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Research Article

Diel Activity Pattern and Co-occurrence of Mammal Species in the North-eastern Landscape, Arunachal Pradesh, India

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ABSTRACT

Diel activity of mammals reflects inter and intraspecific behavior with implications for spatial planning towards conservation management. The assemblage of mammalian species in an Eastern Himalayan landscape unit was studied from 2018 to 2020 using camera traps. We used timestamp photographs to understand the circadian rhythms of the species through activity patterns, temporal overlap with respect to sunrise - sunset and spatial co-occurrence using R core. Among the recorded predators, Dhole was observed to be cathemeral. Most primate species show activity close to sunrise; however, the Arunachal Macaque was active during midday. The Wild Pig, which is nocturnal, also shows an activity peak before sunset. Temporal overlap among primates shows higher paired coefficients between stump-tailed macaque and capped langur with Δ = 0.76. The Marbled Cat exhibits a higher intergroup overlap with Serow, Red Muntjac, and Sambar, with coefficients of 0.84, 0.82, and 0.72, respectively. Dhole has activity overlap with all the prey species (higher with Takin (Δ = 0.59) and goral (Δ = 0.62)). Within the Artiodactyl guild, temporal overlap was higher between the Serow and Red Muntjac (Δ = 0.81). The probabilistic model of species co-occurrence shows species interactions among 16 out of 24 species. The black bear and sun bear show different diurnal activity peaks but no overlap or co-occurrence. The ethological information about Takin and few other small mammals are one of the prominent findings of the present study. Long term studies in the region, will further elucidate the spatiotemporal relationships among the species and aid management and conservation strategies

Keywords: Circadian rhythms , Spatio-temporal, Kamlang Tiger Reserve, Mishmi Takin, Sun bear

INTRODUCTION

Understanding the distribution and dynamics of vertebrate communities across a mosaic of landscapes in changing times is vital for conservation management (Thomas *et al*., 2001). Such community dynamics can be influenced by myriad forms of interspecific interactions amongst the species involved (Shameer *et al.*, 2022). Looking at how different species interact can give us important information about population changes. Conversely, it is possible to predict the composition and distribution of species involved by studying interactions. These interactions can provide insights on predation, parasitism, support, and cooperation. Despite its utility, assessing species interactions among free-ranging vertebrates is often challenging, particularly in forest environments (Caro, 2007). In such forested habitats, direct observations are difficult to make, and ad libitum observations often do not meet sample size requirements to carry out statistical analyses. To circumvent these challenges, in recent years, camera trapping has gained popularity as a reliable method of digital sampling in ecology (Wearn & Glover-Kapfer, 2019). Camera traps have revolutionised the unravelling of rare aspects of wildlife over the last few decades (Di Bitetti *et al*., 2009; Foster *et al*., 2013; Tambling *et al*., 2015; Cusack *et al*., 2017; Mori *et al*., 2020; and Swan *et al*., 2004). To illustrate, for instance, we can characterise the activity pattern of a species in the wild using the time-stamped photo captures generated from camera traps. Despite the challenges, it is now possible to quantify species interactions involving rare and cryptic wildlife even in remote and rugged terrains.

In the twentieth century, methods for analysing data to understand the timing of species interactions improved due to progress in studying biological clocks (Sollberger, 1965). Animal activity in nature usually depends on their internal body processes and outside factors during the 24-hour daily cycle (Aschoff, 1963). The activity rhythms analysis provides an insight into community structure and co-existence in a forest ecosystem (Zhou *et al*., 2014; Liu *et al.,* 2013). One important part of niche selection for any species is how active it is at different times of the day (Norris *et al*., 2010; Pianka, 1973). We broadly classify the species' activity pattern as diurnal and nocturnal. Further information gleaned from activity patterns can be useful in elucidating whether a species is crepuscular or cathemeral in activity (Tattersall, 1988; Jacobs, 1993).

The Indo-Burma region is among the 25 global biodiversity hotspots with a high level of endemism and thus requires continuous focus for advancing conservation (Myers, 2000). Within the Indo-Burma region, northeast India (NE region henceforth) harbours disproportionately high biodiversity (Jain & Das, 2022). The NE region comprises mountain ranges of the Himalaya

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extending into Upper Burma, the Daphabum termination of the Patkoi range. Brooks *et al.* (2006) identified the Eastern Himalayas as "crisis ecoregions," "biodiversity hotspots," "endemic bird areas," "megadiversity countries," and "global 200 ecoregions." This landscape is identified as a biodiversity hotspot that possesses a higher human population than all the other biodiversity hotspots (Mittermeier *et al*., 2004). The Eastern Himalayas possess a unique biodiversity assemblage due to various factors such as geological history, adaptive radiation, etc. (Guangwei, 2002). The Eastern Himalayas have one of the largest remaining intact evergreen forests in the whole of Asia (Ashton & Zhu, 2020). These evergreen forests act as habitats for diverse biodiversity. This NE region has identified more than 65% of mammals reported in the Indian subcontinent (Choudhury, 2013; Sharma, 2015). In the Eastern Himalayan landscape, there exists a gap in ecological knowledge and a need for enhancing research areas to create efficient biodiversity and conservation for the future (Kandel, 2016). IUCN states the region is composed of approximately 20% of species, which fall under the Vulnerable, Endangered, and Critically Endangered categories (Shrestha, 2022).

Ecological studies and expeditions in the recent past have discovered new mammalian species from the region (Talukdar, 2021; Gogoi, 2020). The variety of taxa in the area is influenced by the Indo-Malayan region of Southeast Asia, the Palearctic region, and the area's complicated climate and landscape. The biodiversity of such remote, inaccessible tropical forests is still in the stage of exploration. There are still gaps in research about how species interact in the junction of China, India, and Myanmar.

In recent years, camera trapping has gained popularity as a reliable method of digital sampling in ecology (Wearn & Glover-Kapfer, 2019). The camera trapping was identified as one of the feasible ways to characterise a species activity pattern in the wild. Time stamping on camera trap images records the temporal availability of any species in space (Frey *et al*., 2017; Sollmann, 2018). Also, improvements in circular data analysis methods (Ridout & Linkie, 2009; Rowcliffe *et al*., 2014) make it easier to learn about the activities of many species that are hard to sight (Frey *et al*., 2017). The present study focuses on mammalian species activity pattern and interaction within the species community in the study area. In this study, we have used temporal activity overlap and spatial co-occurrence as measure to understand species interaction within the species community.

STUDY AREA

The extreme northeast land mass of India lies in the state of Arunachal Pradesh with an area of greater than 83740 sq.km. The mountainous state possesses the north-south-running Himalayan Mountains and forms five major valleys of the state: (1) the Lohit, (2) the Kameng, (3) the Subansiri, (4) the Siang, and (5) the Tirap. The Tsangpo River of Tibet, when it reaches the region of Arunachal Pradesh, joins the river Dibang and the river Lohit and runs as the Brahmaputra in the Assam Plains. (Jain & Das, 2022). The state has more than 70 % of the area under forest cover. The major forest types fall under very dense forest, moist deciduous forest, and open forest (FSI 2021). These comprise even more types of forests, including subtropical broad-leaved forests,
subtropical pine forests, long stretches of temperate forest, and subalpine and alpine forests, which make up the forest floors (Kaul & Haridasan, 1987). The protected area network of the state includes 13 Wildlife Sanctuaries, 2 National Parks, and 9 Community Reserves. Also three Tiger Reserves and two Elephant Reserves were declared in the state. The selected landscape unit falls in a region that is a continuous stretch of tropical forest landscape from the Hkawang Wildlife Sanctuary of Myanmar to the Dibang Wildlife Sanctuary of Arunachal Pradesh.

We conducted the study within this highly ecological network of forests. The unit includes regions of Kamlang Wildlife Sanctuary, which is also a Tiger Reserve; Anjaw Forest Division; Lohith Forest Division; and Dibang Forest Division. The area is surrounded by three protected areas: Dibang Wildlife Sanctuary, Namdapha National Park, and Tiger Reserve in the longitudinal ends, and Namai Forest Division and Nampong Forest Division in the latitudinal end in the Indian border. It shares the other end with the international boundaries of the Republic of China. Though the area falls under different administrative blocks, it is a continuous stretch of forest along the crisscrossed river valleys of the tributaries of the Dibang and Lohit Rivers (Fig. 1).

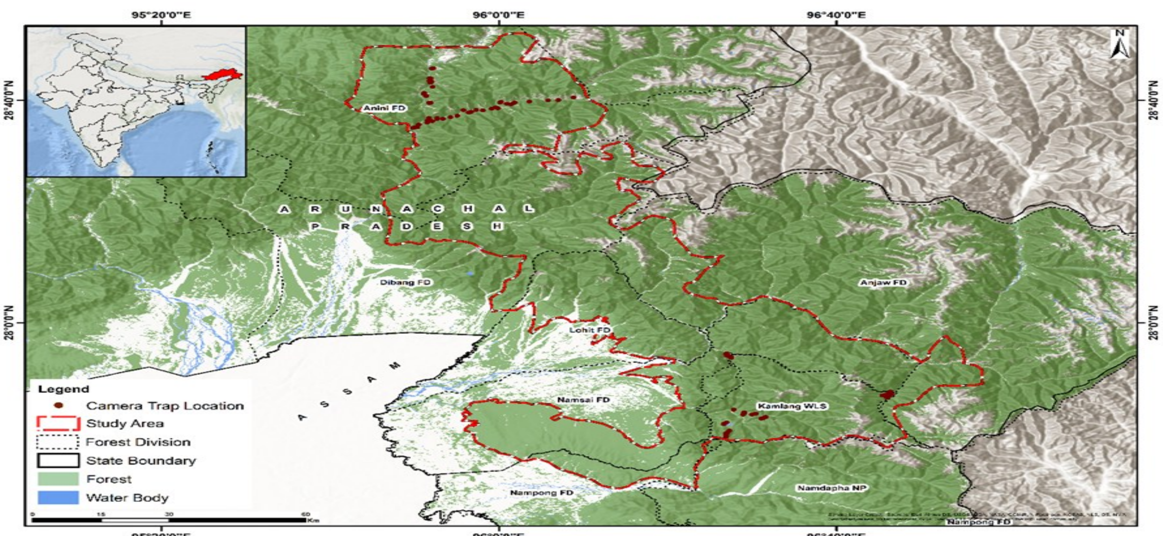

Figure 1. Map showing the study area and Camera trap monitoring stations

METHODOLOGY

Camera trap surveys

A reconnaissance survey was carried out along the identified and accessible locations in the landscape based on available literature information and secondary information. We also obtained information from the indigenous peoples of the region about possible locations to deploy camera traps,which is one of the cost-effective method of monitoring programs (Micaela *et al*, 2020; Daniel & Oliver, 2021). For monitoring we demarcated the area into blocks based on logistic feasibility. We deployed camera traps at the designated locations within the blocks. Cuddeback C1 Day and Night Colour 20 MP Xchange Trail Game Cameras were used and the camera traps were deployed along trails, which were frequently used by wild animals based on prior reconnaissance surveys (Rovero *et al*., 2010). We selected the sites with high capture probabilities for potential species presence in the area. Camera traps were deployed as single cameras per location in most locations, and in a few locations, a pair of cameras were deployed to maximise the probability of animal captures. A total of 92 camera traps were deployed at different locations during the years 2018-2020 (Fig. 1).

