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CAMERA TRAPPING COUPLED WITH FIELD SIGN SURVEY REVEAL THE MAMMALIAN DIVERSITY AND ABUNDANCE AT MURREE-KOTLI SATTIAN-KAHUTA NATIONAL PARK, PAKISTAN

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ABSTRACT

Murree-Kotli Sattian-Kahuta National Park was declared a protected area in 2009, however, not much is known about the diversity and relative abundance of its mammalian fauna. We used sign survey and camera trapping techniques to get an insight into the diversity of mammalian species inhabiting this park. Field Surveys were conducted from April 2023 up to the end of March 2024, to record field signs (scats, pugmarks etc.) of the mammals' species. In addition, we deployed 22 infrared Camera traps" in different areas of the park, for 116 nights and a total of 516 photographs of different mammal species were captured by these camera traps. Results of camera trapping coupled with field signs surveys confirmed the presence of a total of 21 different mammal species (large, meso- and small mammals) in the park. Among carnivores, common Leopard, Asiatic jackal, Red fox, Leopard cats, Jungle cat, Asian palm civet, small Indian civets, grey mongoose and small Indian mongoose were recorded. Among the herbivores, barking deer and Yellow-throated marten were the key species. Wild boar, Asiatic Jackal and Indian-crested porcupine were recorded at 7 (maximum) each out of 11 sampling sites, The leopard cat and the Yellow-throated marten were recorded at only one site each. Leopard and Asian palm civets were overlapping species in the area, as their temporal activity pattern overlapped for 61%. The most abundant mammal species in the park was wild boar (*Sus scrofa*) while the least abundant was the Jungle cat (*Felis chaus*).

Key words: Camera trapping, Diversity, Abundance, Evenness, Distribution, Mammals, overlapped.

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INTRODUCTION

Mammals are the key components of an ecosystem since they exert top-to-bottom effects through the food chain and control the population of many plant and animal species by being herbivores and carnivores. Mammals are extraordinary animals showing a lot of diversity and play a key role in maintaining the ecosystem (Jones *et al.,* 2011). Field visits and scat surveys helps to estimate the diversity of carnivores and their relative abundance (Kabir *et al.,* 2017). Habitat disturbance, fragmentation, migration of species, deforestation, and climate change are major threats to biological diversity (Bukhari and Bajwa, 2011; Bajwa and Waseem, 2013; Bajwa *et al.,* 2015). Every species plays a crucial role within an ecosystem, emphasizing the importance of conserving diversity. Once a species becomes extinct, its restoration is impossible. Various strategies exist for preserving biodiversity, including the safeguarding of biodiversity-rich areas through the establishment of biosphere reserves, national parks, and sanctuaries, a practice known as in-situ conservation (Ebeling *et al.,* 2014). Determining the abundance of a species is crucial for evaluating the risk of extinction among endangered species, monitoring invasive species, and especially for managing populations of threatened species (Yin and He, 2014). A complete understanding of abundance of species in a park is essential for making informed decisions in biological management and conservation, as well as for comprehending population dynamics (Yin and He, 2014). The estimation of abundance is valuable for establishing hunting quotas, assessing prey availability for carnivores, and effectively managing wildlife areas for tourism purposes (Palmer *et al.,* 2023). Abundance estimates play a key role in evaluating conservation initiatives and offer insights into the functioning of ecological communities (Danell *et al.,* 2006; Verberk, 2011; Cox *et al.,* 2017). Examining the

abundance of mammals yields valuable information for implementing effective conservation measures (Galetti *et al*., 2009; Atnafu and Yihune, 2018). Typically expressed as an index value derived from the frequency of signs or observations per standardized unit of sampling effort, relative abundance serves as a practical measure (Wilson and Delahay, 2001). Camera trap data can be utilized to estimate the relative abundance of species (Lahang, 2005; Obrien, 2011). Estimating the species diversity and relative abundance of species in an area is a critical component of biodiversity assessment (Hubbell, 2001; Yoccoz *et al*., 2001). Ecologists leverage data on species relative abundance to infer relationships among different specie within specific communities (Odat *et al.,* 2009). Furthermore, this information is instrumental in estimating ecological disturbance and conducting population viability analyses (Odat *et al.,* 2009). In Pakistan, there are 225 protected areas, which include 37 National Parks containing important wildlife species (Khan *et al.,* 2003). Some of the major mammalian species that are present in the national parks of the country include the common leopard *(Panthera pardus*), barking deer (*Muntiacus vaginalis*), red fox (*Vulpes vulpes*), golden jackal *(Canis aureus*), wolf (*Canis lupus*), Leopard cat (*Prionailurus bengalensis*), jungle cat *(Felis chaus*), wild boar (*Sus scrofa*), etc. The common leopard belongs to the family Felidae and is one of the big cats' present in this era (Breitenmoser *et al.,* 2008). Central and the Southwest Asia, have a wide range and territory of the common leopard, but due to human conflict, its range is confined to only rocky areas (Henschel *et al.,* 2008). In different forest types, ranging from Himalayan forests (up to 5,200 m) to arid mountains and Acacia scrub forests its presence is reported in Pakistan (Nowell and Jackson, 1996). This study centers on the Murree-Kotli Sattian-Kahuta National Park, are relatively recently protected area established in September 2009 to preserve its diverse mammalian fauna. Despite its establishment, the park's Mammalian diversity, abundance, and overall fauna have not been comprehensively studied. Therefore, this research aimed to assess the park's mammalian diversity and abundance using reliable, modern field techniques, including camera trapping.

MATERIALS AND METHODS

Study Area: The current study was conducted in the "Murree-Kotli Sattian-Kahuta" National Park, located in Rawalpindi District, Punjab, Pakistan (Fig. 1). It was declared a "National Park" in September 2009, and it covers an area of approximately 57,581 hectares. Its geographic coordinates include a latitude of 33.6986° N, and longitude is 73.5195° E. Its elevation ranges up to 2300 m, moist temperate coniferous forest and the 'Chir pine subtropical forest' (Chir zone) are mainly found in the Murree area of the park. The climate is generally temperate, with average temperatures of 32 °C in June and 10 °C in the month of January. The average annual rainfall is approximately 1249 mm, most of which occurs during the monsoon season, peaking in July (GOP, 2006). The park's elevation range has resulted in significant variations in physiographic features, precipitation, and temperature profiles, leading to highly diverse vegetation zones. Noteably, there are three distinct forest types including subtropical broad-leaved forest, found on gently sloping to moderately steep mountain slopes approximately 900-1050 meters above sea level. This area receives annual rainfall ranging from 500 to 1350 mm and supports mixed open scrub vegetation. The subtropical chir pine forest zone covers steep mountain slopes, ranging from 900–1050 meters to 1400–1600 meters on cooler aspects and up to 1800 meters on warmer aspects. This zone receives rainfall between 1250 and 1500 mm, which supports the growth of *Pinus roxburghii, Quercus incana, Myrsinea fricana, Berberis lyceum, Dodonea viscosa,* and *Carissa spinarum* (Khan 2003).

Sign Surveys: Evidence of occurrence of various mammalian species in the park was gathered using the indirect method known as the "Field Sign Survey." For this purpose, monthly field visits were made to different areas of the park from April 2023 till March 2024. At the selected sampling sites, a team of three to four members conducted foot surveys along trails and tracks, with assistance from the staff and field watchers of the Rawalpindi District Wildlife Office. The survey team searched to record the field signs (scats, and pugmarks) of the different species of mammals inhabiting the park. Each survey consisted of two consecutive days, during which scat samples of the mammal species were collected and their pugmarks were recorded. Each scat was identified morphologically in the field (carnivore or herbivore) and collected in the self-sealing polythene bags. The geographical coordinates of the site and its elevation information were also recorded using a Global Positioning System (GPS: Garmin e TraxVista) along with other site details. This data was fed in an Excel sheet and used later along with camera trap data to construct distribution maps of the mammalian species inhabiting the park.`Specaccum` function from the`vegan` package was used to plot Species accumulation curves. Two different methods were used to plot these curves. Arrhenius models were fitted to all random accumulations while the Lomolino model was fitted to the exact accumulation curve.

Camera Trapping: "Motion-triggered" infra-red camera traps (Browning Trail Cameras Model BTC-1XV) were used to capture the videos and pictures as evidence of the occurrence of mammalian fauna in the park. To install camera traps in the park, different tracks were selected

which are commonly used by humans, livestock, trails, as well as seasonal streams. A total of 22 camera traps were installed at different locations and elevations. At each station 2 to 3 different sites were selected to install cameras. 2 to 3 different cameras were installed at each station. Each camera trap was installed in the morning and sometime during the daytime and removed during the daytime or in the evening. These cameras were installed for 7 to 10 consecutive days (depending upon the batteries). After 7-10 days cameras removed from sites and data collected in the form of pictures and videos. Overall, camera trap stations were established in such a way as to collect uniform data from the park. The data collected in the camera traps were downloaded and all the pictures of wildlife species were identified along with other details like sites of capture, time of capture, elevation, and others. Camera trap data were collected from multiple locations, each entry recording the capture date, time, location, and number of individuals. The dataset was cleaned by removing rows with missing or incomplete data on major animal species. These pictures were identified by matching with reference picturesof the mammals and by using field guides (Roberts 1997). The data recorded in the camera traps were fed into an Excel sheet for later analysis.

