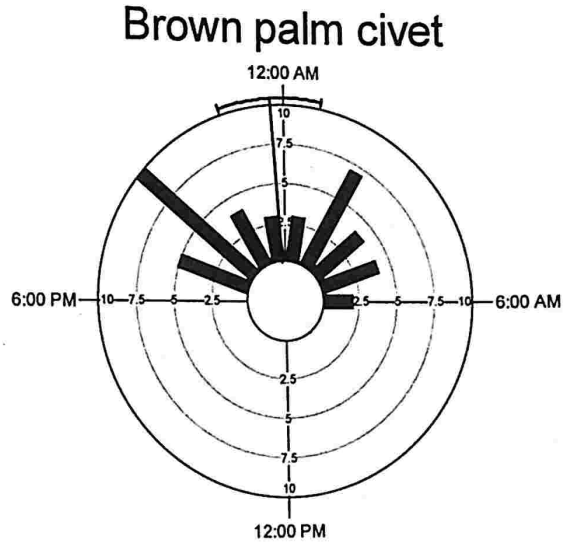
Temporal activity patterns of mongooses

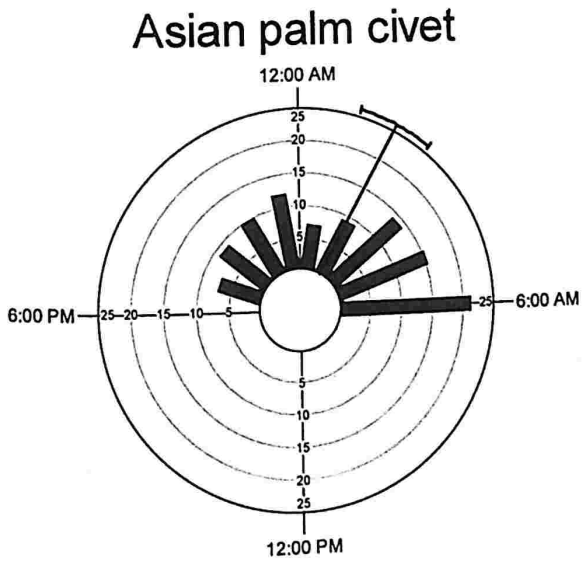


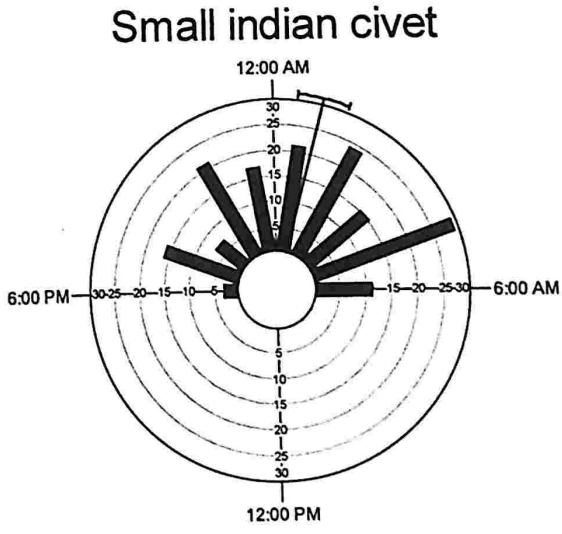




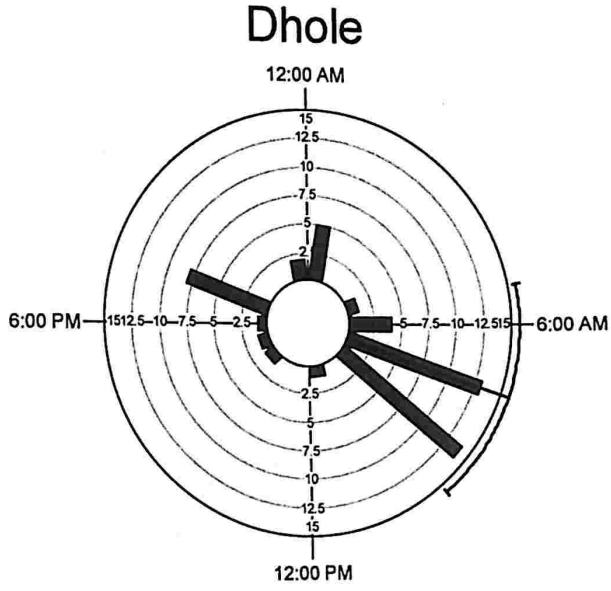
Temporal activity patterns of Civets

