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Temporal Niche Overlap Among Predators and Prey Species of Pothwar Plateau, Pakistan

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Activity pattern, Intraguild interaction, Predator-prey interaction, Seasonal activity, Temporal niche, Mammals

ABSTRACT

Daily activity patterns are an important component of mammalian nature and behavior through which species respond to varieties in biotic, abiotic, and anthropogenic variables. Studies addressing the phenomenon of spatial and temporal activity patterns of mammalian predators and prey species are important to understand the strategies adapted by them for co-existence. In the current study, we investigated activity patterns and the temporal niche overlap among predators and prey species inhabiting the Pothwar Plateau, Pakistan Field surveys were conducted fortnightly aided with installing motion-triggered cameras at selected sampling sites (N = 23) to capture field photographs of predators and prey species. Data on species identification, camera trap station, date of capture, and the numbers of photos captured were recorded systematically. The predator and prey species in the photographic data were identified and their activity patterns were plotted using "R Studio" software and the niche overlap among the temporal activity of the various species were computed. Results revealed that common leopard, red fox, Indian-crested porcupine, Asian palm civet, and Indian desert hare were active at nighttime whereas barking deer and Punjab Urial were found diurnal in their activity pattern. Highest overlap of temporal niche was computed for red fox and common leopard (1.0), followed by red fox and yellow-throated marten (0.70), red fox and barking deer, common leopard and Asiatic Jackal, and red fox and Asiatic Jackal (0.52), each. The comparatively high temporal niche overlap among various mammalian species indicates greater competition for habitat resources, threatening their survival.

INTRODUCTION

Predator–prey dynamics are vital component of any ecosystem. The predator as well as the prey species have got their own various types of niches including feeding niche, spatial niche and the temporal niche. These niches either overlap or are partitioned among the predators and the prey species in the area for successful co-existence (de Roos and Persson, 2002). One strategy for reducing interacting competition with a dominant predator is to divide activity into less active periods of the day, which also reduces the risk of predation (Kronfeld-Schor and Dayan, 2003; Kohl *et al*., 2019). For instance, prey species are found more diurnal with the co-existence of the nocturnal top predators in south Africa (lion, *Panthera leo* and spotted hyaena, *Crocuta crocuta*), while in the neighboring areas where these predators were not found the diurnal existence comparatively decreased (Loarie *et al*., 2013). As a result, the observed niche partitioning could be a mechanism for sustaining coexistence (Carothers and Jaksić, 1984).

Studying interactions between carnivores and their prey can be extremely difficult due to their cryptic nature and low abundance (Ripple and Beschta, 2012). Whereas, studying temporal niche overlap in activity patterns of carnivores and their prey could provide valuable insight into behavioral mitigations of competition.

It is generally observed that the impact of competition on the pattern of daily activity is not similar to that of food or space. Moreover, theoretically, coexistence may be aided by temporal segmentation among competitors and between predators and the prey (Kronfeld-Schor and Dayan, 2003), thus, implying that such biotic factors potentially

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influence the patterns of daily activity. To understand the mechanisms of temporal niche differentiation, there are models that can reflect parameters of great ecological value. One of them is the niche overlap, which determines the degree of resource segregation among different species (Meredith and Ridout, 2016).