Analysis of Activity Pattern and Overlap

A total of 2548 independent captures of various species were recorded and the targeted species in 1110 independent events. We looked at the time overlap of the mammal species caught on camera traps that belonged to the orders Primates, Carnivora, Artiodactyla, and Rodentia (Table 1; Fig. 2 and Fig. 3). Using the overlap package in R (Version 4.4.1) (Meredith & Ridout, 2020), the activity patterns and temporal overlap were calculated based on the time when the different species were active. Diurnal periods were considered as the time duration between an hour after sunrise and an hour before sunset, whereas the nocturnal is the time period between an hour after sunset and an hour before sunrise and crepuscular is the period of an hour before and after sunrise and sunset (Theuerkauf *et al*., 2003; Ross *et al*., 2013). We used species with approximately 15 photo captures to analyse the activity patterns (Nakabayashi, 2021).

Activity patterns among the species may overlap during interactions, including those with predators and prey, and during resource competition as well. We used the coefficient of overlap, a natural measure that facilitates geometrical interpretation to determine temporal overlap. We chose these estimators based on the sample size, following the advice of Ridout and Linkie (2009). If the smaller sample size is less than 50, we used $Dhat_1$. If the sample size is greater than 75, we used $Dhat_4$. The Dhat Δ value is in unit intervals ranging between 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie, 2009). We calculated the overlap patterns between the carnivores, each with their own prey species, and between the two carnivore species.

Table 1. The Mammalian species identified in the camera trap and analysed for activity pattern.

S. no	Classical Order	Family	Common Name	Scientific Name
1	Primates	Cercopithecidae	Capped Langur	*Trachypithecus pileatus*
2	Primates	Cercopithecidae	Stump-tailed Macaque	*Macaca arctoides*
3	Primates	Cercopithecidae	Assamese Macaque	*Macaca assamensis*
4	Primates	Cercopithecidae	Arunachal Macaque	*Macaca munzala*
5	Primates	Cercopithecidae	Northern Pig-tailed macaque	*Macaca leonina*
6	Carnivora	Canidae	Dhole	*Cuon alpinus*
7	Carnivora	Felidae	Mainland Leopard cat	*Prionailurus bengalensis*
8	Carnivora	Felidae	Marbled Cat	*Pardofelis marmorata*
9	Carnivora	Felidae	Clouded leopard	*Neofelis nebulosa*
10	Carnivora	Felidae	Asiatic golden cat	*Catopuma temminckii*
11	Carnivora	Ursidae	Sun bear	*Helarctos malayanus*
12	Carnivora	Ursidae	Asiatic Black Bear	*Ursus thibetanus*
13	Carnivora	Viverridae	Masked Palm Civet	*Paguma larvata*
14	Carnivora	Mustelidae	Yellow-throated marten	*Martes flavigula*
15	Artiodactyla	Bovidae	Mishmi Takin	*Budorcas taxicolor taxicolor*
16	Artiodactyla	Bovidae	Mainland Serow	*Capricornis sumatraensis thar*
17	Artiodactyla	Bovidae	Red Goral	*Naemorhedus baileyi*
18	Artiodactyla	Cervidae	Northern Red Muntjac	*Muntiacus vaginalis*
19	Artiodactyla	Cervidae	Sambar	*Rusa unicolor*
20	Artiodactyla	Cervidae	Gongshan muntjac	*Muntiacus gongshanensis*

21	Artiodactyla	Suidae	Wild Pig	*Sus scrofa*
22	Rodentia	Hystricidae	Asiatic brush-tailed porcupine	*Atherurus macrourus*
23	Rodentia	Hystricidae	Indian crested porcupine	*Hystrix indica*

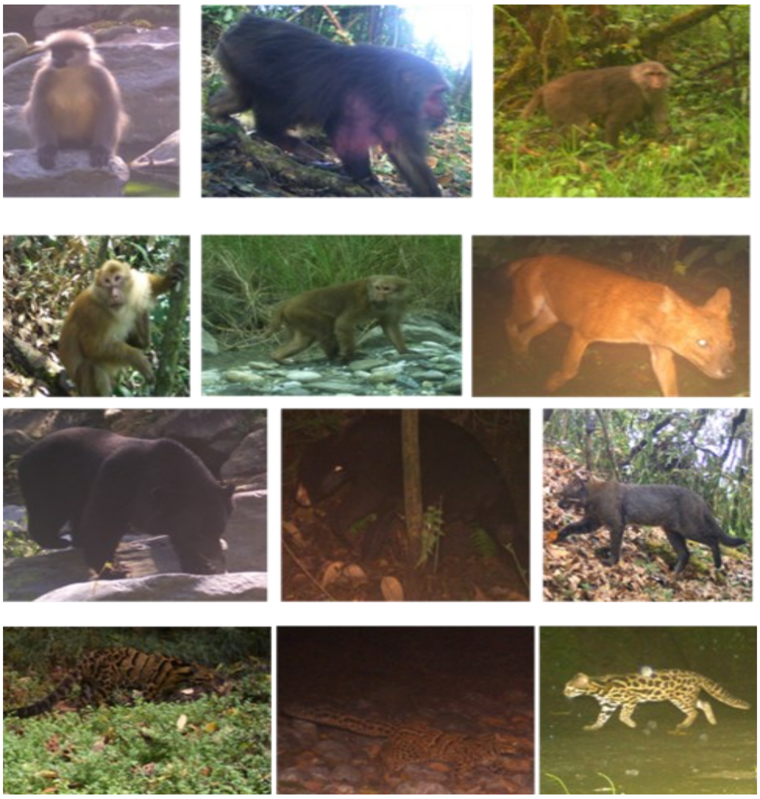

Figure 2. (From left to right horizontally) Camera Trap Images of Capped Langur, Stump-tailed Macaque, Assamese Macaque, Arunachal Macaque, Northern Pig-tailed Macaque, Dhole, Asiatic Black Bear, Sun Bear, Asiatic Golden Cat, Clouded Leopard, Marbled Cat, Mainland Leopard Cat recorded in the study area.

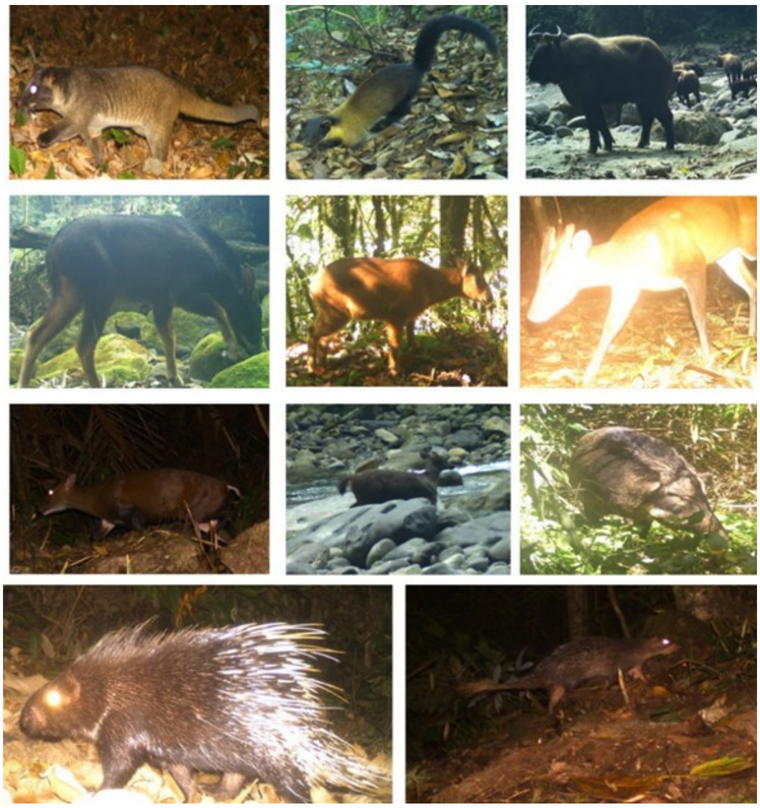

Figure 3. (From left to right horizontally) Camera Trap Images of Masked Palm Civet, Yellow-throated Marten, Mishmi Takin, Mainland Serow, Red Goral, Northern Red Muntjac, Gongshan Muntjac, Sambar, Wild Pig, Indian Crested Porcupine, Asiatic Brush-tailed Porcupine recorded in the study area.

RESULTS

The activity patterns of the species were given as a density plot using the method suggested by Ridout and Linkie (2009) (Fig. 4 & 5). The activity of the Sun Bear showed peak diurnal activity, while the Marbled Cat showed two-peak diurnal activity (Fig. 4). The Clouded Leopard showed activity patterns that resembled crepuscular behaviour (Fig. 4).

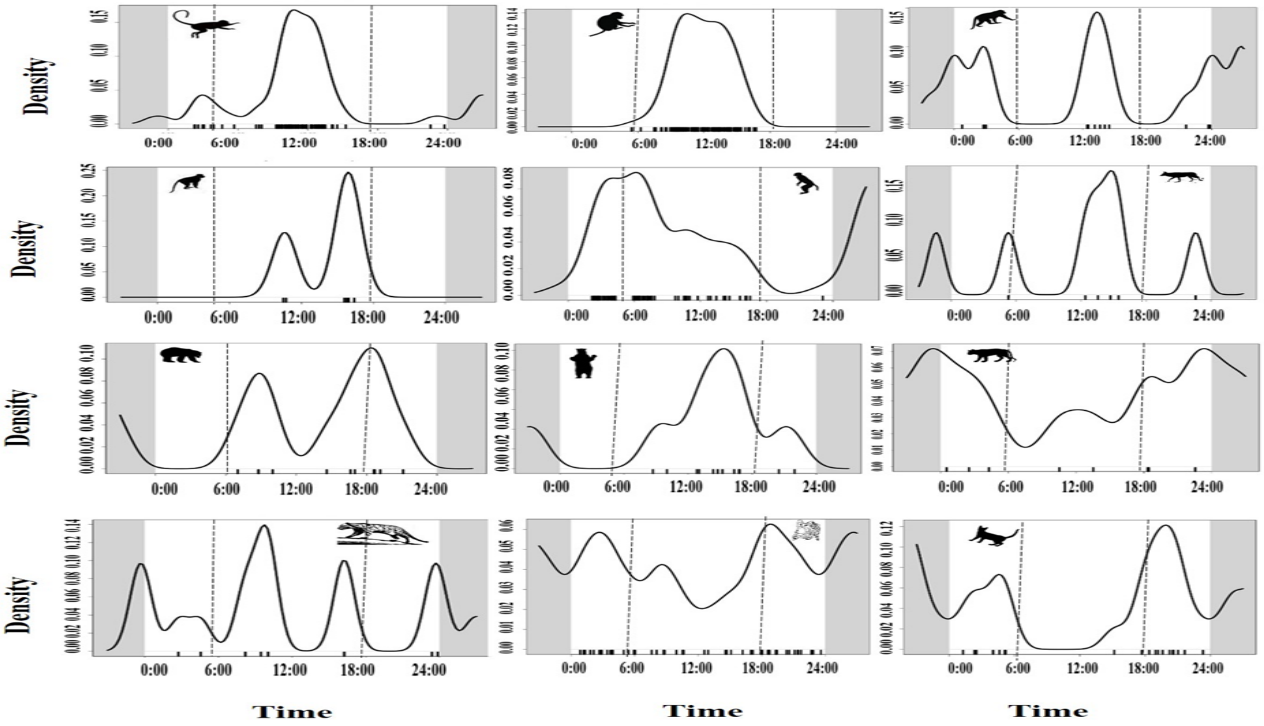

Figure 4. Temporal activity pattern of Capped Langur, Stump-tailed Macaque, Assamese Macaque, Arunachal Macaque and Northern Pig-tailed Macaque, Dhole, Asiatic Black Bear, Sun bear, Asiatic Golden Cat, Clouded Leopard, Marbled cat and Leopard cat (from top left horizontally)