Abundance estimates: The abundance of different mammal species inhabiting the park was estimated by analyzing the cumulative data of total field signs collected during the study period, including the number of camera trap pictures of each mammalian species, the number of scats collected for each species, and the pugmarks of each species. The formula used was:

$$\text{Relative abundance of a species: } \frac{\text{Total numbers of a species in an area}}{\text{Total sum of all species in an area}} \times 100$$

The following formula was used to calculate the relative abundance index following Din *et al.* (2013) and Liu *et al.* (2013). $RAI = Ai/N \times 100$

Diversity Indices: The Shannon Diversity Index (sometimes called the Shannon-Wiener Index) (Shannon and Weaver, 1949) was calculated using the following formula: $\mathbf{H = -\Sigma pi * ln(pi)}$

Where ln stands for natural log and pi stands for the proportion of the entire community made up of a species i. Shannon-Weiner Diversity Index is denoted by H' following Strong *et al*. (2016). R= S-1/LogN. An abundance analysis was performed by grouping the data by scientific names and summarizing the total number of individuals captured. Results were visualized using a bar plot to show the relative abundance of each species. Strong *et al*. (2016)..

Species Richness: The total number of species in an area is referred to as species richness. Mammalian Species richness was calculated by considering the total number of species in the study area.

Species Evenness: The Evenness index was used to measure species evenness (denoted by E) as given by Hill (1973). E= H'/ln (S)

Where, PI = Proportion of the species, i relative to the total number of species In PI = Natural logarithm of this proportion S= Total no. of species N= Total no. of individual

Data Analysis: Using R program, generalized linear models (GLMs) were created to analyze the relationship between the numbers of individuals captured and various environmental variables, including weather, latitude, and longitude. The `effects` package was used to generate and plot the effects of all predictors in the GLM. The Species accumulation curves generated indicated the species richness across different sampling sites. The Lomolino model fitted to the exact accumulation curve showed a good fit, while the Arrhenius models provided insights into the randomness of species accumulation Species accumulation curve showed that site Kotli Sattian had a maximum number of mammal species. Kalaiyan is the site where a minimum number of species is observed.

RESULTS

Field Signs and direct field sightings: During current study, we recorded a total of 225 field signs of 21 different mammalian species inhabiting the park (Table 1; Fig. 2 & 3). These signs included 86 scats of mammals along with pug marks, prey remains of carnivores, dens or burrows, and scratches on the tree trunks etc. (Fig. 2 and 3). Highest numbers of field signs (69) were found at "Sawan" site in Kotli Sattian area of the park, followed by those at Seri and Beor sites at Kahuta area of the national park. Least numbers of field signs of mammals were recorded at karel and Masoot sampling sites in the study area. The maximum signs recorded were scats of the mammals, followed by their pug marks and dens/burrows (Table 1; Fig.2 and 3).

In addition, we recorded pinecones in the field, partially eaten by bats (20), scratching of Indian crested porcupines (7) on tree trunks and roots, field burrows (3) of Indian pangolin, wild boar digging on the soil (9) and prey remains and blood on sites (3). At the Kalaiyan (Punjar) site of the park (elevation 857m), the scats of Indian-crested porcupines, and Asiatic jackals were recorded, as well as the presence of the bats. Body quills of porcupine were also found there. Regarding further evidence for the occurrence of bats, 20 partially eaten pinecones were recorded (fallen on the ground), at the Karel site of the park, along with scats of the barking deer, red fox, and Asiatic jackal. The pugmarks of barking deer were found on the track (Fig. 3) During the visit to the Seri site in Tehsil Kahuta, nine (9) scats were recorded on the track, including those of Asiatic jackal, Indian crested porcupine, small Indian civet, rhesus

monkey, and barking deer. Pugmarks of barking deer were also observed. In addition, prey remains of carnivores were also recorded at this site. Field burrows (03) of Indian pangolin were also recorded in the park (Table 1). Field sightings of northern palm squirrel were made at different sampling sites in the park. Out of a total of 11 different sites in the park, the Sawan site (Kotli-Sattian) maximum numbers of mammalian scats were recorded (Table 1; Fig.2 and 3)211

Camera Trapping Evidence: The second method applied for data collection was "camera Trapping" for recording pictorial evidence about the occurrence of mammalian species in the park. Camera trap data confirmed the pictorial evidence about the presence of 11 different mammalian species in park through a total of 5201 pictures that were captured by these camera traps (Table 2; Fig. 4 and 5). The numbers of photographs of the captured mammal species from the study area included Asiatic jackal (29), barking deer (59), small Indian civet (28), jungle cat (11), red fox (52), leopard cat (6), Indian crested porcupine (48), rhesus monkey (24), common leopard (33), wild boar (206), and yellow-throated marten (Table 2 and 3; Fig. 4 and 5). Overall, a total of 21 mammalian species were recorded in the park through camera trapping, direct field sightings, and indirect field signs like scats, pug marks, and burrows etc. (Table 3).

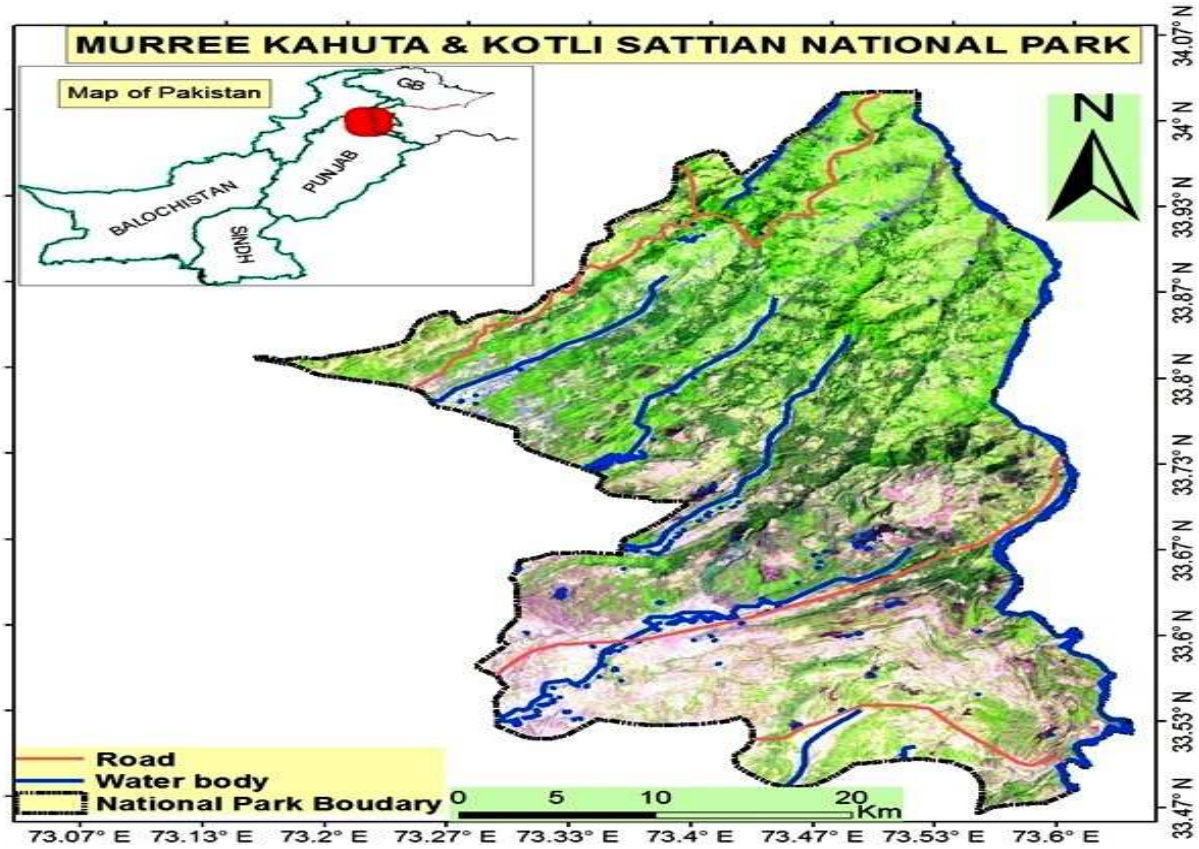
Diversity Index: The Shannon-Diversity-Index (H') indicated that the thick forest mixed with natural vegetation was the most diversified habitat in the park (Fig. 6). The abundance and diversity of mammal species varied significantly among remnant fragments. Many mammal species were recorded from the Sawan area, secondary Seri was the most diversified area of the park. The Diversity Index with Shannon-Diversity-Index (H') was 2.36 (Fig. 6), the least diversified area was Karel and Masoot.

Species richness and Evenness: In the current study, a total of 21 different mammal species were identified in the park; the species richness was found highest for Wild boar 71 and the lowest species richness was recorded for Hedgehog and Indian pangolin 1 (Fig. 5). Similarly, the Species evenness index (E) was found to be 0.81 in the national park (Fig. 6). Species accumulation curves indicated the species richness across different sampling sites. The Lomolino model fitted to the exact accumulation curve showed a good fit, while the Arrhenius models provided insights into the randomness of species accumulation Species accumulation curve showed that site Kotli Sattian had a maximum number of mammal species. Kalaiyan is the site where a minimum number of species is observed (Fig 7).