Advanced utilization of temporal camera-trapping data has been addressing the unresolved issues and queries related to species ecology and their interactions in a community such as a variety of activity patterns and the division over the temporal niche axis. Temporal camera-trap data offer the opportunity to address unresolved questions regarding species ecology and community interactions, such as variation in activity patterns and partitioning along the temporal niche axis. These temporal insights are not only valuable from an ecological perspective, but they also provide insight into human-driven changes to species behaviors and interactions, and the resulting impacts on niche partitioning and community structure. The increase in camera-trap studies focused on temporal analyses is beginning to generate new ecological and applied insights, but a synthesis of recent approaches and trends is lacking. During the last decade, camera trapping has opened the possibility to conduct systematic studies of activity patterns and temporal niche overlap between predators and their prey species (Delisie *et al*., 2021). For example, recent studies have used this approach to demonstrate strong temporal overlaps between Sumatran tigers (*Panthera tigris sumatrae*) and their putative prey (Linkie and Ridout, 2011). These temporal insights are valued not just from an ecological standpoint, but also provide insights on changes in behaviors and interactions caused by humans and their effect on the partitioning of the niche and structuring of the community. The camera-trap studies have increasingly converged on temporal analyses, which have begun to yield new environmental, ecological, and applied observations, however, there is less synthesis of recent methodologies and trends (Bridges and Noss, 2011). Such camera-trap studies have typically focused on the spatial and numerical aspects of species and population ecology (Ridout and Linkie 2009).

One of the highly considered seasonal environments includes the dry forest, many researchers, hypothetically concluded that during dry seasons the temporal niche segregation is often larger with consideration that when food and water resources are concentrated and are in abundance, the other observation claims that because of the lower understory leaf density, visual contact between predators may be more common, potentially increasing interference competition (Valeix *et al*., 2007). Whereas the general expectation is in favor of the fact of avoiding the daytime's high temperature, so, a relatively low daytime activity in the dry seasons was assumed (Pita *et al*., 2011), also considering the factors including low humidity and poor vegetation protection of this period. Studies addressing the phenomenon of spatial and temporal activity patterns of mammalian predators and prey species are important to understand the strategies adapted by them for co-existence. Therefore, in the current study, we investigated activity patterns and the temporal niche overlap among predators and prey species inhabiting Pothwar Plateau, in the northern part of province of Punjab, Pakistan

MATERIALS AND METHODS

Study area

The current study was conducted in the Pothwar Plateau, that comprises of four districts (Attock, Jhelum, Chakwal, and Rawalpindi), in the Punjab province, the Plateau being located at a latitude range from 32-33° and longitude 71-73° (Fig. 1), covering an area of about 22,500 km^2. The ecosystem is characterized by subtropical scrub forest , sandstone and limestone rocks, along with cultivated land. During the monsoon season, the region receives a significant amount of rain (July and August), and the average rainfall is between 380-500 mm.

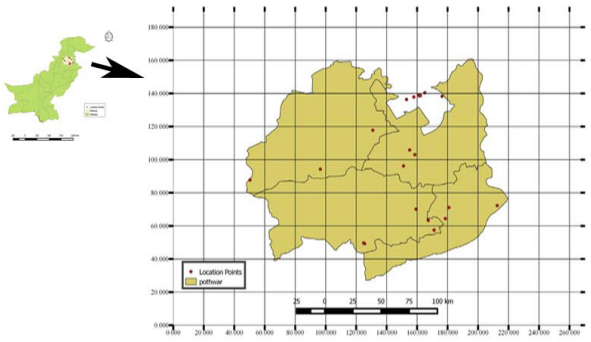

Fig. 1. Map of Pakistan showing Pothwar Plateau (study area) having four districts (Attock, Jhelum, Chakwal and Rawalpindi), divided into 20 x 20 km^2 grids, along with locations of sampling sites used.

The study area has a rich diversity in terms of flora and fauna. The vegetation is a dry sub-tropical, semi-evergreen scrub forest having dominant plant species of *Acacia modesta, Olea ferrugenia, Salvadora alights, Zizyphus nummularia, Dodonea viscosa, Prosopis glandulosa, Adhatoda zeylanica,*and *Calotropis procera* etc. (Nizami *et al*., 2004). However, at higher elevations of Rawalpindi district, sub-tropical chir pine forest also occurs at some places, especially in the Murree hills. The dominant and conservation important mammalian species

are represented by common leopard (*Panthera pardus*), the gray wolf (*Canis lupus*), Asiatic jackal (*Canis aureus*), red fox (*Vulpes vulpes*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), small Indian civet (*Viverricula indica*), Indian pangolin (*Manis crassicaudata*), Indian crested porcupine (*Hystrix indica*), Punjab Urial (*Ovis vignei punjabiensis),* and rhesus monkey (*Macaca mulatta*) (Roberts, 1997).