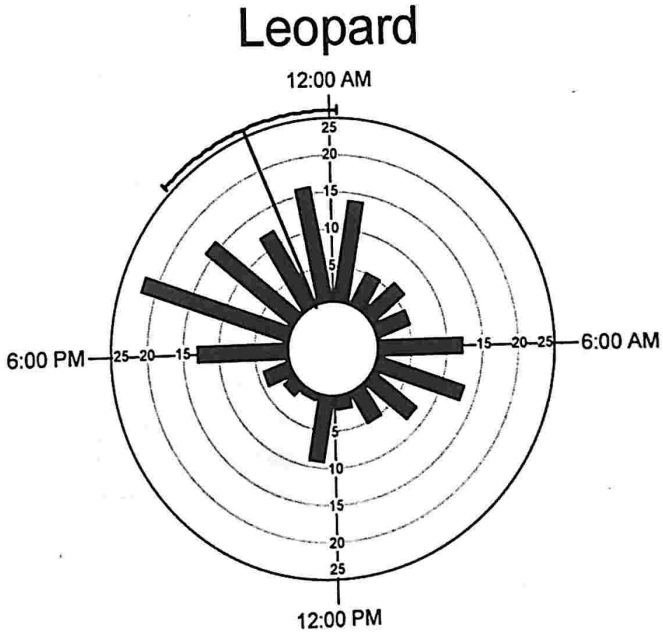




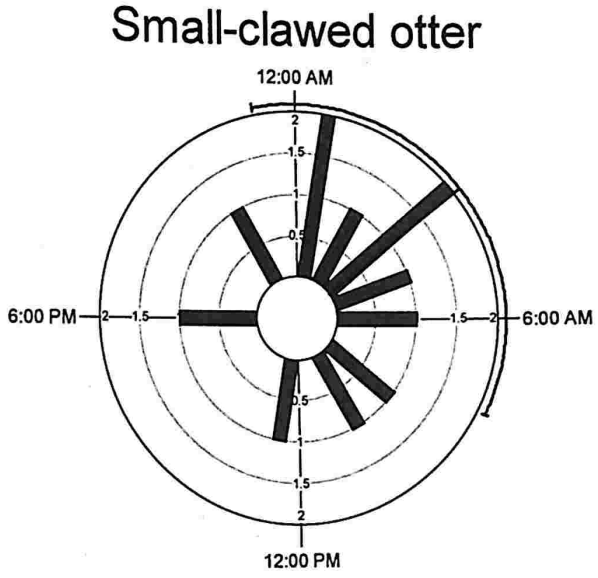


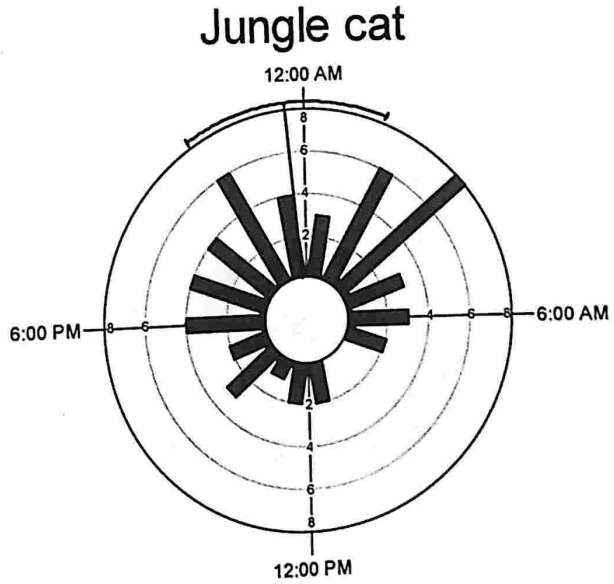
Time-activity patterns of Predators





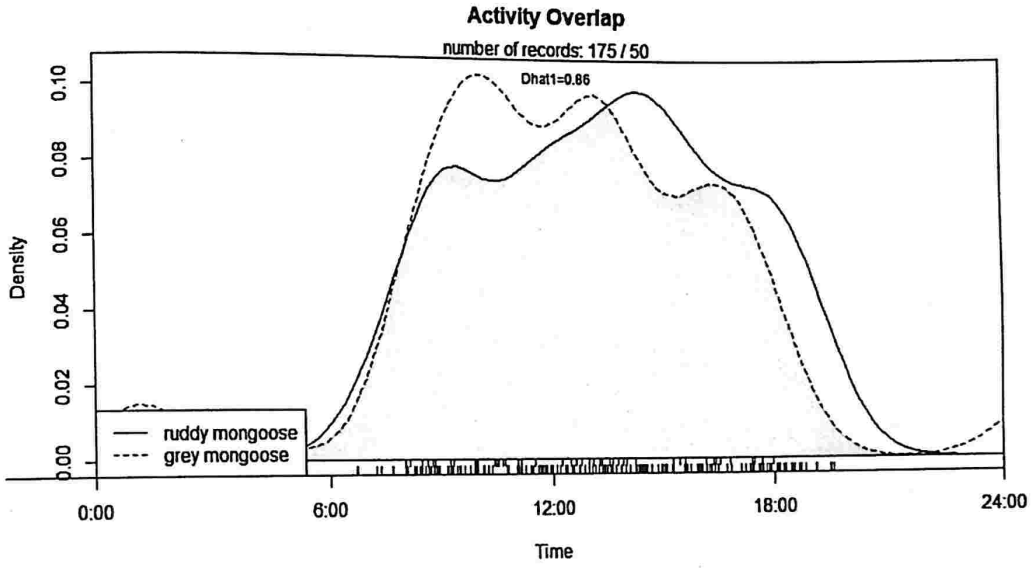
Time activity patterns of Small-clawed otter and Jungle cat