Temporal activity patterns and niche overlap: The mammalian species (both predator and prey species) activity patterns were not homogeneous during the study period. The common leopard was found nocturnal, starting its activity at dusk and staying active till late night. Asiatic jackal and red foxes started their activity at evening time and stayed active at night,, among all species of mammals recorded in the study area. The highest temporal niche overlap was found between common leopard and Asian Palm Civet (0.61) while niche overlap recorded between the common leopard and rhesus monkey (0.23) (Fig 8). For the common leopard highest temporal niche overlap was recorded with Asian Palm Civet (0.61) followed by Porcupine (0.57), Barking deer (0.55), Wild boar (0.53), Golden Jackal (0.34), Red fox (0.30) and monkey (0.23) (Fig 8, 9 and 10), while this apex predator has been observed to have zero/no dietary niche overlap with leopard cats, grey mongooses, and small Indian mongooses. Overall comparison indicated that common leopards showed the highest overlaps with simultaneous sympatric species.

Relative abundance: During the current study, a total of 516 photographs of different mammal species were recorded (camera trap data); among those, maximum pictures were taken for wild boar (206) while lowest number was recorded for the hedgehog (1). The bar plot of species abundance (Fig. 11) revealed that certain species were more frequently captured than others. This information is crucial for understanding species distribution and planning conservation efforts. An abundance analysis was performed by grouping the data by scientific name and summarizing the total numbers of individuals captured, the results were visualized using a bar plot to show the relative abundance of each species (Fig 11). Wild boar, Asiatic Jackal and Indian-crested porcupine were recorded at 7 (maximum) each out of 11 sampling sites, The leopard cat and the Yellow-throated marten were recorded at only one site each. Leopard and Asian palm civets were overlapping species in the area, as their temporal activity pattern overlapped for 61%. The most abundant mammal species in the park was wild boar (*Sus scrofa*) while the least abundant was the Jungle cat (*Felis chaus*).

Non-targeted species captured: In the current study, 4 different non-targeted species were also captured by camera traps; Kalij pheasant (*Lophura leucomelanos*), Peafowl (*Pavo cristatus)*, Butterflies *(Papilio clytia),* and Jerdonii snake eye (*Ophisops jerdonii*).



Figures: Figure 1 Map of Pakistan showing location of Murree-Kotli Sattian-Kahuta National Park (MKKNP).

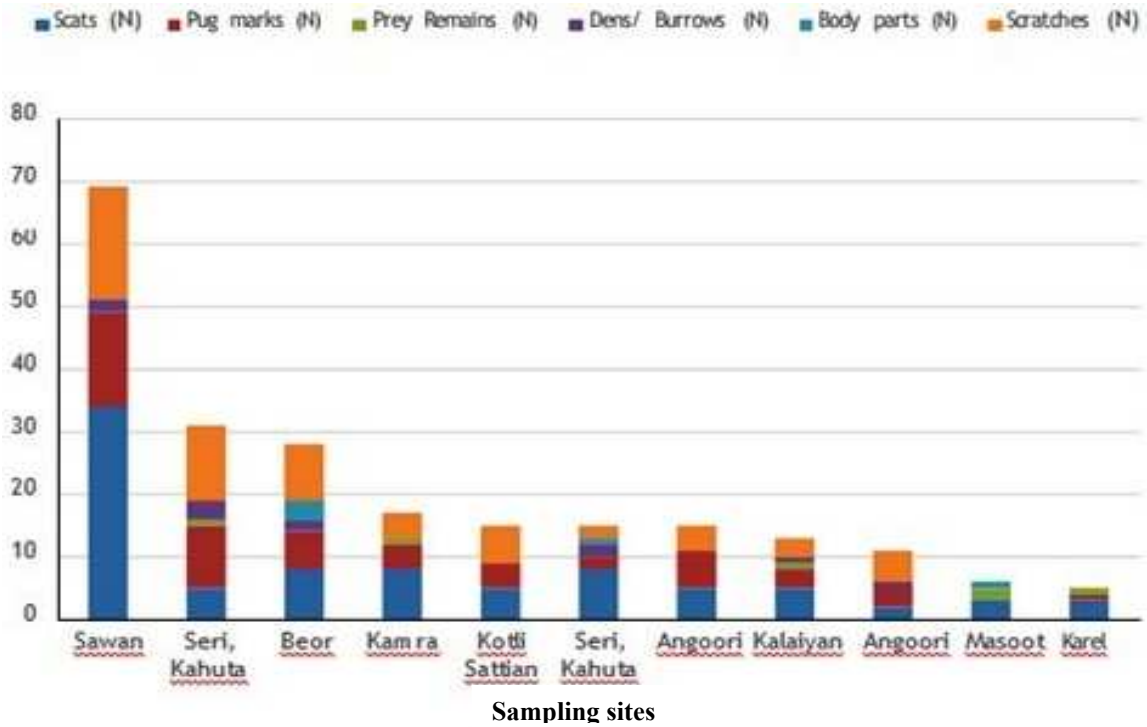


Figure 2 A stacked column chart showing field signs of different mammal species recorded at eleven different sites of the Murree-Kotli Sattian-Kahuta National Park.

Figure 3. Photographs showing field signs of different mammal species recorded in the study area. A to C) Field Burrows of mammals: A) Indian hedgehog, B) Indian Pangolin (C) small Indian mongoose, (D), scratches of Indian crested porcupine, E to H: Scats of mammals, E) Indian crested porcupine, (F) Asiatic Jackal, (G) red fox, (H) Asian palm civet, I to L: Pug marks of mammals, I) barking deer, J) common leopard, K) wild boar, L) a red fox.

Figure 4 Camera traps picture of A) common leopard, B) Leopard cat, C) barking deer, D) Red fox, E) Rhesus monkey, F) Yellow-throated martin, recorded at different sites of MKKNP.

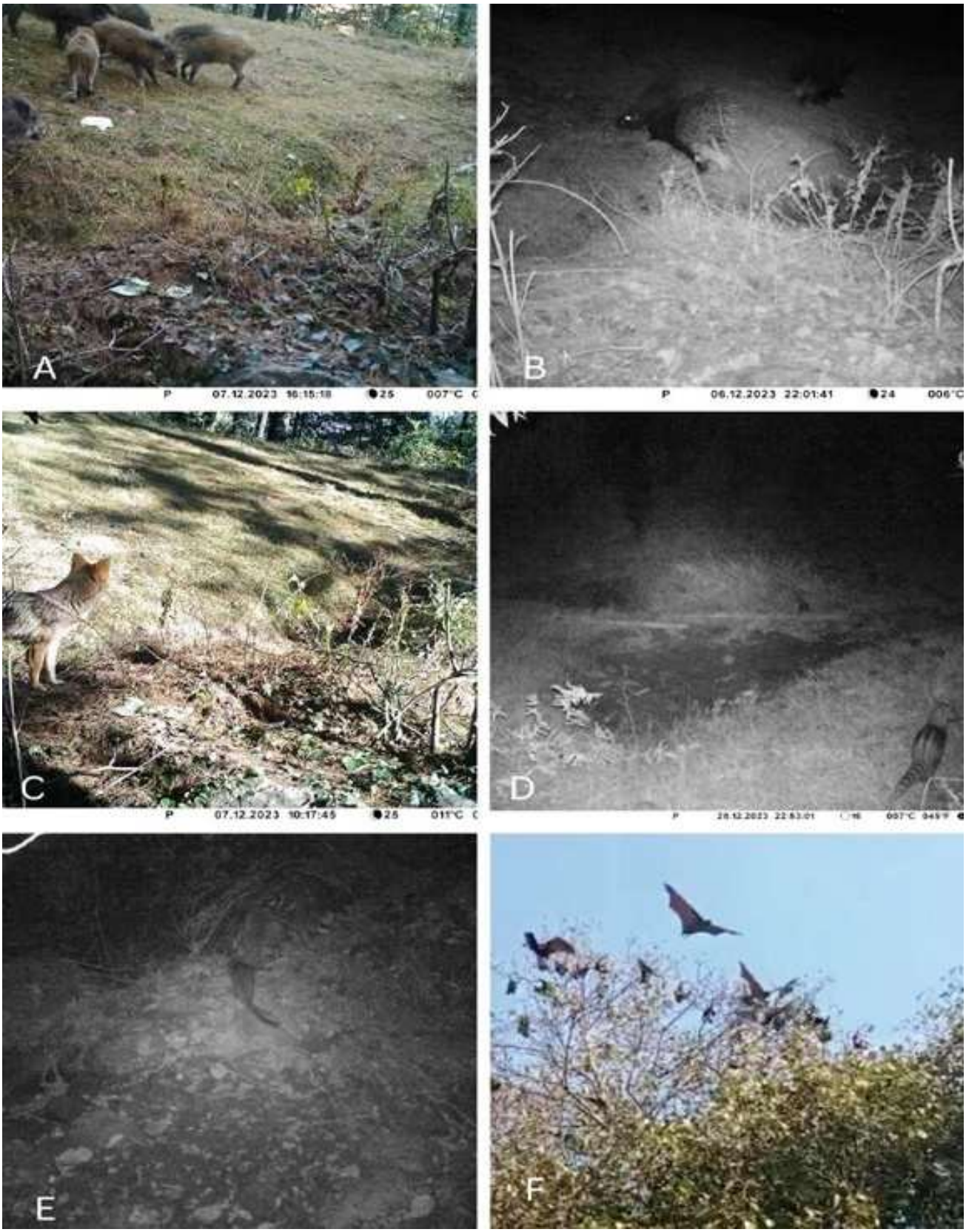


Figure 5 camera trap picture of wild boar (A), Indian crested Porcupine (B), Asiatic jackal (C), Small Indian civet (D), Jungle cat (E), and direct sighting of Bats (F) at different sites of MKKNP.