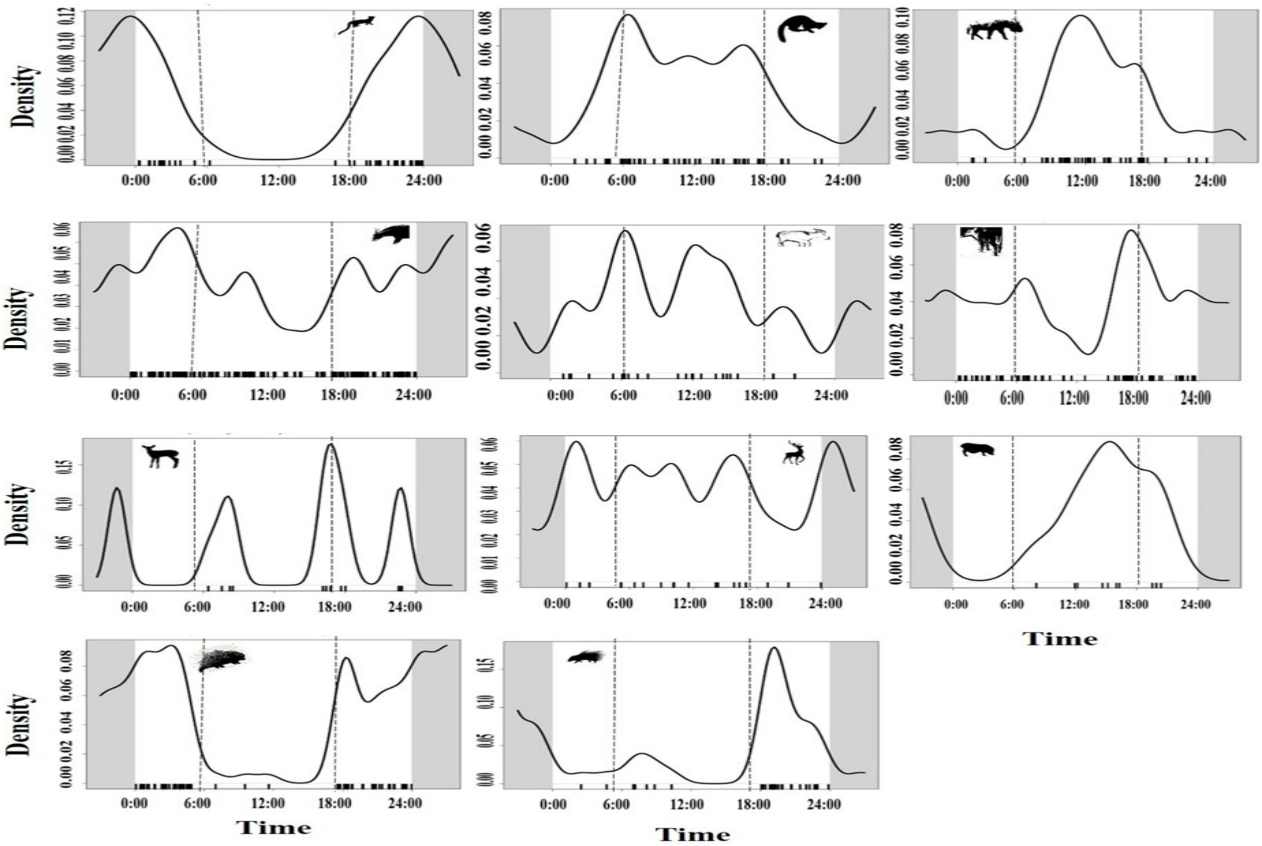

Figure 5. Masked Palm Civet, Yellow-throated Marten, Mishmi Takin, Mainland Serow, Red Goral, Northern Red Muntjac, Gongshan Muntjac, Sambar, Wild Pig, Asiatic Brush-tailed Porcupine, and Indian Crested Porcupine

The overlap analysis reveals different rates of temporal activity overlap coefficients, illustrating how the species in the community interact with one another. Among the primate guild, Stump-tailed Macaque and Capped Langurs showed high temporal overlap with Δ = 0.76 (Table 2).

Similarly, the Northern Pig-tailed Macaque and Red Goral exhibited relatively high temporal overlap of Δ = 0.72 (Table 2). Among the three carnivores, the overlap was considerable between Dhole and Sun Bears with Δ = 0.72 (Table 1).

Table 2. Temporal overlaps between the species of the Primate guild pairs with overlap coefficient values given on top of the cell and the values given in the parentheses in each cell denotes 95 % confidence intervals [estimator used Dhat1 (Δ1)]

	Capped Langur	**Stump-tailed Macaque**	**Assamese Macaque**	**Arunachal Macaque**	**Northern Pig-tailed Macaque**
Stump-tailed Macaque	0.76 (0.67- 0.86)				
Assamese Macaque	0.44 (0.27- 0.65)	0.42 (0.24 - 0.63)			
Arunachal Macaque	0.43 (0.05 - 0.69)	0.56 (0.19 - 0.83)	0.30 (0 - 0.45)		
Northern Pig-tailed Macaque	0.54 (0.36 - 0.64)	0.47 (0.32 - 0.56)	0.39 (0.19 - 0.52)	0.32 (0.08 - 0.50)	
Dhole	0.54 (0.33 - 0.72)	0.58 (0.42 - 0.80)	0.47 (0.31 - 0.73)	0.45 (0.09 - 0.67)	0.57 (0.38 - 0.80)
Mainland Leopard Cat	0.23 (0.09 - 0.30)	0.13 (0.02 - 0.17)	0.39 (0.16 - 0.57)	0.18 (0 - 0.27)	0.49 (0.36 - 0.62)
Marbled Cat	0.42 (0.28 - 0.54)	0.35 (0.21 - 0.43)	0.49 (0.25 - 0.65)	0.33 (0.11 - 0.45)	0.63 (0.50 - 0.76)
Clouded Leopard	0.30 (0.10 - 0.68)	0.35 (0.18 - 0.78)	NA	NA	0.31 (0.15 - 0.61)
Asiatic Golden Cat	0.37 (0.17 - 0.64)	0.31 (0.05 - 0.56)	0.51 (0.33 - 0.82)	0.29 (0.04 - 0.56)	0.50 (0.31 - 0.79)
Sun Bear	0.45 (0.25 - 0.67)	0.58 (0.37 - 0.81)	0.48 (0.26 - 0.69)	NA	0.41 (0.25 - 0.62)
Asiatic Black Bear	0.33 (0.10 - 0.47)	0.41 (0.19 - 0.61)	0.28 (0 - 0.41)	0.46 (0.15 - 0.65)	0.40 (0.21 - 0.58)
Masked Palm Civet	0.20 (0.10 - 0.28)	0.09 (0.01 - 0.13)	0.52 (0.33 - 0.76)	NA	0.37 (0.20 - 0.45)
Yellow-throated Marten	0.59 (0.43 - 0.67)	0.60 (0.45 - 0.68)	0.42 (0.21 - 0.53)	0.47 (0.17 - 0.64)	0.72 (0.60 - 0.86)
Mishmi Takin	0.66 (0.54 - 0.78)	0.70 (0.58 - 0.81)	0.49 (0.29 - 0.65)	0.54 (0.19 - 0.76)	0.57 (0.40 - 0.68)
Mainland Serow	0.43 (0.31 - 0.54)	0.34 (0.23 - 0.39)	0.46 (0.22 - 0.60)	0.28 (0.07 - 0.40)	0.69 (0.56 - 0.78)
Red Goral	NA	NA	NA	NA	0.72 (0.59 - 0.89)
Northern Red Muntjac	0.37 (0.25 - 0.45)	0.33 (0.23 - 0.36)	0.48 (0.25 - 0.63)	0.34 (0.15 - 0.46)	0.55 (0.41 - 0.63)
Sambar	0.50 (0.33 - 0.67)	0.47 (0.27 - 0.62)	0.47 (0.23 - 0.66)	0.38 (0.16 - 0.62)	0.67 (0.51 - 0.85)
Wild Pig	0.43 (0.22 - 0.67)	0.52 (0.31 - 0.79)	0.46 (0.24 - 0.68)	0.52 (0.23 - 0.78)	0.42 (0.22 - 0.62)
Gongshan Muntjac	0.22 (0.05 - 0.31)	0.30 (0.11 - 0.37)	0.29 (0.04 - 0.42)	0.39 (0.14 - 0.59)	0.38 (0.18 - 0.51)

The values are expressed as mean with approximate 95% bootstrap confidence intervals are given in parentheses. Bold values indicate a high degree of temporal overlap (≥ 0.70).

Regarding the prey-predator interactions, Dhole showed significant overlap with all five selected prey species, with a maximum overlap coefficient (Δ = 0.59) with Mishmi takin. In the case of lesser carnivores, palm civets and yellow-throated martens showed a low temporal overlap coefficient (Δ = 0.33) (Table 2). The Marbled Cat had more interguild time overlap with the Mainland Serow, the Northern Red Muntjac, and the sambar (Δ = 0.84, Δ = 0.82, and Δ = 0.72, respectively), as shown in Table 3.

Table 3. Temporal overlaps between the species of the Carnivora guild with its Prey species pairs with overlap coefficient values given on top of the cell and the values given in the parentheses in each cell denotes 95 % confidence