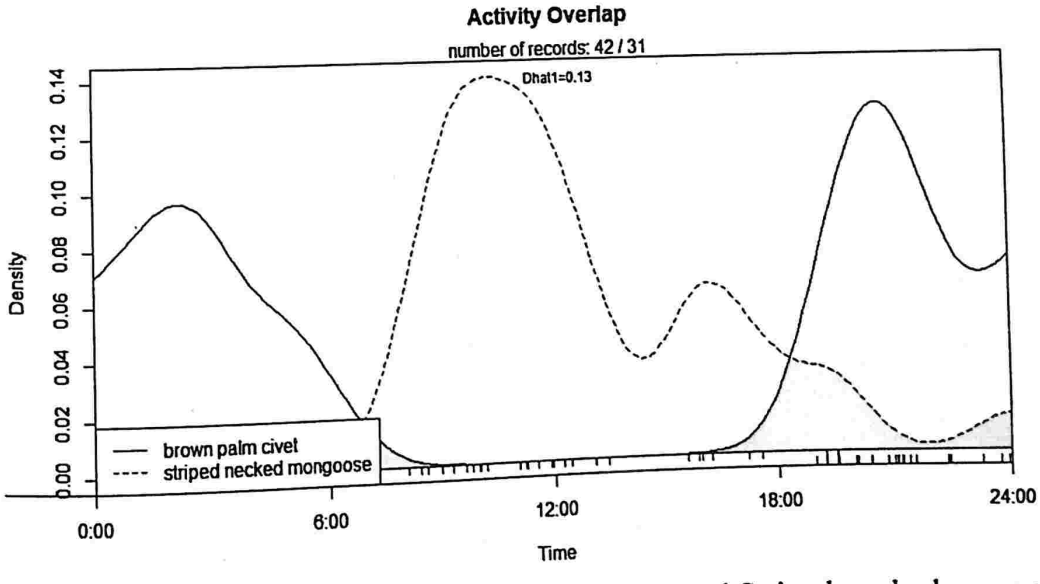


Annexure 3

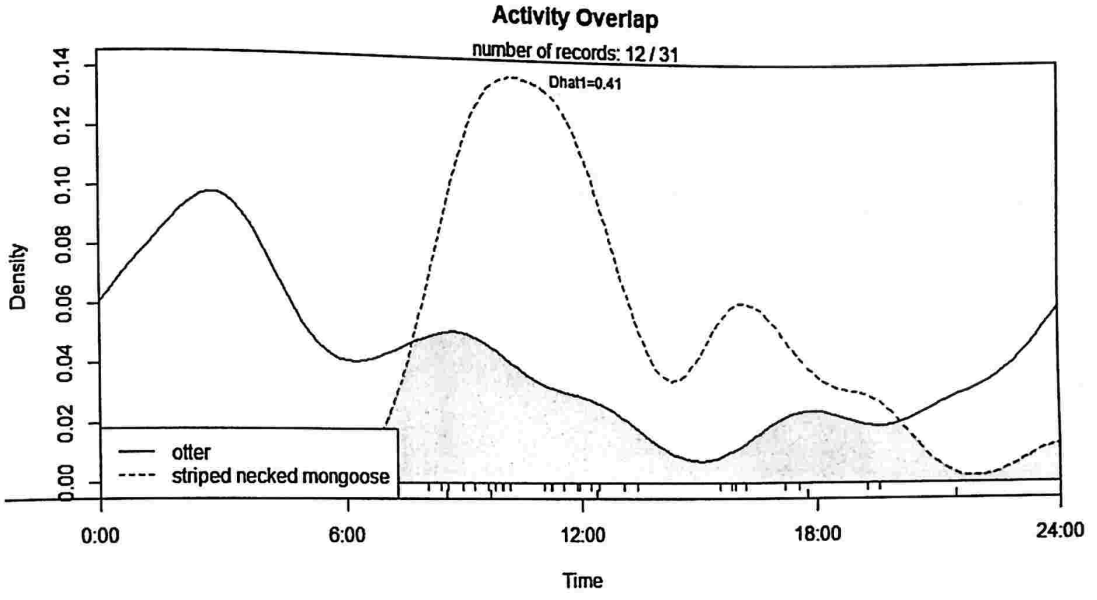
Time activity overlap of small carnivores



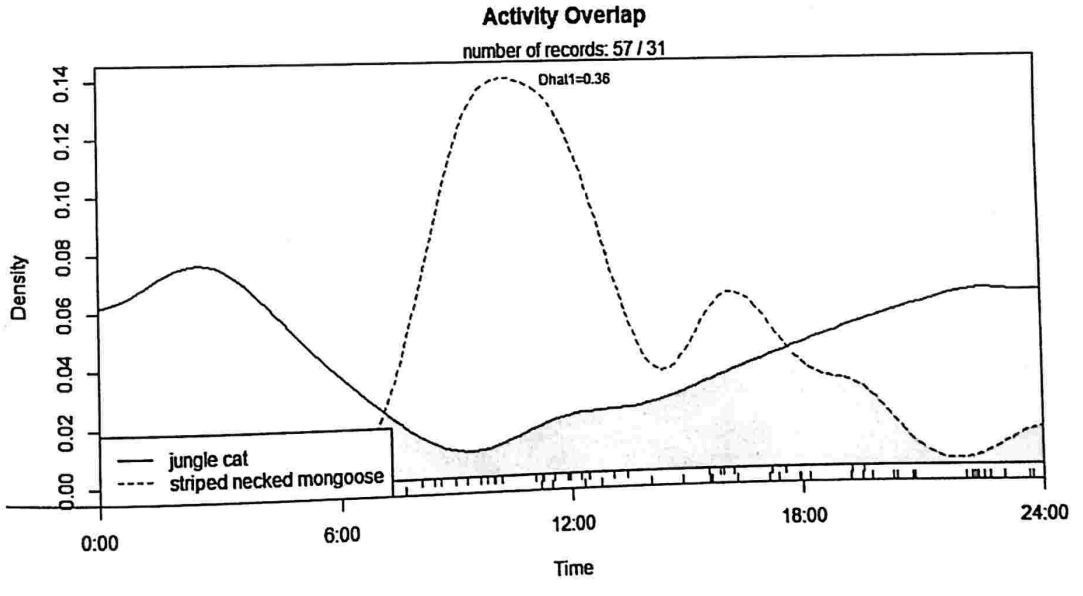
Time activity overlap of Ruddy mongoose and Grey mongoose