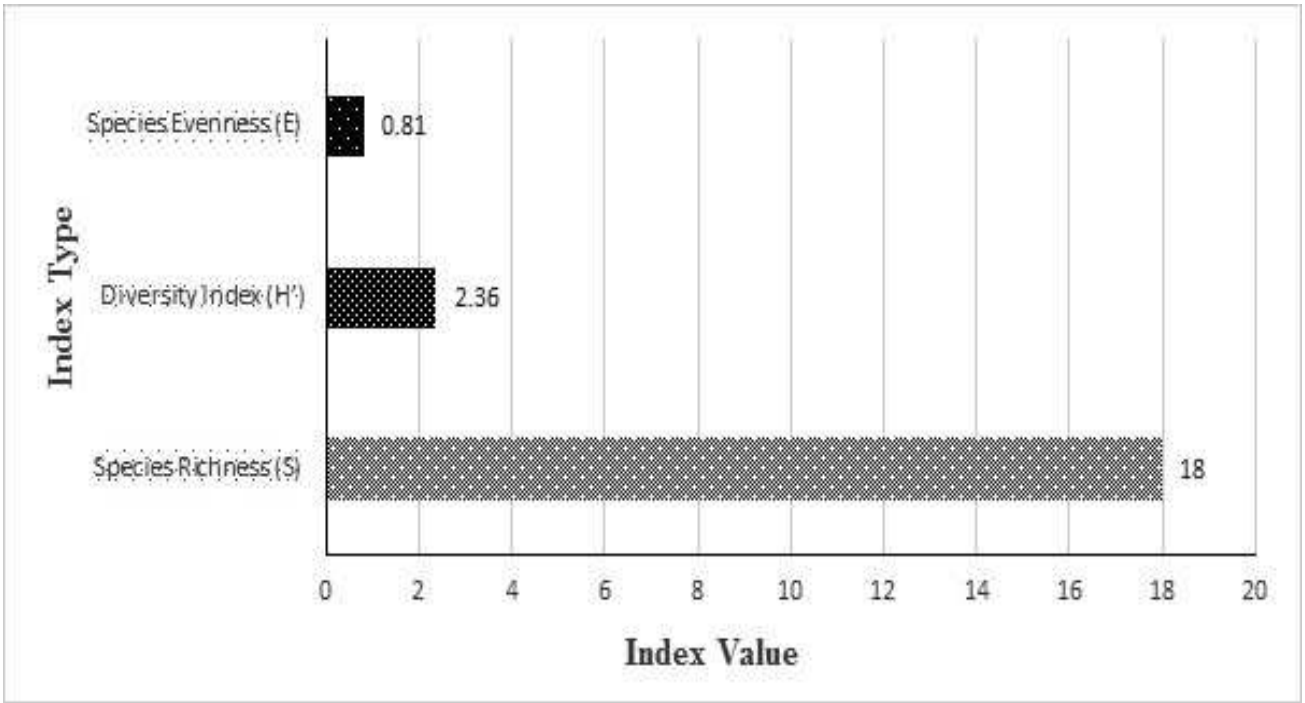


Figure 6 A clustered bar chart showing Species Diversity Index (H'), Species Richness (S), and Evenness index (E) of mammals in MKKNP.

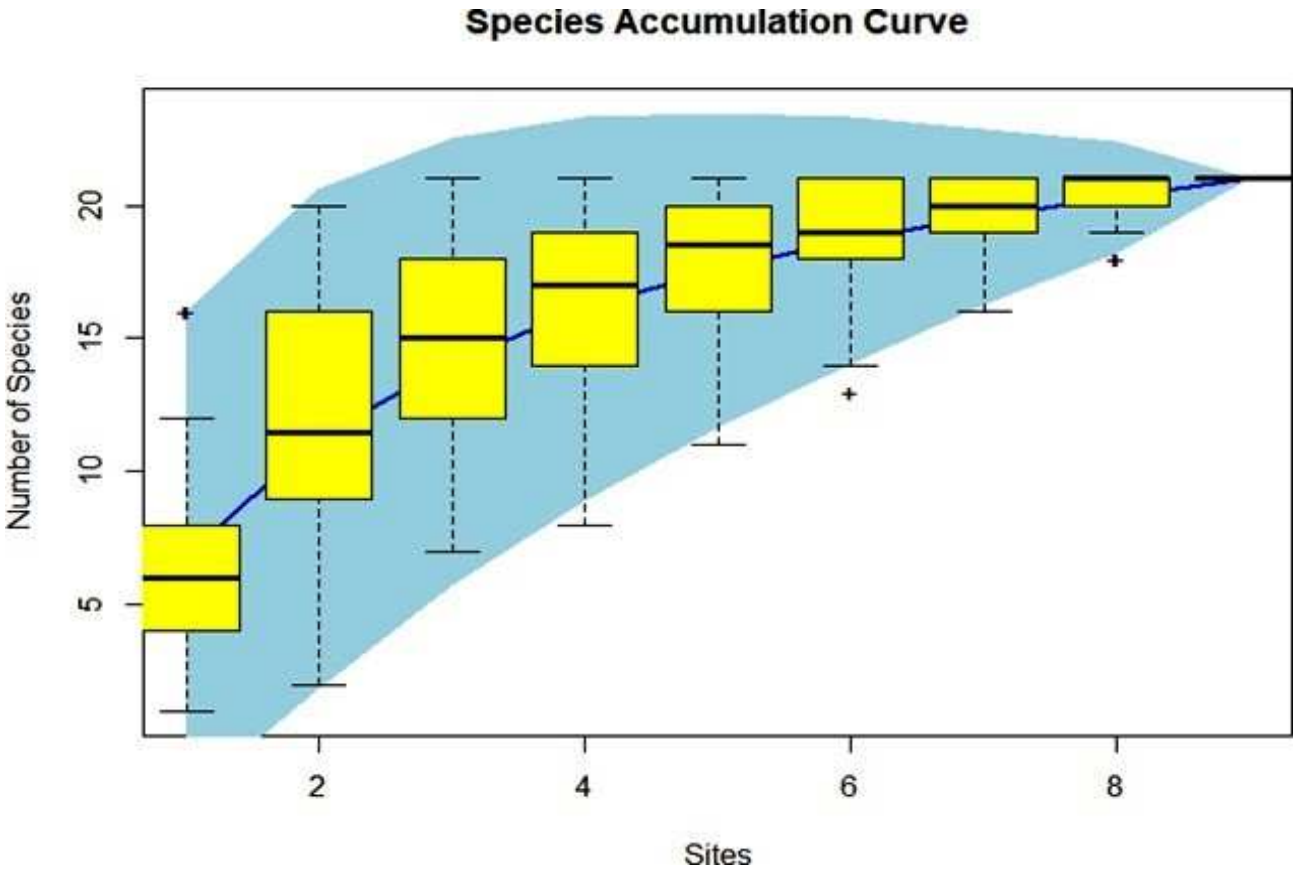


Figure 7 Species Accumulation curves generated showing species richness at different sampling sites in the MKKNP (study area).

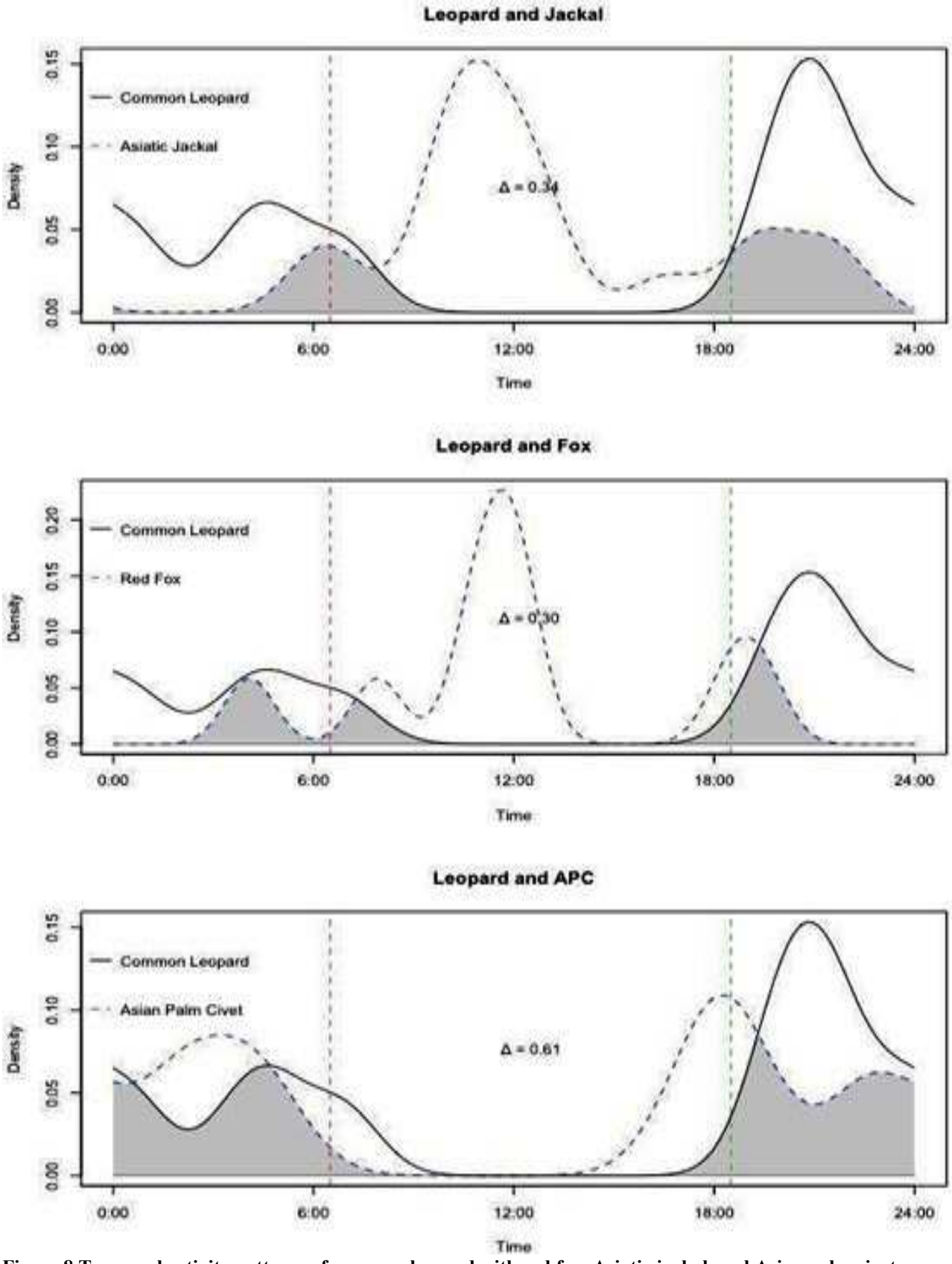


Figure 8 Temporal activity patterns of common leopard with red fox, Asiatic jackal, and Asian palm civet.