Study design

The current study was conducted between December 2020 up to June 2022. A total of 24 field surveys were conducted during the study period. A total of 23 sampling sites were selected in the study area based on the reconnaissance survey conducted at the start of study (Table I). These sites were present in four different districts of the Potohar Plateau, therefore, they are far enough to be representative of the study area. The field surveys were conducted fortnightly in different districts (Rawalpindi, Chakwal, Jhelum and Attock) of the Pothwar Plateau, on the basis of signs of animals, presence of animals scats and on the basis of water availability by installing motion-triggered infra-red cameras (Bushnell Trophy Cam HD Essential 2) at selected sampling sites to capture their field photographs. Date and time were recorded in the captured photos. Each camera was operational for three consecutive days. The whole study area was divided into grids of 20x20 km square grids and a total of 20 camera trap stations, 5 camera trap stations in each district, were established in the study field following Monterroso *et al*. (2013). The data recorded in cameras were compiled in an excel sheet and analyzed with Geographic Information System (GIS) software.

Table I. Details of sampling sites selected for data collection in the four districts of the Pothwar Plateau.

Site No.	Site name	Geographical coordinates	Elevation (m)	Ecosystem type/ climate
District Rawalpindi/ Islamabad				
1	Mari Bir	N 33°.233391, E 072.977989	453	Subtropical
2	Faraash	N 33°.300267°, E 073.059575°	443	Subtropical
3	Dhok Budhal	N 33°.357921°, E 073.000878°	413	Subtropical
4	Trail 5 MHNP	N 33°.7461, E 073°.0865	750	Subtropical
5	Trail 5 MHNP	N 33° 49.945, E 073° 05.204	638	Subtropical
6	Buddu nala MHNP	N 33°45'3.57', E 73°2' 47.27′		Subtropical
7	Rumli top	N 33°.79437, E 073°.13078	1419	Subtropical
8	Ratta Hotter MHNP	N 33°.75539, E 073°.0857	699	Subtropical
9	Ranj Keh Chashma	N 33°.75037, E 073°. 04983	786	Subtropical
10	Dhoke Jeevan MHNP	N 33°.76166, E 073°.0436	1159	Subtropical
District Chakwal				
11	Ara Trail 3	N 32°46.609, E 073°08.844	767	Local steppe climate
12	Dil Jabba	N 32°51.913, E 073°07.324,	496	Local steppe climate
13	Makhyala	N 32°44.571, E 073°07.242	691	Local steppe climate
14	Makhyala	N 32°46.58, E 073°08.88,	748	Local steppe climate
15	Phadail near poultry side	N 32°44.881, E 073°04.607	780	Local steppe climate
16	Phadail	N 32°49.504, E 073°09.123	722	Local steppe climate
District Jhelum				
17	Pond side at Padhri Game reserve	N 32° 5040, E 073° 185	334	Hot and humid
18	Padhri Game reserve	N 32°5038.6, E 073°1759.8	548	Hot and humid
19	Nehar Gujjar	N 32°4833.5, E 073°2014.2	432	Hot and humid
20	Partrige breeding center	N 32°4958.3, E 073°1919.2	975	Hot and humid
District Attock				
21	Makhad Shareef	N 33° 126459, E 071°.734259	226	Hot and humid
22	Ratwal	N 33°.496425, E 072°.709456	540	Hot and humid
23	Ghareebwal	N 33°.217488, E 072°.277168	364	Extreme

Data handling

All photographic data were arranged on a monthly and seasonal basis in excel sheets. The field guide field guide to the large and medium-sized Mammals of Pakistan (Robert, 2005), was used for species identification, captured in the camera traps. The data on species identification, camera trap station site, date of capture, and the number of photos captured were recorded systematically. The predator and prey species in the photographic data were identified and their activity patterns were then plotted using R studio software (R Studio 2021.09.0 Build 351© 2009-2021 R Studio, PBC) The niche overlap among the various mammalian species was computed.