Time activity overlap of Brown palm civet and Striped-necked mongoose

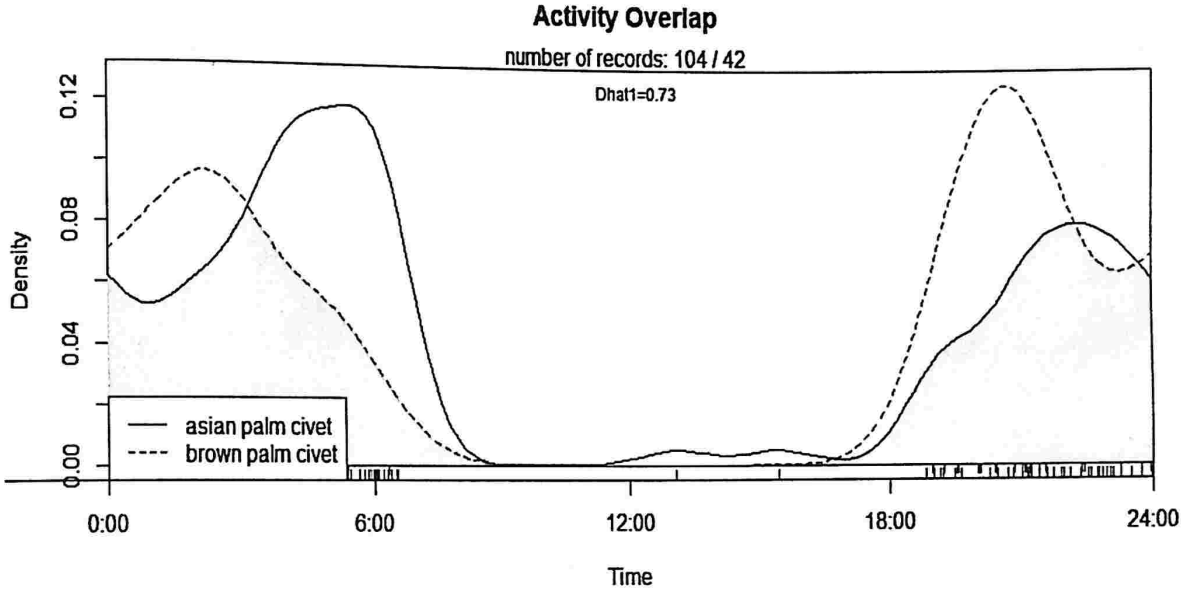


Time activity overlap of Small-clawed otter and Striped-necked mongoose

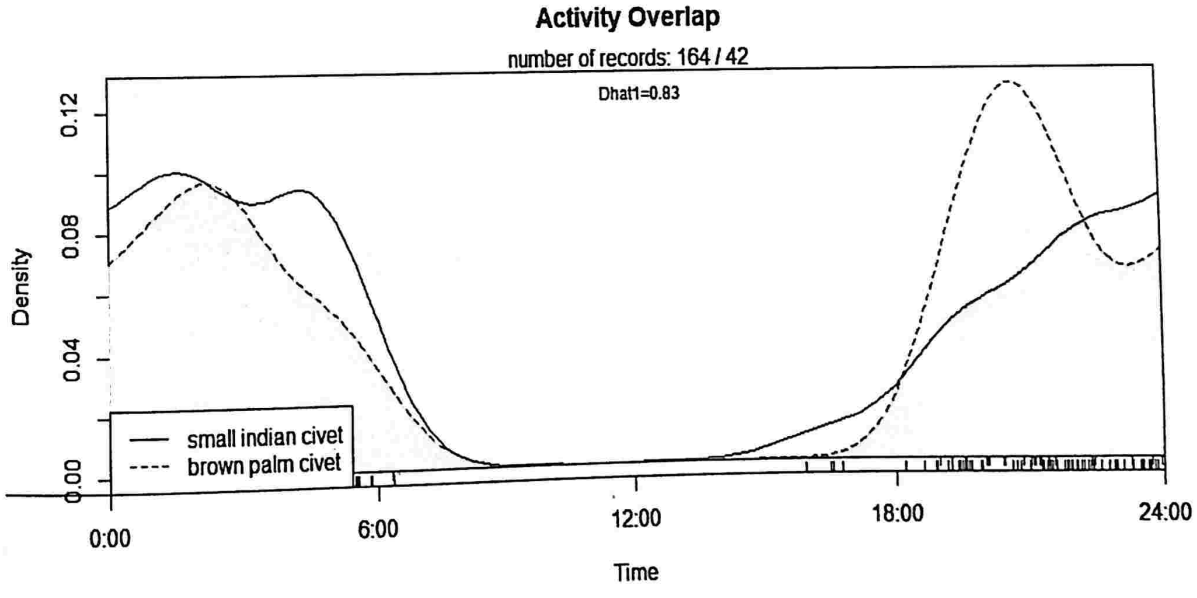