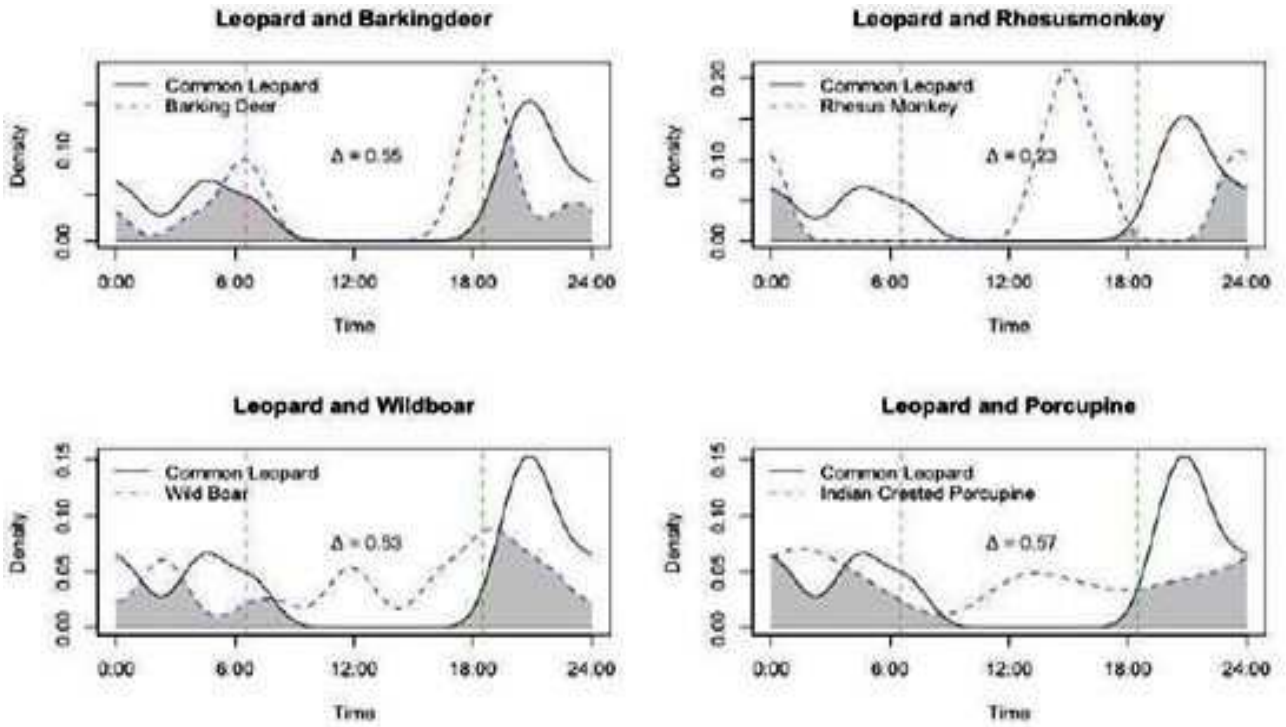


Figure 9 Temporal activity pattern of leopard with barking deer, rhesus monkey, wild boar, and Indian crested porcupine.

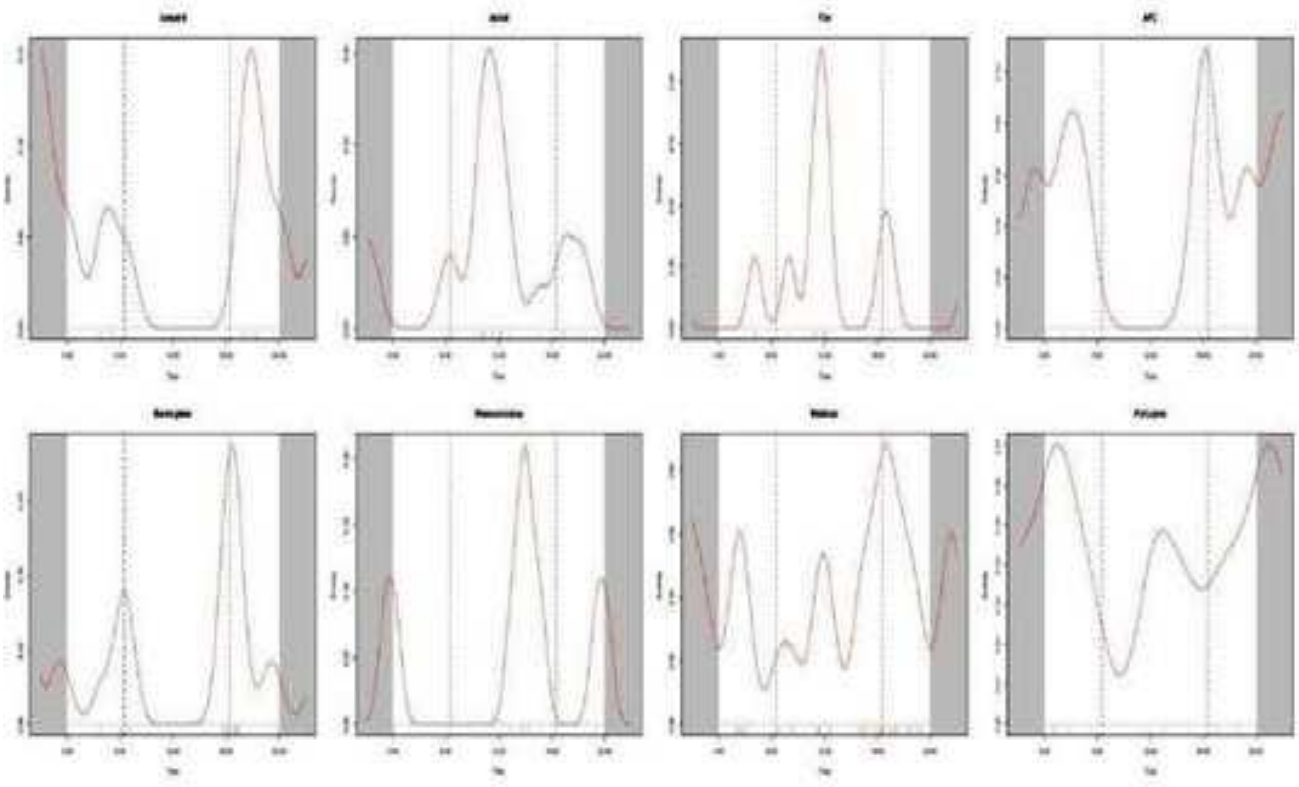


Figure 10 Temporal activity pattern of common leopard, Asiatic jackal, red fox, Asian palm civet, barking deer, rhesus monkey, wild boar, and Indian crested porcupine inhabiting Murree-Kotli Sattian-Kahuta National Park.