	Dhole	**Mainland Leopard Cat**	**Marbled Cat**	**Clouded Leopard**	**Asiatic Golden Cat**	**Sun Bear**	**Asiatic Black Bear**	**Masked Palm Civet**	**Yellow-throated Marten**
Mainland Leopard Cat	0.34 (0.14 - 0.52)								
Marbled Cat	0.49 (0.27 - 0.66)	0.69 (0.59 - 0.83)							
Clouded Leopard	0.42 (0.16 - 0.60)	0.40 (0.14 - 0.53)	0.55 (0.33 - 0.71)						
Asiatic Golden Cat	0.42 (0.18 - 0.71)	0.60 (0.43 - 0.86)	0.66 (0.61 - 1.02)	0.47 (0.25 - 0.74)					
Sun Bear	0.56 (0.42 - 0.85)	0.36 (0.14 - 0.53)	0.51 (0.35 - 0.72)	0.41 (0.19 - 0.64)	0.46 (0.26 - 0.78)				
Asiatic Black Bear	0.39 (0.11 - 0.56)	0.45 (0.26 - 0.64)	0.54 (0.40 - 0.76)	0.44 (0.24 - 0.68)	0.44 (0.20 - 0.71)	0.56 (0.34 - 0.82)			
Masked Palm Civet	0.26 (0.06 - 0.38)	0.68 (0.53 - 0.81)	0.63 (0.48 - 0.75)	0.41 (0.18 - 0.61)	0.62 (0.47 - 0.92)	0.29 (0.08 - 0.49)	0.33 (0.11 - 0.49)		
Yellow-throated Marten	0.64 (0.46 - 0.85)	0.42 (0.25 - 0.49)	0.64 (0.46 - 0.75)	0.57 (0.36 - 0.71)	0.50 (0.28 - 0.77)	0.60 (0.42 - 0.81)	0.55 (0.34 - 0.78)	0.33 (0.16 - 0.38)	
Mishmi Takin	0.59 (0.38 - 0.76)	0.39 (0.22 - 0.49)	0.59 (0.44 - 0.73)	0.54 (0.36 - 0.68)	0.51 (0.28 - 0.78)	0.67 (0.49 - 0.88)	0.55 (0.38 - 0.78)	0.32 (0.16 - 0.41)	0.74 (0.62 - 0.85)
Mainland Serow	0.50 (0.30 - 0.68)	0.68 (0.56 - 0.79)	0.84 (0.79 - 0.98)	0.55 (0.29 - 0.72)	0.65 (0.61 - 1.01)	0.48 (0.32 - 0.69)	0.49 (0.34 - 0.68)	0.62 (0.48 - 0.71)	0.66 (0.51 - 0.73)
Red Goral	0.62 (0.45 - 0.84)	0.51 (0.30 - 0.64)	0.69 (0.52 - 0.84)	0.54 (0.24 - 0.65)	0.56 (0.40 - 0.86)	0.57 (0.40 - 0.79)	0.50 (0.26 - 0.70)	0.42 (0.23 - 0.57)	0.77 (0.68 - 0.95)
Northern Red Muntjac	0.48 (0.29 - 0.66)	0.68 (0.52 - 0.76)	0.82 (0.74 - 0.94)	0.54 (0.38 - 0.73)	0.66 (0.56 - 0.98)	0.55 (0.37 - 0.77)	0.58 (0.42 - 0.77)	0.62 (0.47 - 0.71)	0.61 (0.49 - 0.71)
Sambar	0.53 (0.31 - 0.74)	0.54 (0.33 - 0.68)	0.72 (0.61 - 0.92)	0.59 (0.42 - 0.81)	0.59 (0.49 - 0.94)	0.52 (0.33 - 0.76)	0.50 (0.35 - 0.76)	0.50 (0.28 - 0.67)	0.70 (0.60 - 0.92)
Wild Pig	0.52 (0.37 - 0.81)	0.43 (0.23 - 0.65)	0.55 (0.39 - 0.80)	0.41 (0.15 - 0.61)	0.49 (0.29 - 0.84)	0.67 (0.60 - 1)	0.60 (0.39 - 0.87)	0.35 (0.16 - 0.56)	0.58 (0.39 - 0.83)
Gongshan Muntjac	0.36 (0.14 - 0.51)	0.41 (0.14 - 0.52)	0.50 (0.27 - 0.63)	0.48 (0.29 - 0.72)	0.42 (0.15 - 0.62)	0.48 (0.26 - 0.67)	0.55 (0.36 - 0.79)	0.39 (0.12 - 0.54)	0.48 (0.29 - 0.63)

Yellow-throated Marten had a high overlap with the Red goral (Δ = 0.77) and a low overlap with the Mishmi Takin (Δ = 0.74) and the sambar (Δ = 0.70) (Table 3). As shown in Table 4, the Mainland Serow and the Northern Red Muntjac had the most time-overlapping activities (Δ = 0.81 vs. Δ = 0.75 vs. 0.72 for Red Goral and Sambar. The temporal activity overlap activity with a value of 0.70 was observed for sambar with Northern Red Muntjac and Red Goral (Table 4).

Table 4. Temporal overlaps between the species of the Ungulate guild pairs with overlap coefficient values given on top of the cell and the values given in the parentheses in each cell denotes 95 % confidence intervals [estimator used Dhat1 (Δ1)]

	Mishmi Takin	Mainland Serow	Red Goral	Northern Red Muntjac	Sambar	Wild Pig
Mainland Serow	0.58 (0.44 - 0.69)					
Red Goral	0.69 (0.52 - 0.85)	0.72 (0.56 - 0.84)				
Northern Red Muntjac	0.60 (0.46 - 0.70)	0.81 (0.72 - 0.89)	0.66 (0.50 - 0.80)			
Sambar	0.65 (0.50 - 0.86)	0.75 (0.63 - 0.92)	0.70 (0.56 - 0.92)	0.70 (0.59 - 0.88)		
Wild Pig	0.65 (0.48 - 0.91)	0.53 (0.36 - 0.73)	0.57 (0.41 - 0.83)	0.60 (0.47 - 0.83)	0.52 (0.34 - 0.76)	
Gongshan Muntjac	0.45 (0.27 - 0.56)	0.48 (0.27 - 0.60)	0.44 (0.19 - 0.54)	0.56 (0.37 - 0.71)	0.47 (0.27 - 0.63)	0.47 (0.21 - 0.66)

The values are expressed as mean with approximate 95% bootstrap confidence intervals are given in parentheses. Bold values indicate a high degree of temporal overlap (≥ 0.70).

The Gongshan Muntjac shows considerable overlap with all the other ungulates, in which a higher coefficient was observed with its closely related species, the Northern Red Muntjac. The two species of order Rodentia, Asiatic Brush-tailed Porcupine and Indian Crested Porcupine, that show complete nocturnal and crepuscular activity, respectively, didn't show any overlap in activity (Fig. 5).

The evaluated probabilistic model of species co-occurrence in the sampling unit for species recorded to be distributed in the study unit is given in Figure 6. We removed 362 pairs (77.85%) from the analysis of 465 species pairing combinations because the expected co-occurrence was less than 1, and we subsequently analysed 103 pairs. A total of 16 species show co-occurrence based on camera trap history, and the probability of co-occurrence is listed in Table 5.

Table 5. Pairwise spatial co-occurrence probability

s.no.	Species A	Species B	No. of sites having Species A	No. of sites having Species B	Observed Co-occurrence of A & B	Observed Co-occurrence probability of A & B	Expected Co-occurrence of A & B	p_lt	p_gt
1	Capped Langur	Yellow-throated Marten	7	36	6	0.03	2.7	0.9991	0.01
2	Mishmi Takin	Mainland Serow	5	22	4	0.013	1.2	0.9995	0.01
3	Mainland Serow	Sambar	22	10	7	0.026	2.4	0.9999	0.00
4	Mainland Serow	Stump-tailed Macaque	22	19	9	0.049	4.5	0.9978	0.01
5	Mainland Serow	Brush Tailed Porcupine	22	13	8	0.034	3.1	0.9998	0.00
6	Mainland Serow	Sun Bear	22	6	4	0.016	1.4	0.9973	0.03
7	Wild Dog	Marbled Cat	9	11	5	0.012	1.1	1	0.00
8	Yellow-throated Marten	Marbled Cat	36	11	9	0.047	4.3	0.9997	0.00
9	Yellow-throated Marten	Himalayan palm civet	36	17	13	0.072	6.7	0.9999	0.00
10	Yellow-throated Marten	Northern Pig-tailed Macaque	36	7	6	0.03	2.7	0.9991	0.01

11	Northern Red Muntjac	Clouded Leopard	37	4	4	0.017	1.6	1	0.02
12	Northern Red Muntjac	Indian Crested Porcupine	37	5	5	0.022	2	1	0.01
13	Northern Red Muntjac	Sambar	37	10	10	0.044	4	1	0.00
14	Northern Red Muntjac	Stump Tailed Macaque	37	19	15	0.083	7.6	1	0.00
15	Northern Red Muntjac	Brush Tailed Porcupine	37	13	11	0.057	5.2	1	0.00
16	Northern Red Muntjac	Masked Palm Civet	37	17	13	0.074	6.8	0.9999	0.00
17	Northern Red Muntjac	Sun Bear	37	6	6	0.026	2.4	1	0.00
18	Sambar	Stump Tailed Macaque	10	19	6	0.022	2.1	0.9995	0.00
19	Sambar	Brush Tailed Porcupine	10	13	7	0.015	1.4	1	0.00
20	Sambar	Marbled Cat	10	11	4	0.013	1.2	0.9983	0.02
21	Stump-tailed Macaque	Wild Pig	19	7	4	0.016	1.4	0.9963	0.03
22	Stump-tailed Macaque	Sun Bear	19	6	6	0.013	1.2	1	0.00

Pit < 0.05 and *Pgt* < 0.05 indicate spatial segregation and positive association, respectively. The species A & B indicates the species of comparison. All the species show a positive co-occurrence as shows a Probability of co-occurrence at a frequency greater than the observed frequency.

We found significant co-occurrence between Northern Red Muntjac and Clouded leopard, Indian crested porcupine, Sambar, and Sun bear. Similarly, we identified Sambar with Asiatic Brush-Tailed Porcupine and Sun Bear with Stump-Tailed Macaque (Table 5). Other species show random co-occurrence, and there was no negative association identified in the study (Fig. 6).

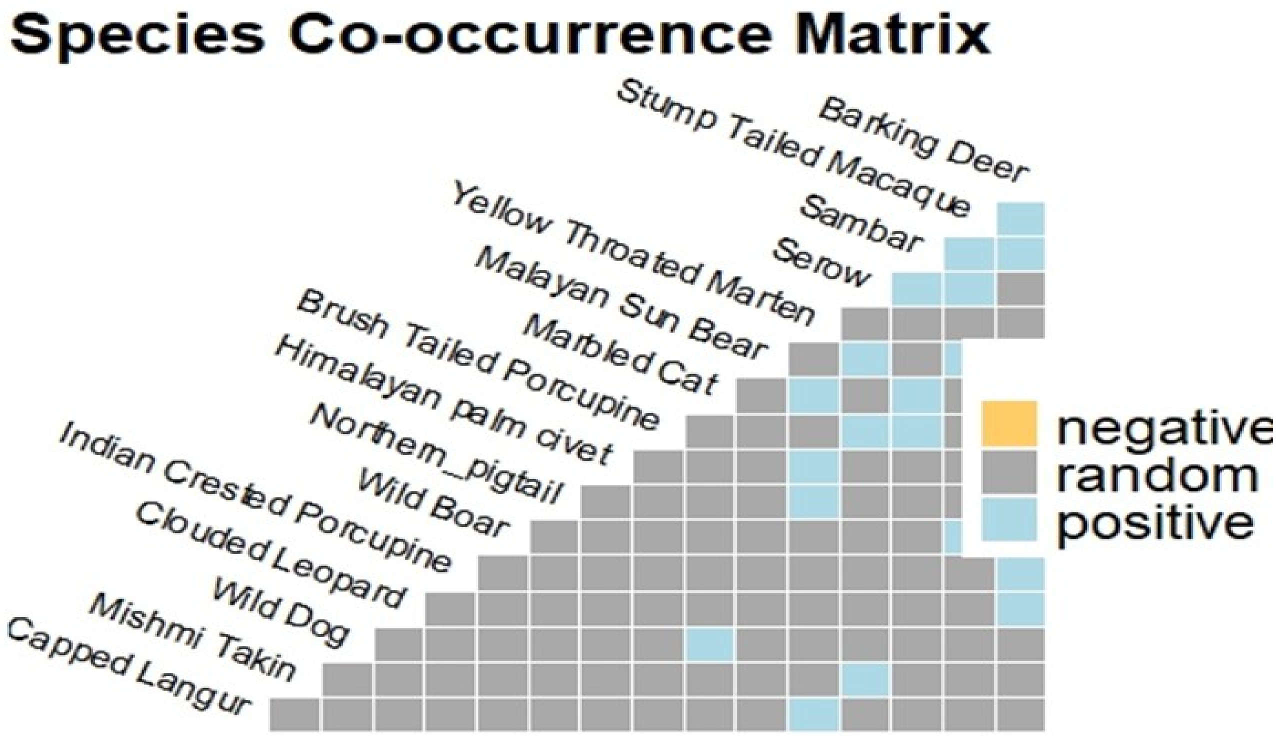

Figure 6. The co-occurrence Matrix created from the Camera trap Capture data using package co-occur in R core.