Time activity overlap of Jungle cat and Striped-necked mongoose

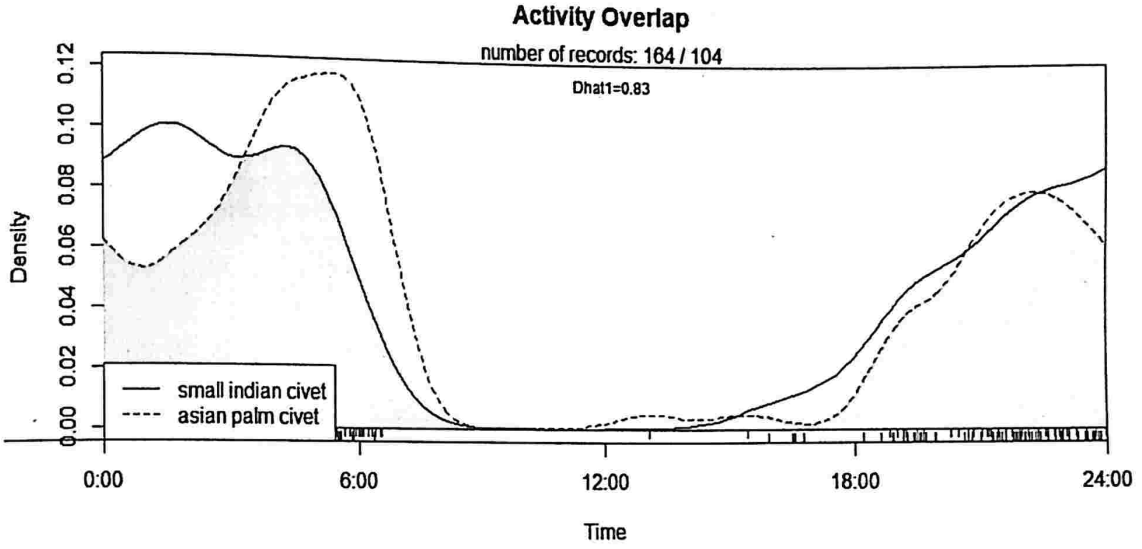
Activity patterns of Sympatric Viverrids (Civets)



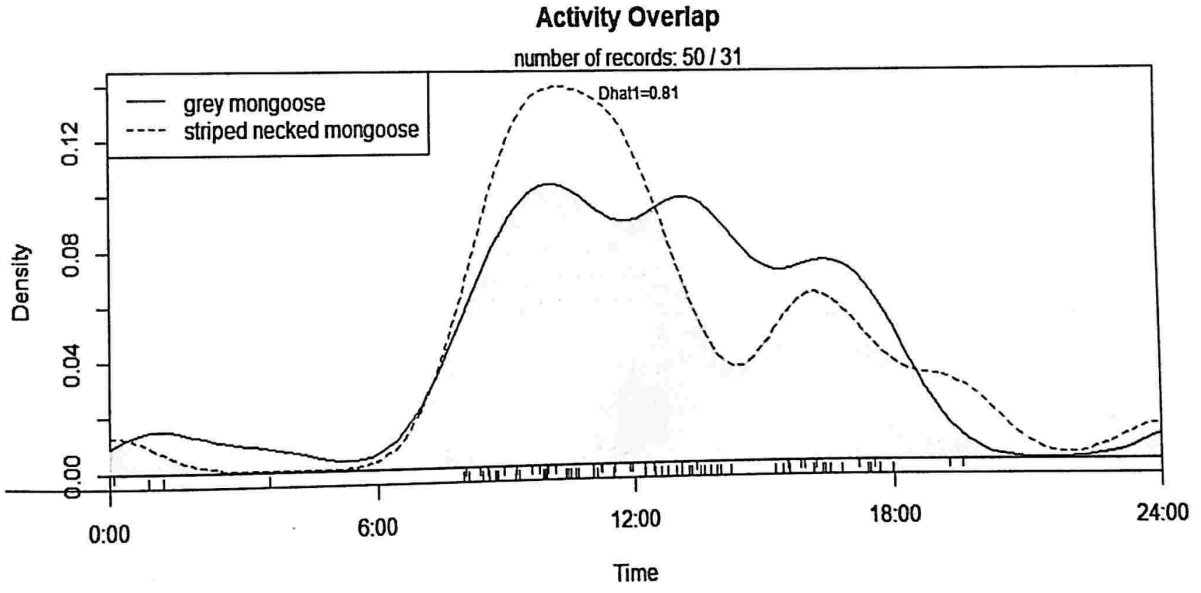
Time activity overlap of Asian palm civet and Brown palm civet