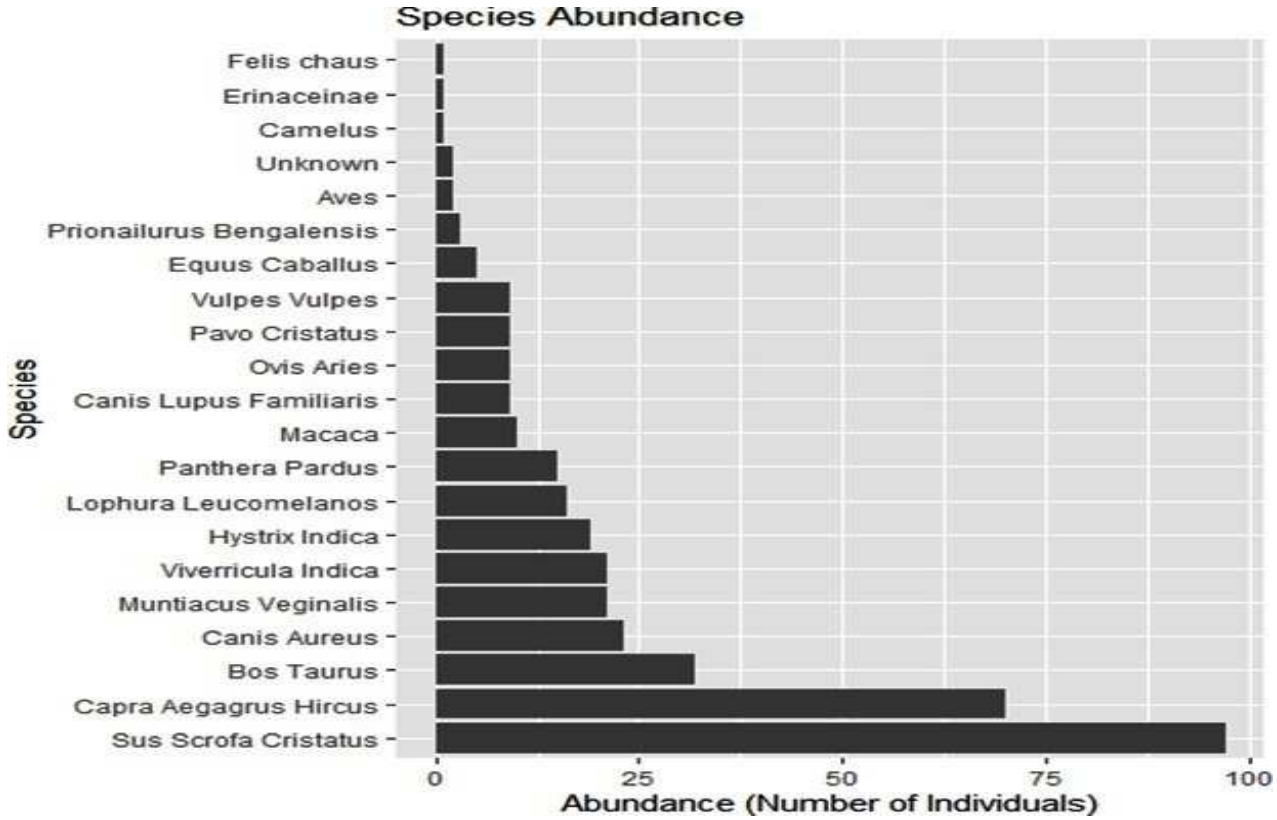


Figure 11 A graph showing the Relative abundance of different mammalian species in the MKKNP.

Table 1 Field signs and direct field sightings (live or dead) of different mammal species recorded / observed during field surveys in different areas of the MKKNP.

S. #	Species	Field signs				Direct filed Sighting (live or dead)
		Pug marks	Scats	Burrows	Prey remains	
1	Common leopard	+	+	–	–	–
2	Leopard cat	–	+	–	–	–
3	Wild boar	+	+	–	–	+
4	Asiatic Jackal	+	+	–	+	–
5	Red fox	+	+	–	+	–
6	Indian-crested porcupine	+	–	–	–	–
7	Jungle cat	–	+	–	–	–
8	Yellow-throated marten	–	–	–	–	–
9	Barking deer	+	+	–	+	+
10	Rhesus monkey	+	+	–	–	+
11	Asian palm civet	–	–	–	–	–
12	Small Indian civet	–	–	–	–	–
13	Indian grey mongoose	–	+	+	–	+
14	Small Indian mongoose	–	–	+		+
15	Northern palm squirrel	–	–	–	–	+
16	Indian pangolin	–	–	+	–	–
17	House rat	–	–	+	+	+
18	Bat sp.	–	–	–	–	+
19	Woolly Flying squirrel	–	–	–	–	+
20	Indian Hedgehog	–	–	+	–	+
21	Smooth coated Otter	+	+	–	–	+

Table 2 Mammalian species captured by infra-red camera traps at different sites of MKKNP

S. #	Common name	Scientific name	Sampling site #										
			I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1	Asiatic leopard	*Panthera pardus*	−	−	−	−	+	−	+	−	+	−	−
2	Leopard cat	*Prionailurus bengalensis*	−	−	−	−	−	−	−	−	+	−	−
3	Asiatic jackal	*Canis aureus*	−	+	+	+		+	+	+	+	−	−
4	Red fox	*Vulpes vulpes*	−	+	−	−	+	+		−	+	−	+
5	Barking deer	*Muntiacus*	−	+	−	−	+	+	+	+	−	−	−
6	Wild boar	*Sus scrofa cristatus*	−	+	+	+	−	+	+	+	−	+	−
7	Asian Palm civet	*Vivericula indica*	−	+	+	+	−	+	+	+	−	−	−
8	Yellow- throated marten	*Martes flavigula)*	−	+	−	−	−	−	−	−	−	−	−
9	Rhesus monkey	*Macaca mulatta*	−	+	−	−	−	−	−	−	+	+	+
10	Jungle cat	*Felis chaus*	−	−	+	+				+	−	−	−
11	Indian crested porcupine	*Hystrix indica*	+	−	+	+	+	+	+	−	+	−	−

**(Present: +, Absent: −)*

Site names: *Site **I;** Kalaiyan, Site **II**; Karel, Site **III**; Seri, Site **IV**; Kamra, Site **V**; Masoot, Site **VI**; Angoori, Site **VII**; Angoori, Site **VIII**; Sawan, Site **IX;** Sawan, Site **X;** Kotli Sattian, Site **XI**; Kotli Sattian-b). Fsfgd Dgdgdh

Table 3 A checklist of 21 different mammalian species (Sign survey method, camera traps) recorded at different sites of MKKNP.

S. no	Species name	Scientific name	Sign survey method	Infra-red camera traps
1	Asiatic Leopard	*Panthera pardus*	+	+
2	Leopard cat	*Prionailurus bengalensis*	-	+
3	Wild Boar	*Sus scrofa cristatus*	+	+
4	Asiatic Jackal	*Canis areus*	+	+
5	Red Fox	*Vulpes vulpes*	+	+
6	Indian crested porcupine	*Hystrix indica*	+	+
7	Jungle cat	*Felis chaus*	−	+
8	Yellow-throated martin	*Viverricula indica*	−	+
9	Barking deer	*Muntiacus vaginalis*	+	+
10	Rhesus monkey	*Macaca mulatta*	+	+
11	Asian palm civet	*Viverricula indica*	+	+
12	Small Indian civet	*Viverricula indica*	+	−
13	Indian grey mongoose	*Herpestes edwardsii*	+	−
14	Small Asian mongoose	*Herpestes javanicus*	+	−
15	Northern palm squirrel	*Funambulus pennantii*	+	−
16	Indian pangolin	*Manis crassicaudata*	+	−
17	House rat	*Rattus rattus*	+	−
18	Bat sp.	*Chiroptera*	+	−
19	Woolly Flying squirrel	*Pteromyini sp.*	+	−
20	Indian Hedgehog	*Erinaceinae*	+	−
21	Smooth coated Otter	*Lutra lutra*	+	+

DISCUSSION

Mammals face severe challenges for survival in their habitats including habitat loss, over-exploitation, and the introduction of invasive species (Schipper *et al.,* 2008). Moreover, they are increasingly becoming vulnerable to climate change impacts (Pacifici *et al.,* 2017). Current tendencies indicate that populations are decreasing in numbers as well as in Diversity (Ceballos *et al.,* 2019), substantial it also causes reductions in the variety and numbers of primates, and the reduction of carnivores and herbivore populations in area (Ripple *et al.,* .2014 and 2015), all of which increases the risk of extinction for numerous mammal species. This downward trajectory not only threatens the survival of these species but also the settlements of the invaluable ecosystem they provide and the vital functions they perform. Mammals has pivotal role in an ecosystem, it is imperative to recognize the challenges of conservation associated with safeguarding these services for human well-being (Lacher *et al,.*2019). Extensive human encroachment for activities such as agriculture, pastureland creation, firewood collection, settlement are causing degradation of numerous mammal habitats are experiencing degradation because of expansion, and various other human endeavours. In the current study, we aimed to estimating the diversity and relative abundance of mammalian fauna inhabiting Murree-Kotli Sattian-Kahuta National Park (MKKNP) using advanced field techniques. National parks, natural forests, wetlands, and protected areas are responsible for maintaining ecological balance and on the other hand also a source of income for the locality (Akhtar *et al*., 2018). For the conservation and protection of wildlife, it is mandatory to properly manage and design a National Park. National (Atwood *et al*., 2010). Park provides stability to the ecosystem and provides suitable habitat and shelter to various wildlife species (Alemu *et al*., 2016). Habitat fragmentation and range contraction is a global threat in the population decline of large carnivores, and the carnivore population can be recovered by reducing negative effects and conservation measures in a managed protected area like a national park. The carnivore abundance is directly related to the availability of prey. In Pakistan, there are more than 414 protected areas including 42 national parks, having diverse and important wildlife species (predators as well as prey) including common leopard *(Panthera pardus*), red fox (*Vulpes vulpes*), Asiatic jackal *(Canis aureus*), grey wolf (*Canis lupus*), barking deer (*Muntiacus vaginalis*), Leopard cat (*Prionailurus bengalensis*), Jungle cat *(Felis chaus*), wild boar *(Sus scrofa*), etc. The common leopard belongs to the family Felidae and is one of the big cats' present in this era (Breitenmoser *et al.,* 2008). The current study has revealed a total of 21 different mammalian species that occur in the park. These species were confirmed through field surveys by getting their indirect field signs, by making direct field sightings of some mammal species like northern palm squirrel, Indian grey mongoose, house rat etc., and most importantly by getting photographic evidence about occurrence of these mammal species through camera trap data. Being a top predator, this species is responsible for maintaining the diversity of the mammalian fauna in the national park. Roberts (1997) reported that common leopard is present in the Himalayan moist temperate coniferous forests of Pakistan, and also reported from some parts of the AJ&K (Chattha, 2015), including Toli Pir National Park (Faiz *et al.,* 2016), and Pir Lasura National Park (Manzoor *et al.,* 2020). According to IUCN, it is a Near Threatened species while in Pakistan is categorized as "Endangered" (Sheikh and Molur, 2004). Although Leopard cat was recorded in the park, however, it occurs at sites where common leopard does not occur, therefore, naturally segregating its feeding niche from the common leopard. The leopard cat also has got limited distribution and is one of the least studied species in the country.