DISCUSSION

Our study generated information about different mammal species activity and their interactions with each other using the time stamp information obtained from camera traps and animal diel activity based on sunrise and sunset. Generally, species interactions were evaluated for priority flagship species, like the Tiger, in Tropical forests. Not much information is available about how different species interact in evergreen forests compared to what we know about tropical forests (Vargas *et al.,* 2022). Though population information remains uncertain from this region (WII, 2018), the activity related information coming from this region provides supplementary information about the species.

The temporal pattern of animal activity is species-specific*;* it may show only a single peak or more than two peaks in 24 hours, but the common pattern observed in most of the studies was two activity peaks per day (Mrosovsky, 2003; Mrosovsky & Hattar, 2005). The circadian rhythms identified in the present study among primates, Capped langurs, show an increase in activity during the dawn as the sunrise and another peak during the noon, which is similar to the two peak activity patterns reported in captivity (Monirujjaman & Khan, 2017). Peak daily activity patterns of Stump-tailed Macaques and Assamese Macaques were the same as those observed in studies from both zoos and the wild (Nigam *et al*., 2014; Li, *et al.,* 2019*)*. The Arunachal Macaque activity during the late morning and inactivity during midday by sleeping was observed in other studies (Kumar *et al*., 2007), which differs from the present study. Our observation shows a mid-day peak and more active capture towards dusk, which may be due to the movement of species to roosting sites away from foraging locations where more camera trap captures might have occurred. Gippoliti (2001) and Feeroz (2012), have identified Northern Pig-tailed Macaques as primarily arboreal and diurnal. The species shows a single peak activity in the early hours of sunrise and does not overlap with other primates; this might be due to its peculiar behaviour, spending most of the time in movement and keeping niche breadth with other sympatric macaques, like stump-tailed macaques (Sharma & Sinha, 2022).

Among the Carnivora, the observations of the current study show similarity with other studies. The dhole shows activity peaks both in the day and also during the night, wherein the species is capable of adjusting its diel activity depending on the habitat where it is distributed. The diurnal activity of dholes and their relation to its prey activity were well studied in low-elevation and mid-elevation parts from other parts of India (Palei 2016). In Southeast Asia, the diurnal activity of the Dhole shows two peaks (Havmøller *et al*., 2004), while in central India, movement mostly happens around dawn and dusk because of other predators (Ghaskadbi *et al,*, 2016). The area doesn't have as many tigers and leopards as other areas (Qureshi *et al*., 2022; Singh *et al*., 2014), which could be the reason why Dholes show cathemeral activity patterns. The species with identical diet preferences might show contrasting time preferences, which also play a major role in the continuous ecosystem process (Charles, 1975). Our study findings provide more information about the species in this particular landscape.

Asiatic Black Bears, which are active throughout the year, exhibit high bimodal activity close to dawn and dusk, as observed in various other studies (Sunar, 2012). In most of the distribution regions, peak activity at night was observed. In China more diurnal activity in regions where brown bears coexist (Ji *et al*., 2022) were observed. Since there is no den behaviour by Black Bear during winter, significant variation in activity in different seasons and activity over time was observed in Taiwan (Hwang *et al*., 2007). The sun bear studied in the Dumpa Tiger Reserve in the hotspot region of the Northeast shows crepuscular activity (Gouda, 2020), which is almost similar to late evening and nocturnal activity recorded in the study. Kawanishi (2009) observed the Asiatic Golden Cat's mostly showing nocturnal activity, as well as some activity during the day. Clouded leopards are most active during mid-to-late evenings (Can, 2020), and our observations show there is also activity during the early hours of the day. Such an extended behaviour for cryptic species needs further examination to understand the diel cycles. Another study (Rufino *et al*., 2010) also observed that some animals are active at night and during dusk. The leopard cat's nighttime activity (Singh, 2017) and the mixed activity during both night and day (Can, 2020) in the Himalayan region were found to be similar to what we observed. The semi-arboreal Marbled Cat species showed crepuscular and more nocturnal behaviour in the study, differing from a few earlier reports as being diurnal (Hendry *et al*., 2023; Singh, 2017).

Mishmi Takin shows activity peaks during daytime and was found to be active in the morning and evening and reduced activity toward darkness (Wang *et al*., 2024), which may be due to various environmental and ecological factors. There are reports that Dhole and Clouded Leopards prey on the Mishmi Takin herd because of which Takin prefers being active during the day, particularly to keep their calves safe (Calhim *et al*., 2006; Kamler *et al*., 2007). Fluctuation activity was observed in Mainland Serow throughout the day (Paudel, 2012), and Red Goral was active close to sunrise and during the daytime, and also the Sambar was recorded with cathemeral activity in the Himalayan region (Bhattacharya *et al*., 2012) is evident from our observations. The Northern Red Muntjac is active during the day in two main periods (Singh, 2022). In contrast, the Gongshan Muntjac is active at different times throughout the day and night. The lack of studies on this species necessitates further research. The current observations will enhance ecological knowledge about the recently described species (Choudhury, 2009). Wild Pigs are mostly nocturnal and more active around midnight as they are influenced by light (Gordigiani *et al.* 2022, Hazlerigg & Tyler, 2019). In our observations, they were found to increase their activity around dusk, which may be due to this region facing a light fall earlier than the actual sunset. Studies have reported that the Masked Palm Civet is active at night, while the Yellow-throated Marten is busy during the day with two peak times reported, and these small carnivores did not show much difference in activity from other regions. Asiatic brush-tailed porcupine studies showed a single peak activity at midnight and also found to be influenced by the phases of the moon (Wen *et al*., 2016). Our study shows two activity peaks with a crepuscular rhythm during dawn and dusk. The nocturnal activity of Indian crested porcupines exhibits a greater preference for darkness (Mukherjee *et al*., 2018; Shameer & Ninad, 2021), which aligns with our observations.

The species might possess varying activity pattern lengths and states, which can keep interacting species in different associations of stature (Cords 1987). Pebsworth & LaFleur (2014) launched the camera trap study on primates to investigate their 'geophagy' activity, and for other kinds of activity analysis, specific procedures have been developed in due course. We explore the diel activity of primate species as effectively as possible; yet, from the observation, it can be noted that the temporal and spatial interaction examination has not reached the expected level. This is because we didn't adopt a specific camera trapping recommendation by primatology research (Matsubayashi et al. 2007). There is a need to design and employ specialised techniques in activity monitoring to attain a holistic goal (Hanya *et al*., 2018) about understanding the effects of various factors on primate activity patterns.

The activity pattern of the dhole will be influenced by a dominant predator such as the tiger and the leopard (Vernes, 2022). There is a need to assess the influence of both the top predators, which are estimated to be less abundant in the region (Qureshi et al., 2023; Qureshi et al., 2022), to identify the interaction with other species. Sambar was considered important prey for Dholes in the NE region (Singh, 2020), but our finding shows random spatial co-occurrence and a low temporal overlap coefficient. Dhole didn't show either positive or random in our analysis, but negative interaction with the Asiatic Black bear in the eastern Himalayan region (Vernes, 2022). The dholes are not considered predators of sun bears, like tigers and leopards (Naing, 2020). They do exhibit a moderate temporal overlap with other prey species. This overlap is particularly high with Takin, as Takin exhibits activity throughout the day, like the dholes. Some studies found that dholes are seen more often with smaller prey, like wild Pig and barking deer, than with larger prey like gaur and sambar. However, they do still share space with the larger animals (Shameer *et al*., 2021). Our study did not observe the temporal overlap between dholes and large felids, as reported in the previous study by Singh, 2017from the region. The moderate overlap between prey species indicates there is an influence of various ecological and environmental variables. Xiang *et al*., (2024) reported that the association of sympatric ungulates may or may not be influenced by various factors like altitude and season. Information that suggests activity overlaps between prey and predators is crucial for understanding the ecosystem and planning conservation strategies (Havmiller *et al*., 2020). There was a random pattern of co-occurrence between the mammal species. This could be because sympatric prey-predator species use different spatial scales and form different associations in the study areas (Padie *et al*., 2015; Makin *et al*., 2017). This may require further investigation at a finer ecological scale. The NE region possesses three of the four bear species, of which the distribution of the sloth bear is limited to the Indian region, and the sun bear distribution is not found in the peninsular region (Garshelis *et al*., 2022). In such a distribution range, the Asiatic black bear and the sun bear coexist (Steinmetz *et al*., 2013) but don't show temporal overlap or spatial co-occurrence, as both species possess a difference in resource use. The sun bear is more of an insect-diet-preferring species, and the Asiatic black bear depends on a frugivorous diet (Steinmetz *et al*., 2021). The Marble Cat and Mainland Leopard Cat are identified to be temporally segregated (Mukherjee, 2019), and there is a need to create a specific monitoring protocol for small cats rather than utilising data obtained from methods adopted for other large-bodied species (Borries *et al*., 2014).

The Marble Cat and Mainland Leopard Cat are identified to be temporally segregated (Mukherjee, 2019), and there is a need to create a specific monitoring protocol for small cats rather than utilising data obtained from methods adopted for other large-bodied species (Borries *et al*., 2014). The yellow-throated marten, which is capable of acting as a top predator in forests where there is a less abundant top predator (Appel *et al*., 2014) also the reason for the species shows a higher rate of temporal overlap, mostly with the prey species. The diurnal yellow-throated marten shows positive spatial co-occurrence with arboreal species. The masked palm civet is a nocturnal species (Li *et al*., 2022) that shares its habitat with the Northern Pig-tailed Macaque. The species, such as the clouded leopard and the Asiatic golden cat, were identified as temporally overlapping species (Lynam *et al*., 2013) in the Southeast Asia distribution range. Our estimation was unable to identify such an association, which might be an artefact of site-specific activity. The Asiatic golden cat and leopard cat's difference in temporal activity was observed in other distribution ranges (Kamler, 2020). Environmental factors also played a significant role in the establishment of these elusive felids (Choki *et al*., 2025).

Though the distribution of goral and serow was reported to be in close habitats based on some of the ecological studies. Red goral was found to prefer open area habitats and steep slopes with greater than 30^0 slopes (Green, 1985; 1987). As they have escape behaviours, they prefer cliff-occupied forests (Johnsingh & Manjrekar, 2013). However, there isn't much overlap between the serow and red goral. This could be because serows like to inhabit areas with lots of scrub (Green, 1985), while gorals stay away from these kinds of understory habitats. Gorals inhabit limited areas in NE region, whereas serows are more common in this region. Red Goral, Northern Red Muntjac, Sambar, and Mainland Serow show high temporal overlap, but the activity peak varies among the species at various rates, which might be due to differences in feeding preferences (Ribeiro, 2016). The sambar shows positive spatial co-occurrence with serow and red muntjac but not with goral. The distinction may be due to the feeding behaviour, as sambar and the other two species are browsers, whereas goral are grazers (Green 1987). Though there appears to be a considerable temporal overlap of Takin with all the ungulate species, the species is expected to be capable of maintaining niche separation with other large and medium-sized mammals (Zhang *et al*., 2021). The activity pattern of Takin shows a unimodal peak, differing from other species. Additionally, there is a positive spatial co-occurrence with Serow. Both species are browsers and engage in seasonal movement between altitudinal gradients (Li *et al*., 2022). The Gongshan Muntjac was considered to be a syntopic with other species of muntjac (Ma *et al.,* 1994) which was not observed in the study unit either temporally of spatially. The existence of separation of niche among the sister species based on elevation was observed in the evaluated habitats (Schaller & Rabinowitz, 2004) which need an extended assessment. Scientists have observed the mutually beneficial group association among species, particularly between ungulates and primates (Newton, 1989; Stensland *et al*., 2003). The Temporal association of various other combinations between Prey-predator and among the similar guild did not show considerable overlap as per our analysis. For example, though the species shows bimodal and unimodal activity peaks, the goral and Northern pig-tailed macaque show temporal overlap but not spatial co-occurrence. In contrast, some species, such as barking deer, serow, and sambar, show spatial co-occurrence but not temporal overlap. The activity variation at a finer scale among the ungulates is influenced by the scale of risk, which in turn also influences space uses (Hebblewhite & Merrill, 2008; Kohl *et al*., 2018). To understand the rhythms of species that are primary consumers, there needs to be an extensive study, monitoring, and large-scale information.