Time activity overlap of Small Indian civet and Brown palm civet

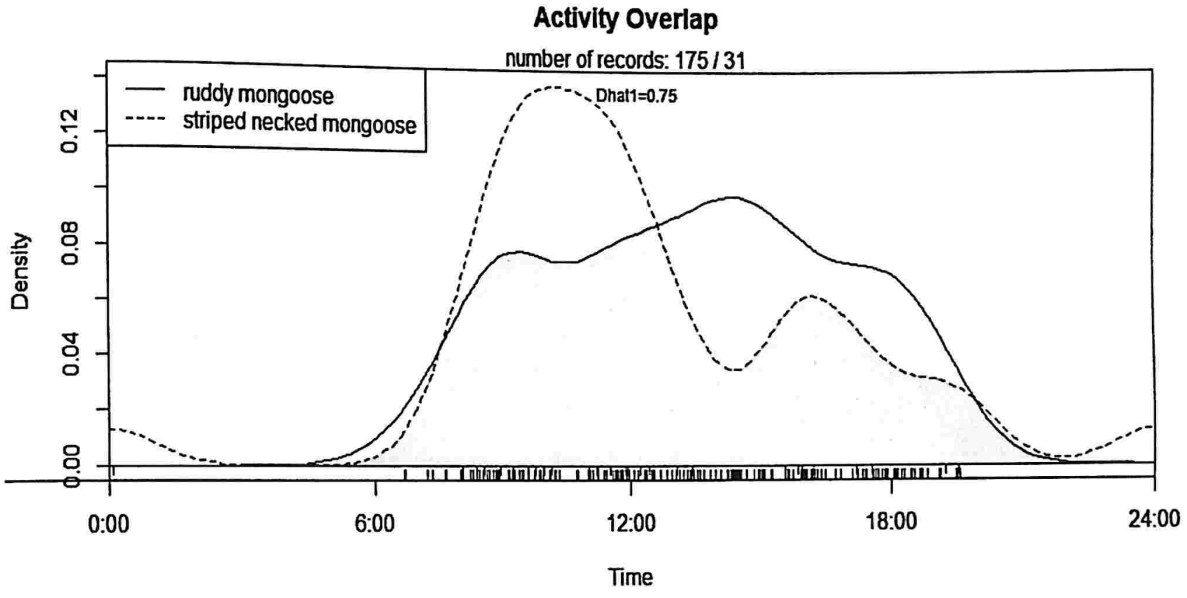


Time activity overlap of Small Indian civet and Brown palm civet

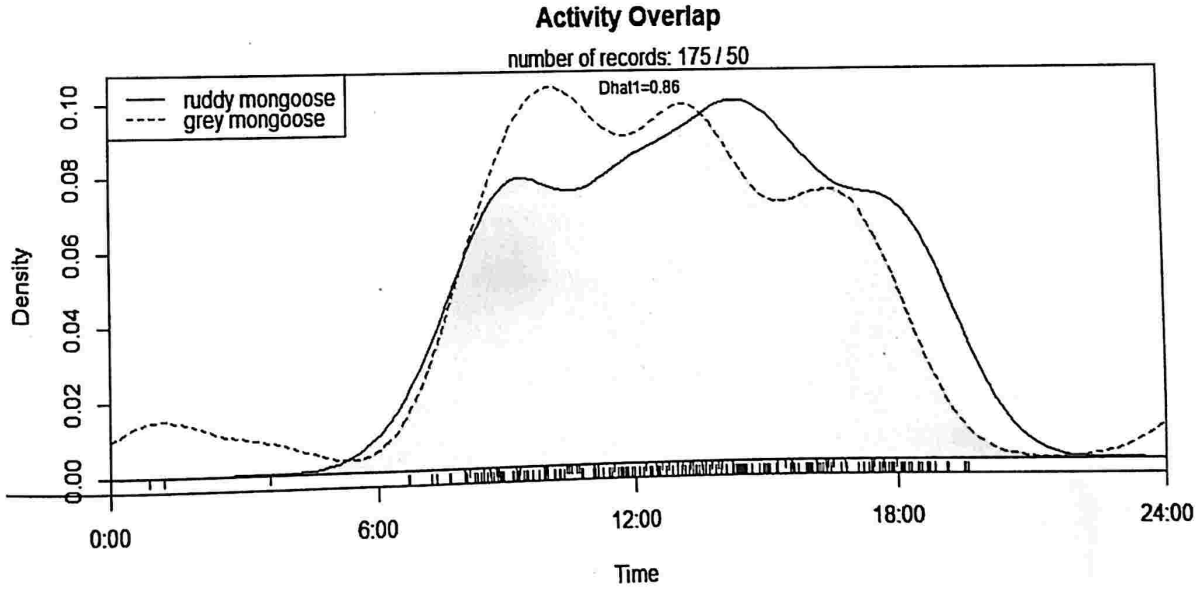


Time activity overlap of Grey mongoose and Striped-necked mongoose

Activity overlap of mongooses