We have also recorded two sympatric canid species (red fox and Asiatic jackal) in the study area, which, by being omnivores, play vital role in seed dispersal of various plants by feeding on wild fruits of the forest. Two species of civets; small Indian civet and northern palm civet, recorded in the study area, also play this vital role of seed dispersal. Besides these, Jungle cat was also recorded in the park, which is relatively larger cat. Another two important herbivore species recorded in the current study include yellow-throated marten and the barking deer. The yellow throated marten has got restricted distribution in the country, and it occurs in some national parks at relatively higher elevations, also playing an important role of dispersing plant seed and contributing in the forest regeneration. The barking deer species recorded in the study area has got very limited distribution in the country, found in limited range of Margalla Hills National Park Islamabad, and in the Kahuta region (in Murree-Kahuta-Kotli Sattian National Park), and few adjoining regions (Anwar, 1997). In Azad Jammu and Kashmir (AJ&K), barking deer have been recorded from Pir Lasura National Park (PLNP) and Choch in Kotli district, Poonch river border in Mirpur district, and Thoppatni and Malni in Bhimber district (Iftikhar, 2006). Similarly, Pokharel and Chalise (2015) reported that, in Nepal, barking deer used middle ranged mountains with dense vegetation and with less disturbance due to humans. Faecal pellets or signs were not observed beyond 1500m. In Bardia National Park, Nepal, this

species was found associated with riparian forests followed by the *Mallotus* and *sal* spp. forest (Heggdal, 1999). Barking deer also preferred mid elevations (1100-1300 m) with thick covering of vegetation, low human disturbance and enough water sources (Pokharel and

Chalise, 2010). Barking deer consume tender, fresh fruit, buds, and leaves, from various lower plants. It is an omnivore, browser and grazer with ivy, prickly bushes, grasses, barks, low growing leaves, fruits, branches, and eggs. The species typically occurs near the forest's edge or in open areas. For fruit producing plants the species act as a dispersal agent in Thailand (Lekagul and McNeely, 1977). The current study also recorded one wild primate species in the study area: rhesus monkey (*Macaca mulatta*). This species is also an important herbivore and performs the functioning seed dispersal of plants. We also recorded some pest mammalian species in the park including wild boar and Indian crested porcupine. These two pest species need to be managed in the study area. The findings of the current study also highlight another "endangered" species, Indian pangolin (*Manis crassicaudata*) (Mahmood *et al.,* 2015). This species has also been recorded in the Murree-Kotli Sattian-Kahuta national Park. This is an insectivorous species, feeding exclusively on ants and termites (Irshad *et al*. 2014). Indian pangolin is regarded as most trafficked mammal on the globe, as the species is illegally hunted and smuggled to China and Vietnam where its body scales are used in the traditional medicines (Waseem *et al.*, 2020). Conserving this endangered species in the study area is also vital for the park managers. The current study also reports another insectivorous species from this park; Indian hedgehog, this species is also least studied in the country. The findings of the current study also highlight the occurrence of two mongoose species in the park; small Indian mongoose *(Herpestes auropunctatus*) and the Indian grey mongoose (*Herpestes edwardsii*), both species consume rodents, snakes, and insects. In such feeding niche scenario, these two mustelid species are important to conserve. Akrim *et al.* (2018) reported that the feeding niche of two mongoose species overlaps in their habitat and because of high niche overlap both the mongoose species compete for their resources. Similarly, Fatima *et al.* (2020) reported that sympatric mongoose species may avoid competition of food sources by opting for spatial adjustments. Another important mammalian species recorded in the study area is "Woolly Flying Squirrel". This species has also got limited distribution in the country, and it only occurs in some northern most regions of the country. So, occurrence of this species in the Murree- Kotli Sattian-Kahuta national park is very promising. Qamar *et al.* (2012) had reported its occurrence in the Neelum Valley of Azad Jammu & Kashmir part of Pakistan. Similarly, Akrim *et al.* (2018) reported the diet composition of this species in Kotli District of AJ&K., Relative abundance data of species provides habitat preferences of different species, which is helpful for wildlife conservation and management protocols. Murree-Kotli Sattian-Kahuta National Park has been found to have a diverse array of mammalian fauna; it includes common species, apex predators, important herbivores, pest species, as well as the rare species. The common leopard *(Panthera pardus*) and barking deer (*Muntiacus vaginalis*) highlight the importance of the biodiversity of the park. The diversity index of mammal species observed in the park was found to be high (H'=2.36). The highest relative abundance of wild boar (*Sus scrofa*), barking deer (*Muntiacus vaginalis*), common leopard and the presence of Asiatic Jackal (*Canis aureus*) shows a healthy predator-prey relationship and trophic niche in the study area.

Conclusion: The Murree-Kotli Sattian-Kahuta National Park is home to a diverse array of mammalian species. This study identified 21 distinct mammal species within the park, underscoring its ecological significance and the urgent need for conservation efforts to safeguard this wildlife. Additionally, the research highlights the effectiveness of camera trap data combined with advanced statistical methods in analyzing species distribution and abundance in the study areas.

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REFERENCES

Akhtar, N., R. Muhammad, K. Saeed, M. F. Khan, M. Shah, J. Zeb, and A. Hussain (2018). Distribution of wild mammalian fauna of Mahaban and Malka Valley District Buner. Pakistan J. Zool. 50(2): 775-777

Akrim, F., T. Mahmood, M. S. Nadeem, S. Qasim, and S. Andleeb (2018). Assessment of bias in morphological identification of carnivore scats confirmed with molecular scatology in northeastern Himalayan region of Pakistan. PeerJ. 6: 52–62. DOI: 10.7717/peerj.5262.

Alemu, M., Z. Asfaw, Z. Woldu, B. A. Fenta, and B. Medvecky (2016). Cowpea (Vigna unguiculata (L.) Walp.)(Fabaceae) landrace diversity in northern Ethiopia. Int. J. Biodivers. Conserv. 8(11): 297-309.

Anwar, M. (1997). Distribution, population status and conservation of barking deer (*Muntiacus muntjac*) in Margalla Hills National Park. In: S.A. MUFTI, C.A. WOODS and S.A. HASSAN, eds. Biodiversity of Pakistan.

Gainesville, USA: Pakistan Museum of Natural History, Islamabad, Pakistan and Florida Museum of

Natural History, pp. 485-495.

Atnafu, G., and M. Yihune (2018). Species composition and relative abundance of medium and large mammals in Mengaza communal forest, East Gojjam, Ethiopia. J. Ecol. Nat. Environ. 10(2): 34-40. DOI: 10.5897/JENE2017.0667

Atwood, T. C., and E. M. Gese (2010). Importance of resource selection and social behavior to partitioning of hostile space by sympatric canids. J. Mammal. 91: 490–499. DOI: 10.1644/09-MAMM-A-078.1

Breitenmoser, U., M. V.Arx, F. Bego, G. Ivanov, E. Keçi, D. Melovski, and J. D. Linnell (2008). Strategic planning for the conservation of the Balkan lynx. In Proceedings of the III Congress of Ecologists of the Republic of Macedonia with International Participation (pp. 06-09).

Bukhari S.S.B. and G.A. Bajwa (2011). Climate change trends over coniferous forests of Pakistan. Pakistan J. Forest. 61: 1-14

Ceballos, G., P. R., Ehrlich, J. Pacheco, N. Valverde-Zúñiga, and G. C. Daily (2019). Conservation in human-dominated landscapes: Lessons from the distribution of the Central American squirrel monkey. Biol. Conserv. 237: 41-49. https://doi.org/10.1016/j.biocon.2019.06.008.

Chattha, S. A., S. M. Hussain, A. Javid, M. N. Abbas, S. Mahmood, M. G.Barq, and M. Hussain (2015). Seasonal Diet Composition of Leopard (Panthera pardus) in Machiara National Park Azad Jammu and Kashmir Pakistan. Pakistan J. Zool. 47(1): 201-207

Cox, K. D., M. J. Black, N. Filip, M. R. Miller, K. Mohns, J. Mortimor, and S. E. Dudas, (2017). Community assessment techniques and the implications for rarefaction and extrapolation with Hill numbers. Ecol. Evol. *7*(24): 11213-11226. DOI: 10.1002/ece3.3580.

Danell, K., R. Bergström, P. Duncan, and J. Pastor, (Eds.). (2006). *Large herbivore ecology, ecosystem dynamics and conservation* (11). Cambridge University Press.

Ebeling, A., S. T. Meyer, M. Abbas, N. Eisenhauer,., H. Hillebrand, M.Lange, and W. W. Weisser (2014). Plant diversity impacts decomposition and herbivory via changes in aboveground arthropods. PloS One*.,* 9(9): e106529.

Fatima, H., T. Mahmood, A. Sakhawat, A. Faraz, F. Muhammad, and S. Andleeb (2020). Sympatric mongoose species may opt for spatial adjustments to avoid feeding competition at Margalla Hills National Park Islamabad, Pakistan. Wildl. Biol. (2): 1-9. DOI: 10.2981/wlb.00654

Faiz, A. H., and F. I. A Fakhar-i-Abass (2016). Mammalian diversity of Tolipir National Park, Azad Jammu and Kashmir, Pakistan. Pakistan J. Zool. 48(4): 1209-1212.