Methodology

The study area was divided into 20x20 km square. grids and a total of 20 camera trap stations, including 5 camera trap stations at each district, were established in the study area. The field surveys were conducted fortnightly and motion-triggered infra-red cameras (Bushnell Trophy Cam HD Essential 2) were installed to capture the field photographs of the mammalian species (both predator and the prey species). The placement of the camera trap in each grid was determined by the presence/absence of mammalian signs and the security of the camera traps was also considered. The trail in front of the camera was cleared from vegetation to avoid any false triggers. Each camera trap was programmed to record the time and date when triggered and was put on tree trunks or self-designed iron or steel poles at knee height, roughly 0.5–1.0 m from the ground. The global positioning system (GPS) location of each camera trap was recorded using a handheld GPS device (GARMIN GPSMAP 62S) to prepare a distribution map of the species recorded in the end. The camera traps were set to operate for 24 h and to capture 3 photos in burst mode to increase detection. Each camera trap was set to remain operational for three consecutive days (twice a month) after which they were removed, inspected for pictures captured and data were downloaded.

RESULTS

Animal species camera trapped

During the current study period a total of 13 animal species were camera trapped at different sampling sites (Table II, Fig. 2); these mainly included mammals and one bird species, and categorized as predator or prey species. The photo-capturing events also recorded activity time of each species at particular site, indicating the diel activity pattern.

Out of total 57 camera trapped photographs of various mammalian species, red fox appeared in maximum photographs (N= 11), followed by Indian crested porcupine (N = 10), common leopard (N= 7), Yellow-throated marten (N= 6), Asiatic jackal and barking deer (N= 5 each) but least (N= 1) for Punjab Urial (Table II).

Table II. Details of the animal species photo-captured in the camera traps at different sampling sites in the Pothwar Plateau.

S. No.	Common name	Scientific name	Capture district	No. of targeted photos captured
1	Common leopard	*Panthera pardus*	Rawalpindi/ Islamabad	7
2	Asiatic jackal	*Canis aureus*	Rawalpindi/Islamabad/Chakwal/Attock	5
3	Red fox	*Vulpes vulpes*	Rawalpindi/Islamabad/Chakwal/Jhelum	11
4	Yellow-throated marten	*Martes flavigula*	Islamabad	6
5	Indian-crested porcupine	*Hystrix indica*	Rawalpindi/Islamabad/Chakwal/Attock	10
6	Barking deer	*Muntiacus muntjac*	Rawalpindi/Islamabad	5
7	Small Indian civet	*Viverricula indica*	Islamabad	4
8	Jungle cat	*Felis chaus*	Islamabad	1
9	Punjab Urial	*Ovis vignei punjabiensis*	Jhelum	1
10	Wild boar	*Sus scrofa*	Rawalpindi/Islamabad/Chakwal	4
11	Indian desert hare	*Lepus tibetanus*	Islamabad/Chakwal	2
12	Jungle babbler	*Turdoides striata*	Rawalpindi/Islamabad	1
Total				57