CONCLUSION

The mammalian species show various circadian rhythms during different life stages; e.g., the activity during the initial days following birth is not consolidated around the clock during the postpartum period (Bloch *et al*., 2013). Mammal communities are closely linked to random population changes, the quality of their habitat, and competition between different species in an area (Ziv, 2003). When species migrate, the availability of food and their energy reserves affect how active they are at night and during the day. More long-term studies that focus on specific species and communities would give useful insights for conserving and managing biodiversity in this area. Direct observation in the least accessible habitats can contextually explain animal behavior. This camera trap-based activity information helps to better understand behavioural ecology and species interaction in a least studied area that lies in a junction of three biogeographic realms viz., Indo-Malayan, the Palearctic, and Indo-Chinese. The timing pattern also varies considerably such that the extension of such monitoring can provide insights about the influence of biogeography and geographic gradients in determining the activity pattern of the species of interests (Bennie *et al*. 2014). The assessment activity pattern from the NE region is being considered preliminary (Mukherjee, 2019). We need to integrate other aspects, such as dietary preferences and spatial use patterns, to further examine this activity information. The estimated spatial co-occurrences show a majority of associations as random and some of the species associations as positive; there may be various influencing factors in the environment (Brazeau & Schamp, 2019). The above observation in our study of the circadian activity of species like Dhole, Clouded Leopard, and Marbled Cat shows certain differences from other distribution areas. We need to conduct more research on the competition between different species within a community. This should involve ongoing observation over a long time, along with developing new ideas about how species coexist (Chesson, 2000). This information about activity patterns and the spatial-temporal use of individual species is very important for the management and conservation of biodiversity in the rugged terrain of this valley. The co-occurrence of the analysed species shows a possible favourable probability frequency. As such, spatial interaction can be influenced by species space use, movement, strata, and other factors (Pellissier *et al*., 2010; García-Girón *et al*., 2020). Currently available co-occurrence results provide valuable information for scientific management. There is a requirement for other species-related information, like population, behaviour, and life history traits, such as movement and migration, which require a detailed long-term study (Alves, 2023).

REFERENCES

Anju Jain and Anubha Das 2022. North-East India: A Unique Biodiversity Paradise Unexplored or Lost?. *International Journal of Scientific and Research Publications (IJSRP*) 12(4) (ISSN: 2250-3153), DOI: http://dx.doi.org/10.29322/IJSRP.12.04.2022.p12417

Appel, Angelika & Khatiwada, Ambika. 2014. Yellow-throated Martens Martes flavigula in the Kanchenjunga Conservation Area, Nepal. 14-19.

Aschoff, J. 1963. Comparative physiology: diurnal rhythms. *Annual review of physiology*, 25(1), 581-600.

Ashton P, Zhu H. 2020 The tropical-subtropical evergreen forest transition in East Asia: an exploration. *Plant Diversity*, 42, 255-280.

Bhattacharya, Tapajit & Bashir, Tawqir & Poudyal, Kamal & Sambandam, Sathyakumar and Saha, Goutam. 2012. Distribution, Occupancy and Activity Patterns of Goral (Nemorhaedus goral) and Serow (Capricornis thar) in Khangchendzonga Biosphere Reserve, Sikkim, India. Mammal Study. 37. 173-181. 10.3106/041.037.0302.

Borries, C., Z.M. Primeau, K. Ossi-Lupo, S. Dtubpraserit & A. Koenig. 2014. Possible predation attempt by a marbled cat on a juvenile Phayre's Leaf Monkey. Raffles Bulletin of Zoology 62: 561–565.

Brazeau, H.A. and Schamp, B.S. 2019. Examining the link between competition and negative co-occurrence patterns. Oikos, 128: 1358-1366. https://doi.org/10.1111/oik.06054

Brooks,TM; Mittermeier, RA; da Fonseca, GAB; Gerlach, J; Hoffmann, M; Lamoreux, JF; Mittermeier, CG; Pilgrim, JD; Rodrigues, ASL. 2006. Global biodiversity conservation priorities. Science 313:58-61

Calhim, S., Shi J., and Dunbar R.I.M. 2006. Sexual segregation among feral goats: testing between alternative hypotheses. Animal Behaviour. 72: 31–41.

Can, Özgün. & Yadav, Bhupendra & Johnson, Paul & Ross, Joanna & D'Cruze, Neil & Macdonald, David. 2020. Factors affecting the occurrence and activity of clouded leopards, common leopards and leopard cats in the Himalayas. Biodiversity and Conservation. 29. 10.1007/s10531-019-01912-7.

Charles-Dominique P. 1975. Nocturnality and Diurnality. in: Luckett W.P., Szalay F.S. (ed) Phylogeny of the Primates. Springer, Boston, MA. https://doi.org/10.1007/978-1-4684-2166-8_4

Chettri, N., Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., Oli, KP., and Choudhury, D. 2010. Biodiversity in the Eastern Himalayas: Status, trends and vulnerability to climate change; Climate change impact and vulnerability in the Eastern Himalayas. Technical report 2. Kathmandu: ICIMOD

Choki, Karma & Droge, Egil & Sillero, Claudio & Macdonald, David & Penjor, Ugyen. 2025. Anthropogenic and environmental correlates of spatial patterns of co-occurrence of small felids in a montane landscape. Global Ecology and Conservation. 58. 10.1016/j.gecco.2025.e03422.

Choudhury, A. 2006. The Status of Endangered Species in Northeast India. Journal of the Bombay Natural History Society, 103 (2-3), 1pp. 57-167.

Choudhury, A.U. 200). Records and distribution of Gongshan and leaf muntjacs in India. Deer Specialist Group News 23: 2-7.

Cords M 1987 Mixed-species association of Cercopithecus monkeys in the Kakamega Forest, Kenya. Univ Calif Publ Zool 117:1–109

Cusack, J. J., Dickman, A. J., Rowcliffe, J. M., Carbone, C., Macdonald, D. W., and

Coulson,T. 2015. Random versus game trail-based camera trap placement strategy for monitoring terrestrial mammal communities. PloS one, 10(5), e0126373.https://doi.org/10.1371/journal.pone.0126373.

Dan Xiang, Bingshun Meng, Bo Xie, Xiaolong Huang, Cheng Wang, Jingcheng Ran, Haijun Su, Mingming Zhang, 2024. Daily activity rhythm of sympatric ungulate species in Fanjingshan Reserve, China, Global Ecology and Conservation, Volume 56, https://doi.org/10.1016/j.gecco.2024.e03271.

Frey, S., Fisher, J. T., Burton, A. C., and Volpe, J. P. 2017. Investigating animal activity patterns and temporal niche partitioning using camera-trap data: Challenges and opportunities. Remote Sensing in Ecology and Conservation, 3(3), 123-132. https://doi.org/10.1002/rse2.60.

Fusani L, Cardinale M, Carere C, and Goymann W. 2009. Stopover decision during migration: physiological conditions predict nocturnal restlessness in wild passerines. Biol. Lett.5, 302–305. doi:10.1098/rsbl.2008.0755.

Fusani L, Cardinale M, Schwabl I, and Goymann W. 2011. Food availability but not melatonin affects nocturnal restlessness in a wild migrating Passerine. Hormones and Behavior. 59, 187–192. doi:10.1016/j.yhbeh.2010.11.013.

García-Gir´on, J., Heino, J., García-Criado, F., Fern´andez-Al´aez, C., and Alahuhta, J. 2020. Biotic interactions hold the key to understanding metacommunity organisation. Ecography 43 (8), 1180–1190.

Garshelis, D. L., Dharaiya, N., Sharp, T. R., & Pigeon, K. E. 2022. Investigating Co occurrence among Look-alike Species: The Case of Three Bears in Northeast India. Diversity, 14(9), 717. https://doi.org/10.3390/d14090717

Gippoliti, S. 2001. Notes On the taxonomy of Macaca nemestrina leonina Blyth, 1863 (Primates: Cercopithecidae). HystrixIt. I. Mamrn. (n.s.) 12 (1): 51-54.

Gordigiani, L., Viviano, A., and Brivio, F. et al. 2022. Carried away by a moonlight shadow: activity of wild Pig in relation to nocturnal light intensity. Mammal Research. 67, 39–49 https://doi.org/10.1007/s13364-021-00610-6

Goymann W, Spina F, Ferri A, and Fusani L. 2010. Body fat influences departure from stopover sites in migratory birds: evidence from whole-island telemetry. *Biology Letters*. 6, 478–481. (doi:10.1098/rsbl.2009.1028).

Green, M. J. 1987. Ecological separation in Himalayan ungulates. Journal of Zoology, 1(4), 693-719. https://doi.org/10.1111/j.1096-3642.1987.tb00751.x.

Green, M. J. B. 1985. Aspects of the ecology of the Himalayan musk deer. PhD Thesis,University of Cambridge, Cambridge.

Griffith, D., Veech, J., & Marsh, C. 2016. Cooccur: Probabilistic Species Co-Occurrence Analysis in R. Journal of Statistical Software, 69(2), 1-17. doi:10.18637/jss.v069.c02.

Guangwei, C. 2002. Biodiversity in the Eastern Himalayas: Conservation through dialogue, summary reports of the workshops on biodiversity conservation in the Hindu Hush-Himalayan ecoregion. Kathmandu, ICIMOD

Hanya G, Otani Y, Hongo S, Honda T, Okamura H, et al. 2018. Activity of wild Japanese macaques in Yakushima revealed by camera trapping: Patterns with respect to season, daily period and rainfall. PLOS ONE 13(1): e0190631. https://doi.org/10.1371/journal.pone.0190631

Havmøller, L. W., Wahyudi, H. A., Iqbal, M., Nawangsari, V. A., Setiawan, J., Chandradewi, D. S.,Møller, P. R., Træholt, C., and Havmøller, R. W. 2024. Exploring temporal activity of dholes, their prey, and competitors in East Java, Indonesia. Ecology and Evolution, 14, e11666. https://doi.org/10.1002/ece3.11666

Havmøller, R.W., Jacobsen, N.S., Scharff, N., Rovero, F. and Zimmermann, F. 2020. Assessing the activity pattern overlap among leopards (Panthera pardus), potential prey and competitors in a complex landscape in Tanzania. J Zool, 311: 175-182. https://doi.org/10.1111/jzo.12774

Hazlerigg DG, and Tyler NJC. 2019. Activity patterns in mammals: Circadian dominance challenged. PLoS Biol. 15;17(7):e3000360. doi: 10.1371/journal.pbio.3000360. PMID: 31306430; PMCID: PMC6657935.