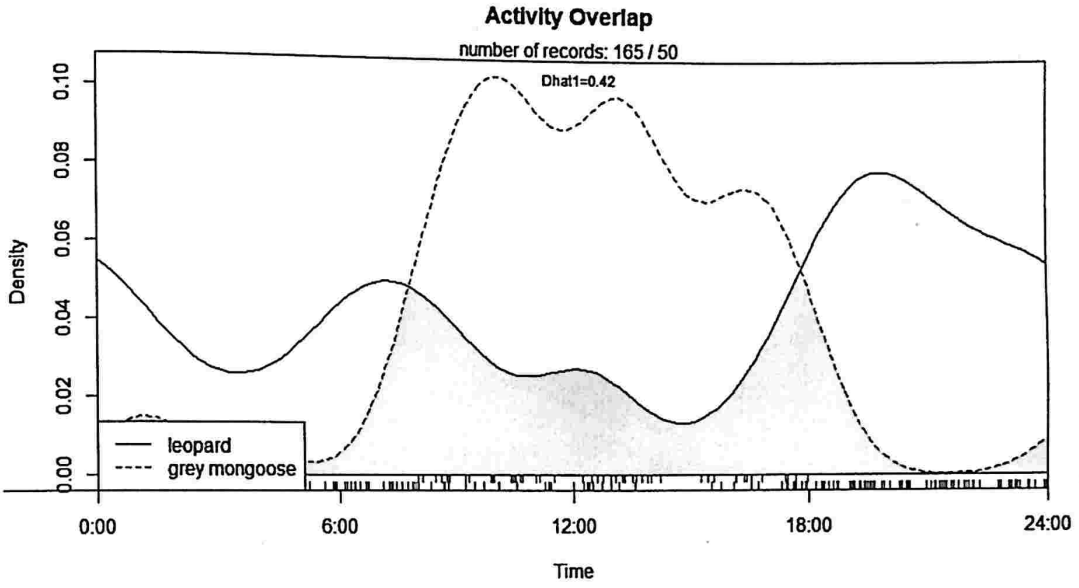


Time activity overlap of Ruddy mongoose and Striped-necked mongoose

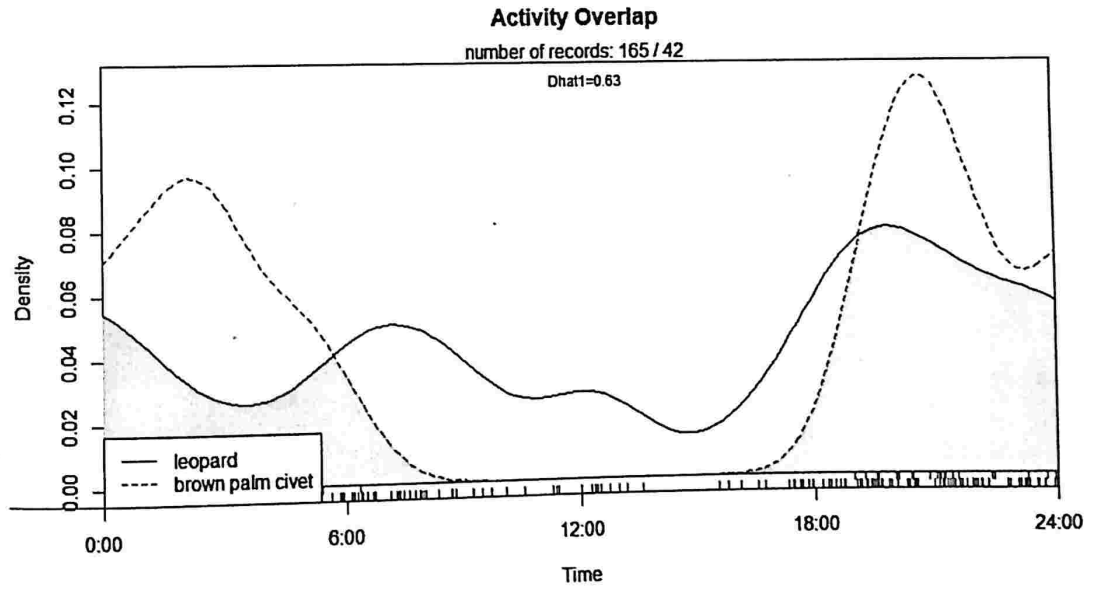


Time activity overlap of Ruddy mongoose and Grey mongoose

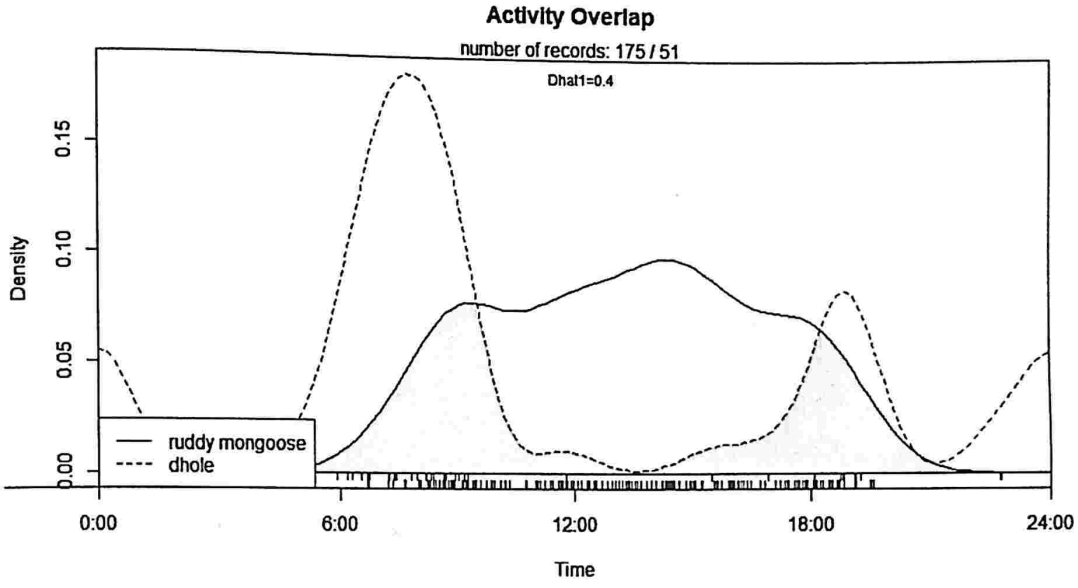
Activity Overlap of Leopard and other small carnivores