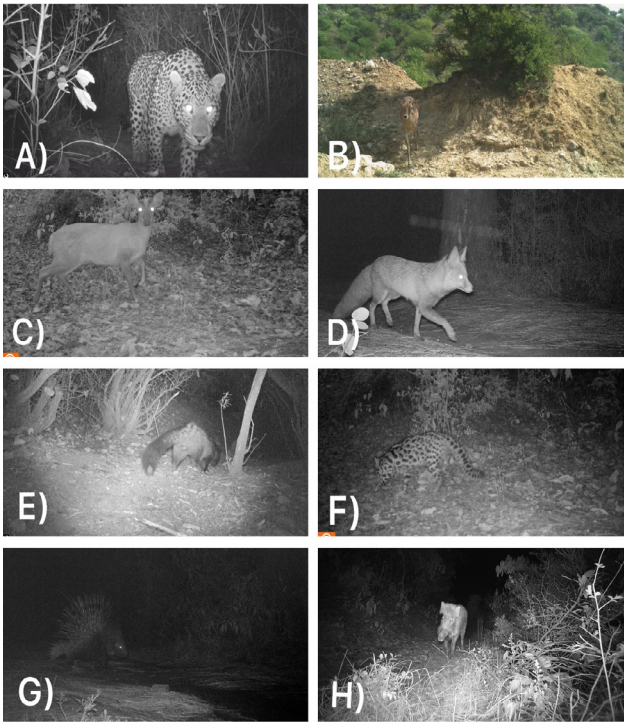

Fig. 2. Animal species camera trapped in the study area. (A) shows Common leopard, (B) Punjab Urial, (C) Barking deer, (D) Red fox, (E) Asian palm civet, (F) Small Indian civet, (G) Indian Crested porcupine and (H) shows wild boar.

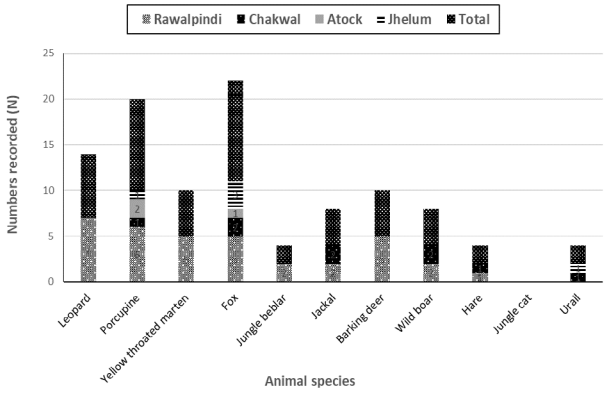

Fig. 3. Numbers of animal species captured in camera traps in four district of Pothwar Plateau.

Activity patterns

The collected data revealed that the jungle babbler (*Argya striata*), Asiatic jackal (*Canis aureus)*, barking deer (*Muntiacus muntjac)*, wild boar (*Sus scrofa)* and desert hare (*Lepus nigricollis)* were active during dawn and dusk times, but the activity of wild boar and barking deer was also observed during day h. Red fox, common leopard and Asian palm civet as well as Indian-crested porcupine were found nocturnal (Figs. 2, 3 and 4). On comparative grounds, Asiatic Jackal was recorded active at early dawn till late morning next. The Indian-crested porcupine were active from dawn to dusk h while the highest density was recorded during the mid-night (Figs. 2, 3 and 4). Red fox activities were recorded were found more active during mid-night, yellow throated marten activity was recoded between late afternoon and dust h (Figs. 2 and 4).

The common leopards foraging times were recorded to be after midnight to next dawn, mid-day, dusk to mid-night (Figs. 2 and 3). The activity times for wild boar were from dusk to mid night and highest density were recorded during early night (Figs. 2 and 3). Similarly, the barking deer and Punjab Urial were recorded as more active during the dawn and dusk h (Figs. 2 and 3).