Hebblewhite, M., & Merrill, E. H. 2007. Multiscale wolf predation risk for elk: does migration reduce risk?. Oecologia, 152, 377-387.https://doi.org/10.11609/jott.4662.11.4.13432-13447

Helm B. 2006. Zugunruhe of migratory and non-migratory birds in a circannual context. *Journal of Avian Biology*. 37, pp. 533–540.

Hendry, Alexander, Zachary Amir, Henri Decoeur, Calebe Pereira Mendes, Jonathan H. Moore, Adia Sovie, and Matthew Scott Luskin. 2023. Marbled Cats in Southeast Asia: Are Diurnal and Semi-Arboreal Felids at Greater Risk from Human Disturbances?. Ecosphere 14(1): e4338. https://doi.org/10.1002/ecs2.4338

Hwang, M.-H, and D.L Garshelis. 2007. Activity Patterns of Asiatic Black Bears (Ursus Thibetanus) in the Central Mountains of Taiwan. Journal of zoology (1987) 271.2 : 203–209.

Jacobs, G. H. 1993. The distribution and nature of colour vision among the mammals. Biological Reviews of the Cambridge Philosophical Society, 68(3), 413-

Ji, Y., Liu, F., Li, D., Chen, Z., and Chen, P. 2022. Spatial–Temporal Patterns of Sympatric Asiatic Black Bears (Ursus thibetanus) and Brown Bears (Ursus arctos) in Northeastern China. Animals. 12, 1262. https://doi.org/10.3390/ani12101262

Jia Li, Diqiang Li, Charlotte Hacker, Wei Dong, Bo Wu, Yadong Xue, 2022. Spatial co-occurrence and temporal activity patterns of sympatric mesocarnivores guild in Qinling Mountains, Global Ecology and Conservation,Volume 36 https://doi.org/10.1016/j.gecco.2022.e02129

Johnsingh, A. J. T., and Manjrekar, N. 2013. Mammals of South Asia, Vol. I.Kamler, J.F., Jędrzejewska B., and Jędrzejewski W. 2007. Activity patterns of red deer in Białowieża National Park, Poland. J. Mammal. 88: 508–514.

Kamler, Jan & Inthapanya, Xaysavanh & Rasphone, Akchousanh & Bousa, Anita & Vongkhamheng, Chanthavy & Johnson, Arlyne & Macdonald, David. (2020). Diet, prey selection, and activity of Asian golden cats and leopard cats in northern Laos. Journal of Mammalogy. 101. 1-12. 10.1093/jmammal/gyaa113.

Kaul, R. N. and Haridasan, K. 1987. Forest types of Arunachal Pradesh – a preliminary study. *Journal of Economic and Taxonomic Botany* 1987, 9, 379–389.

Kawanishi, Kae. 2009. Food habits and activity patterns of the Asiatic golden cat (Catopuma temminckii) and dhole (Cuon alpinus) in a primary rainforest of Peninsular Malaysia.Mammal Study. 33. 173-177. 10.3106/1348-6160-33.4.173.

Kohl, M. T., Stahler, D. R., Metz, M. C., Forester, J. D., Kauffman, M. J., Varley, N., ... & MacNulty, D. R. 2018. Diel predator activity drives a dynamic landscape of fear. Ecological Monographs, 88(4), 638-652.

Kumar, Suresh & Mishra, Charudutt & Sinha, Anindya. 2007. Foraging ecology and time-activity budget of the Arunachal macaque Macaca munzala- A preliminary study. Current Science. 93. 532-539.

Li, J., Xue, Y., Liao, M., Dong, W., Wu, B., & Li, D. 2022. Temporal and Spatial Activity Patterns of Sympatric Wild Ungulates in Qinling Mountains, China. Animals, 12(13), 1666. https://doi.org/10.3390/ani12131666

Li, Y., Ma, G., Zhou, Q., & Huang, Z. 2020. Seasonal variation in activity budget of Assamese macaques in limestone forest of Southwest Guangxi, China. Folia Primatologica, 91(5), 495–511. https://doi.org/10.1159/000506593

Lynam, Antony & Jenks, Kate & Tantipisanuh, Naruemon & Chutipong, Wanlop & Ngoprasert, Dusit & Steinmetz, Robert & Sukmasuang, Ronglarp & Jr, Lon & Cutter, Passanan & Kitamura, Shumpei & Bhumpakphan, Naris & Reed, David & Baker-Whatton, Megan & McShea, William & Songsasen, Nucharin & Leimgruber, Peter. 2013. Terrestrial activity patterns of wild cats from camera-trapping. The Raffles bulletin of zoology. 61. 407-415.

Ma, S.-L., Han, L. and Lan, D. 1994. Bird and mammal resources and nature conservation in the Gaoligongshan region, Yunnan province, People's Republic of China. Kunming Institute of Zoology, Kunming, Yunnan, China.

Matsubayashi, H., Lagan, P., Majalap, N., Tangah, J., Sukor, J. R. A., & Kitayama, K. 2007. Importance of natural licks for the mammals in Bornean inland tropical rain forests. Ecological Research, 22(5), 742-748.

Makin, D. F., Chamaillé-Jammes, S., & Shrader, A. M. 2017. Changes in feeding behavior and patch use by herbivores in response to the introduction of a new predator. Journal of Mammalogy, 99(2), 341-350. https://doi.org/10.1093/jmammal/gyx177.

Meredith, M., & Ridout, M. S. 2020. Overview of the overlap package. R Project, 1-9.

Micaela Camino, Jeffrey Thompson, Laura Andrade, Sara Cortez, Silvia D. Matteucci, Mariana Altrichter, 2020. Using local ecological knowledge to improve large terrestrial mammal surveys, build local capacity and increase conservation opportunities,Biological Conservation, Volume 244, https://doi.org/10.1016/j.biocon.2020.108450.

Mishra, C., Raman, T., & Johnsingh, A. 1994. Survey of primates, serow, and goral in Mizoram. Report, Wildlife Institute of India, Dehra Dun.

Mishra, C., Shankar Raman, T. R., & Johnsingh, A. J. T. 1998. Habitat, hunting and conservation of rupicaprines in Mizoram, Northeast India. Journal Bombay Natural History Society, 95, 215-220.

Monirujjaman and M. Monirul H. Khan. 2017. Comparative activity pattern and feeding behaviour of Capped Langur (Trachypithecus pileatus) and Rhesus Macaque (Macaca mulatta) in Madhupur National Park of Bangladesh, Jahangirnagar University J. Biol. Sci. 6(1): 1-12,

Mukherjee, S., P. Singh, A.P. Silva, C. Ri, K. Kakati, B. Borah, T. Tapi, S. Kadur, P. Choudhary, S. Srikant, S. Nadig, R. Navya, M. Björklund & U. Ramakrishnan. 2019. Activity patterns of the small and medium felid (Mammalia: Carnivora: Felidae) guild in northeastern India. Journal of Threatened Taxa 11(4): 13432–13447;

Mukherjee, Aditi & Kumara, Honnavalli & Bhupathy, Subramanian. 2018. Environmental determinants of activity variation of an overlooked burrowing rodent: The Indian crested porcupine. Mammalia. 82. 10.1515/mammalia-2017-0124.

Naing, Hla & Htun, Saw & Kamler, Jan & Burnham, Dawn & Macdonald, David. 2020. Large carnivores as potential predators of sun bears. Ursus. 2019. 51. 10.2192/URSU-D-18-0022.2.

Nakabayashi M, Kanamori T, Matsukawa A, Tangah J, Tuuga A, Malim PT, Bernard H, Ahmad AH, Matsuda I, Hanya G. 2021. Temporal activity patterns suggesting niche partitioning of sympatric carnivores in Borneo, Malaysia. *Scientific Reports* 2021 Oct 6;11(1):19819. doi: 10.1038/s41598-021-99341-6. PMID: 34615956; PMCID: PMC8494825.

Newton, P.N. 1989. Associations between Langur Monkeys (Presbytis entellus) and Chital Deer (Axis axis): Chance Encounters or a Mutualism?. Ethology, 83: 89-120. https://doi.org/10.1111/j.1439-0310.1989.tb00522.x

Nigam P., Nilofer B., Srivastav A. & Tyagi P.C. 2014. National Studbook of Stump-tailed Macaque (Macaca arctoides), Wildlife Institute of India, Dehradun and Central Zoo Authority, New Delhi.

Norris, D., Michalski, F., & Peres, C. A. 2010. Habitat patch size modulates terrestrial mammal activity patterns in Amazonian forest fragments. Journal of Mammalogy, 91(3), 551-560.

Padié, S., Morellet, N., Hewison, A. M., Martin, J. L., Bonnot, N., Cargnelutti, B., & Chamaillé-Jammes, S. 2015. Roe deer at risk: teasing apart habitat selection and landscape constraints in risk exposure at multiple scales. Oikos, 124(11), 1536-1546. https://doi.org/10.1111/oik.02115.

Palei, N.C., Rath, B.P., Kumar, S.S., & Palei, H.S. 2021. Occurrence and Activity Pattern of Endangered Dhole (*Cuon alpinus*) in Debrigarh Wildlife Sanctuary, Odisha, India. Proceedings of the Zoological Society, 75, 134 - 138.

Pallavi Ghaskadbi, Bilal Habib, Qamar Qureshi. 2016 A whistle in the woods: an ethogram and activity budget for the dhole in central India, Journal of Mammalogy, Volume 97, Issue 6, 5 December 2016, Pages 1745–1752, https://doi.org/10.1093/jmammal/gyw141

Pebsworth, P.A., LaFleur, M. 2014. Advancing Primate Research and Conservation Through the Use of Camera Traps: Introduction to the Special Issue. International Journal of Primatology, 35, 825–840. https://doi.org/10.1007/s10764-014-9802-4

Pianka, E. R. 1973. The structure of lizard communities. Annual review of ecology and systematics, 4(1), 53-74.

Pierce, Andrew & Sukumal, Niti & Khamcha, Daphawan. 2014. A Yellow-throated Marten (Martes flavigula) feeding on a Red Muntjac (Muntiacus muntjak) carcase. Small Carnivore Conservation. 51. 76–78.

Priya Singh, David W Macdonald. 2017. Populations and activity patterns of clouded leopards and Marbled Cat in Dampa Tiger Reserve, India, Journal of Mammalogy, Volume 98, pp 1453–1462, https://doi.org/10.1093/jmammal/gyx104

Qamar Qureshi, Y.V. Jhala, S.P. Yadav and A. Mallick (eds) 2023. Status of Tigers in India - 2022: Photo-captured Tigers, Summary Report. National Tiger Conservation Authority and Wildlife Institute of India, Dehradun. TR. No./2023/03.

Qamar Qureshi, Yadvendradev V. Jhala, Satya P. Yadav, Virendra R. Tiwari, Rajendra Garawad, and Amit Mallick 2024. Status of Leopards in India, 2022.(eds) National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun. ISBN No: 81-85496-86-2

Rheingantz, M. L., Leuchtenberger, C., Zucco, C. A., & Fernandez, F. A. 2016. Differences in activity patterns of the Neotropical otter Lontra longicaudis between rivers of two Brazilian ecoregions. Journal of Tropical Ecology, 32(2), 170-174.

Ridout, M. S., & Linkie, M. 2009. Estimating overlap of daily activity patterns from camera trap data. Journal of Agricultural, Biological, and Environmental Statistics, 14(3), 322-337.