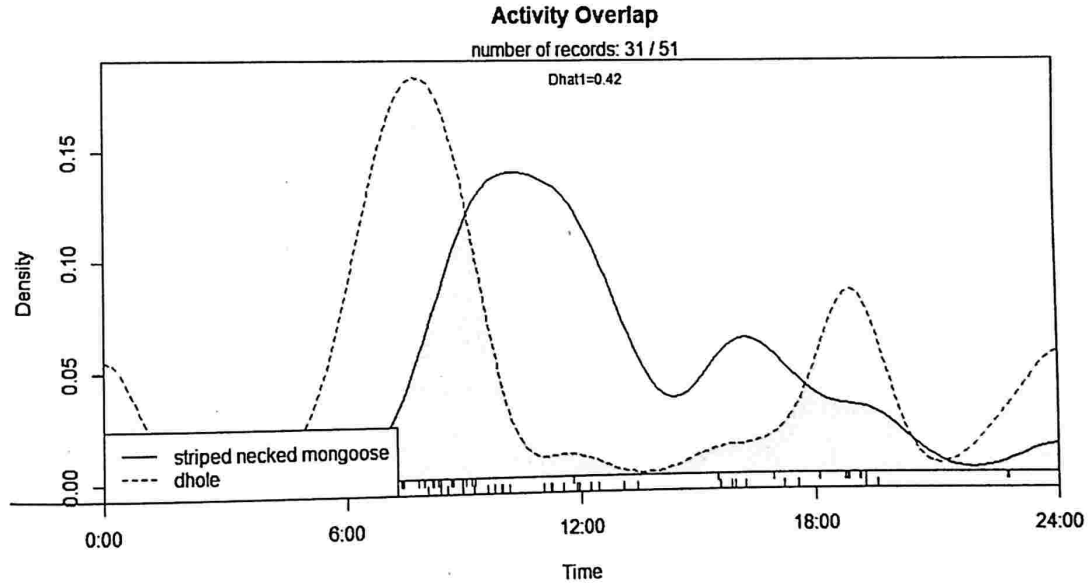
Time activity overlap of Leopard and Grey mongoose



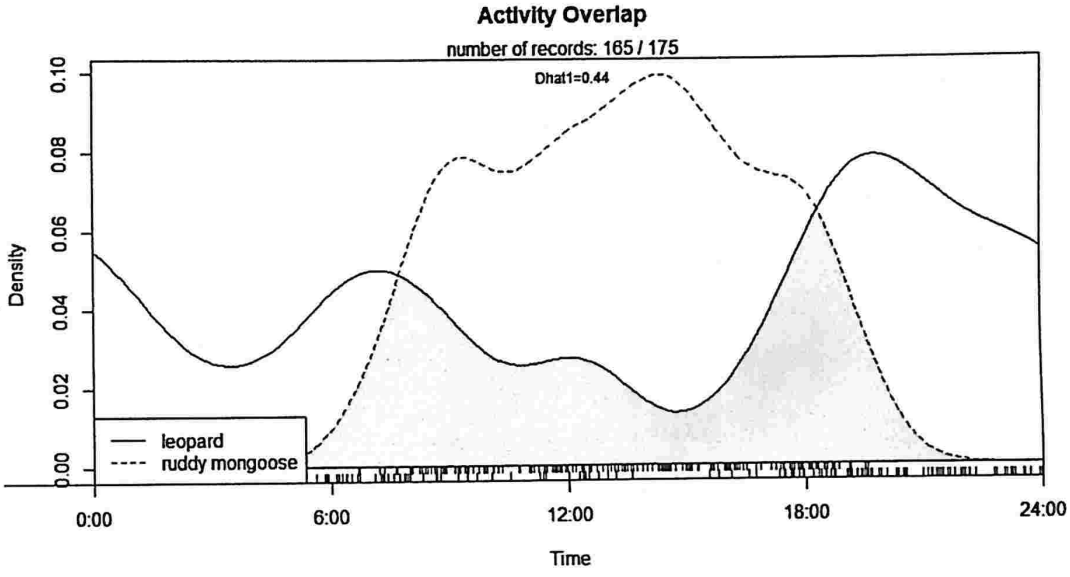
Time activity overlap of Leopard and Brown palm civet



Time activity overlap between Ruddy Mongoose and Dhole



Time activity overlap of Striped-necked mongoose and Dhole



Time activity overlap of Leopard and Ruddy mongoose