Galetti, M., H. C. Giacomini, R. S. Bueno, C. S. Bernardo,, R. M. Marques, R. S. Bovendorp, and C. A. Peres (2009). Priority areas for the conservation of Atlantic forest large mammals. Biol. Conserv. 142(6): 1229-1241. DOI: 10.1016/j.biocon.2009.01.023.

Henschel, P., Hunter, L., Breitenmoser, U., Purchase, N., Packer, C., Khorozyan, I., Bauer, H., Marker, L., Sogbohossou, E. & Breitenmoser-Wursten, C. (2008). Panthera pardus. The IUCN Red List of Threatened Species. Version 2014.1. www.iucnredlist.org [July 2014].

Heggdal, P.O. (1999). Spatial organization, habitat preferences and activity of barking deer during the dry season in Royal Bardia National Park. Nepal: Norway Agricultural University. Doctoral dissertation in Zoology. Hubbell, S.P. (2001). A unified theory of biodiversity and biogeography. Princeton

University Press, Princeton Ritchie, D. (1986). Shannon and Weaver: Unravelling The paradox of information. Commun. Res. 13(2): 278-298.

Irshad, N., T. Mahmood, R. Hussain, and M. S. Nadeem, (2014). Distribution, abundance and diet of the Indian pangolin (*Manis crassicaudata*). Anim. Biol. 65(1): 57-71. DOI: 10.1163/15707563-00002462.

Iftikhar, N. (2006). Wildlife of Azad Jammu and Kashmir. Department of Wildlife, Azad Jammu and Kashmir. Alsheikh Press Muzaffarabad.

Irshad, N., Akhter, M., Mahmood, T., Akrim, F., Khan, M. R., and M. S. Nadeem (2021). Dietary Habits of Altai Weasel (*Mustela altaica*) in Bunjosa Game Reserve Rawalakot, Azad Jammu and Kashmir,Pakistan. Pakistan J. Zool. 54(5): 2259-2265 DOI: https://dx.doi.org/10.17582/journal.pjz/20210406060437

Jones, J. P., B. E. N. Collen, G., Atkinson, P. W. Baxter, P. Bubb, J. B. Illian,and , E. J. M. Gulland (2011). The why, what, and how of global biodiversity indicators beyond the 2010 target. Conserv. Biol. *25*(3): 450-457.

Kabir M, S. Hameed, H. Ali, L. Bosso, J. U. Din, R. Bischof, S. Redpath and M. A. Nawaz (2017) Habitat suitability and movement corridors of grey wolf (*Canis lupus*) in Northern Pakistan. Plos One. 12(11): pe0187027. DOI: https://doi.org/10.1371/journal.pone.0187027.

Khan, Z. I. (2003). Protected areas in Pakistan: Management and issues. J. Nat. Sci. Found. Sri Lanka, 31(1-2). DOI: 10.4038/jnsfsr.v31i1-2.3036.

Lacher, Jr. T.E., A. D. Davidson, T. H. Fleming, E. P. Gómez-Ruiz, G. F. McCracken, N. Owen-Smith, and S. B. Vander-Wall (2019). The functional roles of mammals in ecosystems. J. Mammal. 100(3): 942-964.

Lekagul, B. and J.A. McNeely (1977). Mammals of Thailand. Bangkok: Kuruspha Press.Meteorological Department 1982. Monthly and annual rainfall of Thailand: 30 Year Period (1951- 1980). Bangkok: Ministry of Communications.

Lahang, P. (2005). Using camera-trapping data to calculate diversity, activity pattern and relative abundance of terrestrial mammals at Lambir Hills National Park. Bachelor of Science with Honors in Animal Resource and Management Science thesis submitted to the Faculty of Resource Science and Technology, Universiti Malaysia, Sarawak. pp. 1-24.

Liu, X., P. Wu, M. Songer, Q. Cai, He, Y. Zhu, and X. Shao, (2013). Monitoring wildlife abundance and diversity with infra-red camera traps in guanyinshan nature reserve of Shaanxi Province, China. Ecol. Indicat., 33: 121 128. https://doi.org/10.1016/j. ecolind.2012.09.022

Mahmood, T., N. Irshad, R. Hussain, F. Akrim, I. Hussain, M. Anwar, M. Rais, and M. S. Nadeem (2015b). Breeding habits of the Indian Pangolin (*Manis crassicaudata*) in Potohar Plateau, Pakistan. Mammalia. 80(2): 231–234; http://doi.org/10.1515/mammalia-2014-

Manzoor, M., S. W. Khan, and S. A.Shah, (2020). An annotated checklist of butterflies at elevated protected areas of Pakistan. J. Biores. Manag. , *7*(1): 5. DOI: https://doi.org/10.35691/ JBM. 0202.0119

Nowell, K. and P. Jackson, (1996). Wild cats. Status survey and conservation action plan. IUCN/SSC Cat Specialist Group. IUCN, Gland, pp. 382.

O'Brien, T. G. (2011). Abundance, density and relative abundance: a conceptual framework. In *Camera traps in animal ecology: methods and analyses* (pp. 71-96). Tokyo: *Springer Japan*. https://doi.org/10.1007/978-4-431-99495-4_6.

Odat, Nidal., M.T.L Moh'd,., M. Riyadh, A. Faisal,., R.M. Abdel, Al-Tawaha, and L.Saleem (2009). Predicting species relative abundance in ecological communities. Jordan J. Biol. Sci., 2: 83-88.

Pacifici, K., B. J. Reich, D. A. Miller, B. Gardner, G. Stauffer, S. Singh, and J. A. Collazo (2017). Integrating multiple data sources in species distribution modeling: a framework for data fusion. Ecology. 98(3): 840-850. DOI: 10.1002/ecy.1710.

Palmer, C., B. Fischer, C. Gamborg, J. Hampton, and P. Sandoe (2023). *Wildlife ethics: the ethics of wildlife management and conservation*. John Wiley & Sons. https://doi.org/10.1002/9781119611332.

Pokharel, K. P., T. Ludwig, and I. Storch (2015). Spatial niche partitioning in sub-tropical solitary ungulates: four-horned antelope and barking deer in Nepal. PLos One. 10:e0117917. doi: 10.1371/journal.pone.0117917

Pokharel, K., and M. K. Chalise (2010). Status and distribution pattern of barking deer (Muntiacus muntjak Zimmermann) in Hemja VDC, Kaski. Nepal J. Sci. Tech. 11: 223-228. DOI: 10.3126/njst.v11i0.4149.

Qamar, Q. Z., A. Usman, R. A.Minhas, N. I. Dar,., and M. Anwar (2012). New distribution information on woolly flying squirrel (*Eupetaurus cinereus* Thomas, 1888) in Neelum Valley of Azad Jammu and Kashmir, Pakistan. Pakistan J. Zool. 44(5): 1333-1342.

Ripple, W. J. T. M. Newsome, C. Wolf, R. Dirzo, K. T. Everatt, M. G., M. W. Hayward, G. I. H. Kerley, T. Levi, P. A. Lindsey, D. W. Macdonald, Y. Malhi, L. E. Painter, C. J. Sandom, J. Terborgh, and B. V. Valkenburgh. (2015). Collapse of the world's largest herbivores. Sci. Advances. 1(4): DOI: 10.1126/sciadv.140010.

Ripple, W. J., J. A. Estes, R. Bescht, C. C. Wilmers, E. G. Ritchie, M. Hebblewhite, and A. J. Wirsing (2014). Status and ecological effects of the world's largest carnivores. Science. 343(6167): 1241484. DOI: 10.1126/science.1241484.

Roberts, T. J. (1997). *The Mammals of Pakistan*, Revised edition, Oxford University Press, Karachi, Pakistan.

Schipper, J., J. S. Chanson, F. Chiozza, N. A. Cox, M. Hoffmann, V. Katariya, and B. E. Young (2008). The status of the world's land and marine mammals: diversity, threat, and knowledge. Science. 322(5899): 225-230. (DOI: 10.1126/science.1165115).

Sheikh, K. M. and S. Molur (2004). (Eds.) Status and Red List of Pakistan's Mammals. Based on the Conservation Assessment and Management Plan. 312pp. IUCN Pakistan.

Strong, W. L. (2016). Biased richness and evenness relationships within Shannon–Wiener index values. Ecol. Indic. 67: 703-713.

Verberk, W. (2011). Explaining general patterns in species abundance and distributions. Nat. Edu. Knowl. 3(10): 38.

Waseem, M., A. Raza, H. Aisha, N. A. Awan, T. Ahmad, R. Nazir, and T. Mahmood. (2020). Scale of Illegal Killing and Trade Associated with Indian Pangolin (*Manis crassicaudata*) in Pakistan. Pakistan J. Zool. 52(1):69-77.

Wilson, G. J., and R. J. Delahay, (2001). A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. Wildl. Res. 28(2): 151-164. 151-164. https://doi.org/10.1071/WR00033.

Yin, D., and F. He (2014). A simple method for estimating species abundance from occurrence maps. Methods Ecol. Evol. 5:336-343. https:// doi.org/10.1111/2041-210X.12159.

Yoccoz, N.G., J. Nichols, and D.B., Thierry, (2001). Monitoring of biological diversity in space and time. Trends Ecol. Evol. 16(8):446-453. https://doi. org/10.1016/S0169-5347 (01)02205-4.