Robert Steinmetz, David L. Garshelis, Wanlop Chutipong, Naret Seuaturien. 2013. Foraging ecology and coexistence of Asiatic black bears and sun bears in a seasonal tropical forest in Southeast Asia, Journal of Mammalogy, Volume 94, Issue 1, 15 February. Pages 1–18, https://doi.org/10.1644/11-MAMM-A-351.1

Ross, J., Hearn, A. J., Johnson, P. J., & Macdonald, D. W. 2013. Activity patterns and temporal avoidance by prey in response to Sunda clouded leopard predation risk. Journal of Zoology, 290(2), 96-106.

Rovero, F., Tobler, M., & Sanderson, J. 2010. Camera trapping for inventorying terrestrial vertebrates. *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring*, (6), 100-128.

Rowcliffe, J. M., Kays, R., Kranstauber, B., Carbone, C., & Jansen, P. A. 2014. Quantifying levels of animal activity using camera trap data. Methods in Ecology and Evolution, 5(11), 1170-1179. https://doi.org/10.1111/2041-210X.12278.

M.B.M, Rufino & Abdul, Abu & Ten, Dennis & Magintan, David & Ngau, Cosmas & Ismail, Abu & Jamaludin, Hamidi & Zainal, Munawwarah & Rasdi, Idlan & Zainal Abidin, Fauzul Azim. 2010. A study on activity patterns of Clouded Leopard and Marbled Cat in Temenggor Forest Reserve, Hulu Perak. Journal of Wildlife and Parks. 26. 59-66.

Schaller, G.B. and Rabinowitz, A. 2004. Species of barking deer (genus Muntiacus) in the eastern Himalayan region. Journal of the Bombay Natural History Society 101: 442-444.

Shameer, Thekke & Mungi, Ninad. 2021. How can spatio-temporal overlap in mammals assist in maximizing biodiversity conservation? A case study of Periyar Tiger Reserve. Biologia. 10.2478/s11756-020-00645-1.

Shankar, A., Salaria, N., Sanil, R., Chackaravarthy, S. D., & Shameer, T. T. 2020.
Spatio-temporal association of fishing cats with the mammalian assemblages in the
East Godavari mangrove delta, India. Mammal Study, 45(4), 1-11.
https://doi.org/10.3106/ms2020-0015.

Sharma, N., & Sinha, A. 2022. Niche partitioning and coexistence of sympatric macaques in a fragmented habitat of the Upper Brahmaputra Valley, northeastern India. bioRxiv.

Sherry, T. W. 1979. Competitive interactions and adaptive strategies of American Redstarts and Least Flycatchers in a northern hardwoods forest. The Auk, 96(2), 265-283. https://doi.org/10.1093/auk/96.2.265.

Shrestha, L., Sarkar, M.S., Shrestha, K., Aung, P., Wen, X., Yongping, Y., Zhipang, H., Xuefei, Y., Shaoliang, Y., & Chettri, N. 2022. Mammalian Research, Diversity and Conservation in the Far Eastern Himalayan Landscape: A Review. Global Ecology and Conservation.

Silveira, L., Jacomo, A. T., & Diniz-Filho, J. A. F. 2003. Camera trap, line transect census and track surveys: a comparative evaluation. Biological conservation, 114(3), 351-355. https://doi.org/10.1016/S0006-3207(03)00063-6.

Sinclair, A. R. E. 2003. Mammal population regulation, keystone processes and ecosystem dynamics. Philosophical Transactions of the Royal Society. London. B 358 (1438), 1729–1740. https://doi.org/10.1098/rstb.2003.1359.

Singh P, Srivathsa A, Macdonald DW. 2020. Conservation status of the dhole Cuon alpinus in north-east India, with a focus on Dampa Tiger Reserve, Mizoram. Oryx. ;54(6):873-877. doi:10.1017/S0030605319000255

Singh, Hemant & Sharief, Amira & Joshi, Bheem Dutt & Kumar, Vineet & Mukherjee, Tanoy and Chandra, Kailash & Bhardwaj, Nitin & Thakur, Mukesh & Sharma, Lalit. 2022. Multi-species occupancy modeling suggests interspecific interaction among the three ungulate species. Scientific Reports. 12. 10.1038/s41598-022-20953-7.

Singh R, Chauhan DS, Mishra S, Krausman PR, Goyal SP. 2014. Tiger density in a tropical lowland forest in the Eastern Himalayan Mountains. Springerplus. doi: 10.1186/2193-1801-3-462. PMID: 25187884; PMCID: PMC4152472.

Sollmann, R. 2018. A gentle introduction to camera-trap data analysis. African Journal of Ecology, 56(4), 740-749. https://doi.org/10.1111/aje.12557.

Soma, H. 1990. Serows (genus Capricornis). In Grzimek's Encyclopedia of Mammals, Vol. 5 McGraw Hill Publising Company, New York. P. 505-506, 508-509.

Taher, Mohammed. 1993. The peopling of Assam and and social structure , in A. Ahmed (ed.) Social structure and regional development, Rawat, Jaipur.

Steinmetz, R., Garshelis, D. L., & Choudhury, A. 2021. Adaptations and competitive interactions of tropical Asian bear species define their biogeography: Past, present, and future. Bears of the World: Ecology, Conservation and Management; Penteriani, V., Melletti, M., Eds, 45-52.

Stensland E, Angerbjorn A, Berggren P. 2003. Mixed species groups in mammals. Mamm Rev 33:205–223

Tannerfeldt, M., Elmhagen, B., & Angerbjörn, A. 2002. Exclusion by interference competition? The relationship between red and arctic foxes. Oecologia, 132(2), 213-220.

Tattersall, J. 1988. Cathemeral activity in primates: a definition. Folia Primatol. 49: 200-202.

Terrill SB. 1987. Social dominance and migratory restlessness in the dark eyed junco (Junco hyemalis). *Behavioral Ecology and Sociobiology*. 21, 1–11. (doi:10.1007/BF00324429)

Theuerkauf, J., Jędrzejewski, W., Schmidt, K., Okarma, H., Ruczyński, I., Śniezko, S., and Gula, R. 2003. Daily patterns and duration of wolf activity in the Białowieza Forest, Poland. Journal of Mammalogy, 84(1), 243-253. DOI 10.1644/1545-1542(2003)084<0243:dpadow>2.0.co;2.

Tilman, D., & Kareiva, P. 1997. Spatial ecology : the role of space in population dynamics and interspecific interactions. Ecology.

Treves, A., Mwima, P., Plumptre, A. J., & Isoke, S. 2010. Camera-trapping forest–woodland wildlife of western Uganda reveals how gregariousness biases estimates of relative abundance and distribution. Biological Conservation, 143(2), 521-528.

Tylianakis, J. M., R. K. Didham, J. Bascompte, and D. A.Wardle. 2008. Global change and species interactions in terrestrial ecosystems. *Ecology Letters,* 11(12), 1351–1363. https://doi.org/10.1111/j.1461-0248.2008.01250.x.

Van der Zee EA, Havekes R, Barf R P, Hut R A, Nijholt I M, Jacobs E H, Gerkema M P. 2008 Circadian time place learning in mice depends on Crygenes. *Current Biology.* 18, 844–848.

Vazquez, C., Rowcliffe, J. M., Spoelstra, K., & Jansen, P. A. 2019. Comparing diel activity patterns of wildlife across latitudes and seasons: Time transformations using day length. Methods in Ecology and Evolution, 10(12), 2057-2066. https://doi.org/10.1111/2041-210X.13290.

Veech, J. A. 2013. A probabilistic model for analysing species co-occurrence. Global Ecology and Biogeography, 22(2), 252-260. 252–260. doi:10.1111/j.1466 8238.2012.00789.x.

Vernes, Karl & Rajaratnam, Rajanathan & Dorji, Sangay. 2022. Patterns of species co-occurrence in a diverse Eastern Himalayan montane carnivore community. Mammal Research. 67. 139 - 149. 10.1007/s13364-021-00605-3.

Venkataraman, A. B. 1995. Do dholes (Cuon alpinus) live in packs in response to competition with or predation by large cats?. Current science, 934-936.

Vallejo-Vargas, A.F., Sheil, D., Semper-Pascual, A. et al.,. 2022. Consistent diel activity patterns of forest mammals among tropical regions. *Nature Communications*, 13, 7102 https://doi.org/10.1038/s41467-022-34825-1

Wang, Y.; Lv, Y.; Wang, G.;Liu, F.; Ji, Y.; Liu, Z.; Zhao, W.;Liu, W.; Dun Zhu, P.B.; Jin, K. 2024. Identification of Individuals of TwoTakin Subspecies Using Biological and Ecological Criteria in Eastern Himalayas of China. Animals ,14, pp. 24-26. https://doi.org/10.3390/ani14162426

Waser PM. 1980. Small nocturnal carnivores: ecological studies in the Serengeti . *African Journal of Ecology*. 18:167–185.

Wearn, O. R., & Glover-Kapfer, P. 2019. Snap happy: camera traps are an effective sampling tool when compared with alternative methods. Royal Society open science, 6 (3),181748.

Wen, Lijia & Guo, Yumin & Huang, Jian & Yang, Song. 2016. The Activity Rhythm of the Asiatic Brush-tailed Porcupine (Atherurus macrourus) and Its Correlation with the Phases of the Moon. Chinese Journal of Zoology 2016, 51(3): 347 ~ 352 51. 347-352. 10.13859/j.cjz.201603002

Wildlife Institute of India. 2018. National Studbook of Pig-tailed Macaque (Macaca leonina): II Edition, Wildlife Institute of India, Dehradun and Central Zoo Authority, New Delhi.TR. No. 2018/24 Pages: 58

Williams, T. M., Estes, J. A., Doak, D. F., & Springer, A. M. 2004. Killer appetites: assessing the role of predators in ecological communities. Ecology, 85(12), 3373-3384. https://doi.org/10.1890/03-0696.

Wittemyer, G., Elsen, P., Bean, W. T., Burton, A. C. O., & Brashares, J. S. 2008. Accelerated human population growth at protected area edges. Science, 321, 123–126.

Wittemyer, G., Polansky, L., Douglas-Hamilton, I., & Getz, W. M. 2008. Disentangling the effects of forage, social rank, and risk on movement autocorrelation of elephants using Fourier and wavelet analyses. Proceedings of the National Academy of Sciences, 105(49), 19108-19113. https://doi.org/10.1073/pnas.081744105.

Youbing Zhou, Chris Newman, Francisco Palomares, Shuiyi Zhang, Zongqiang Xie, David W. Macdonald. 2014. Spatial organization and activity patterns of the masked palm civet (Paguma larvata) in central-south China, Journal of Mammalogy, Volume 95, Issue 3, 534–542, https://doi.org/10.1644/13-MAMM-A-185

Zayonc, Daniel & Coomes, Oliver. 2021. Who is the expert? Evaluating local ecological knowledge for assessing wildlife presence in the Peruvian Amazon. *Conservation Science and Practice*. 4. 10.1111/csp2.600.

Zeng, Z. G. & Song, Y. L. 2001. Diurnal activity rhythm and behavioral time budgets of Qinling takin in spring and summer (written in Chinese). Acta Theriologica Sinica. 2001; 21(1):7–13.

Zhang, Y., He, X., Liu, X. et al. 2021. Fine-scale activity patterns of large- and medium-sized mammals in a deciduous broadleaf forest in the Qinling Mountains, Journal *of Forestry Research* 32, 2709–2717 https://doi.org/10.1007/s11676-021-01291-2

Yaron Ziv. 2003. Predicting Patterns of Mammalian Species Diversity from a Process-Based Simulation Model, Journal of Mammalogy, Volume 84, Issue 1,Pages 1–19, https://doi.org/10.1644/1545-1542(2003)084<0001:PPOMSD>2.0.CO;2