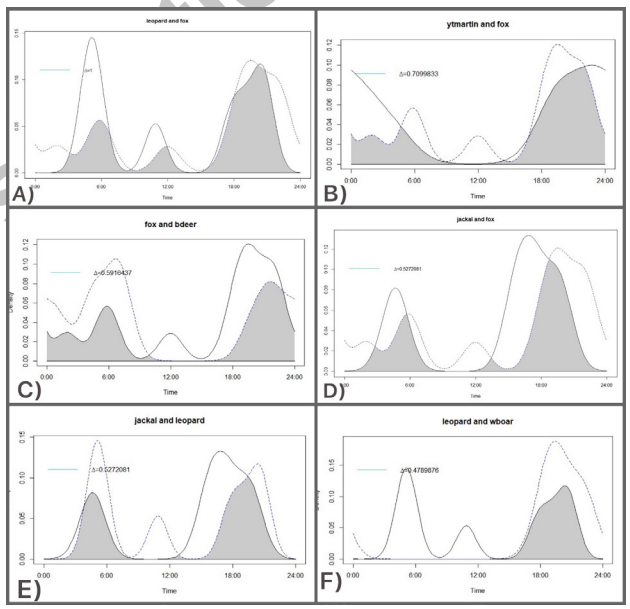

Fig. 4. Graphical presentation of the comparative niche overlap between different mammalian species camera trapped in the Pothwar Plateau; (A) Temporal niche overlap between Common leopard and red fox, (B) Yellow throated Marten and red fox, (C) red fox and barking deer, (D) Asiatic jackal and red fox, (E) Asiatic Jackal and common leopard, and (F) Common leopard and wild boar.

Temporal niche overlap

The collected data in the form of photo-capture events were analyzed in terms of activity timing of each animal species, to compute the temporal niche of each species captured in the Pothwar plateau. Then a comparison was made between two species. The data were analyzed in R studio for comparing the temporal niche overlap between

two species and result was delta value computed by the software. The Delta value may range between 0.1 up to 1.0; the 0.1 showing lowest niche overlap between two species compared while 1.0 value of delta shows complete overlap between the two species compared (Figs. 4 and 5).

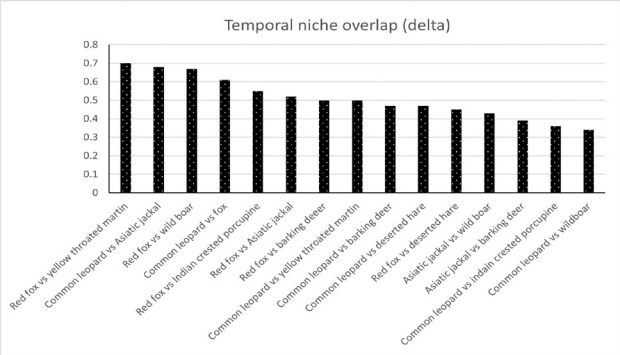

Fig. 5. Graphical comparison of the temporal niche overlap between different mammalian species in the Pothwar Plateau.

Results indicate that the overlap of the temporal niche between red fox and common leopard was highest (delta= 1.0), between red fox and yellow-throated marten was 0.70. Similarly, the temporal niche overlap between Asiatic Jackal and red fox was found also high (delta = 0.52), and the similar results were recorded for niche overlap between common leopard and Asiatic Jackal, barking deer and red fox was 0.59, common leopard and wild boar was 0.47, whereas the temporal niche of Asiatic Jackal and Indian crested porcupine were found overlapped at 0.34 (Figs. 4 and 5).

DISCUSSION

The current study provides a primary empirical description of the temporal ecology of mammalian species, in the Pothwar Plateau, where top predators are locally extinct or functionally absent. We successfully camera trapped 13 different mammalian species from various sites of the study area. We used these data for analysis of 24 h diel activity patterns to compute the temporal niche overlap between these different mammalian species. Regarding activity patterns, the camera trapped data showed that common leopard was active at night-time mainly starting from late evening, and from 20:00 h onwards, and around 03:00 am. Asiatic Jackal remained active from late evening time till 20:00 (8 pm) to 21:00 h (9 pm) and also occasionally captured in the camera trap around 4:00 am. For red fox more capture events were recorded from late evening till midnight, however a couple of daytime captures were also found. For wild boar, the activity time was from late evening till midnight. Similar was the case of desert hare, showing its activity from very late evening till late night. The barking deer was found active an early morning and at nighttime. Indian crested porcupine also found nocturnal, being active only at nighttime. Similar was the case with yellow throated marten being active from late evening all the night.

In the current study, the recorded activity patterns are qualitatively somewhat similar to those described in the literature previously , for example, red fox is reported to be nocturnal-crepuscular (Diaz-Ruiz *et al*., 2016). According to the Rayleigh test, the species' activity patterns are not uniform throughout the circadian cycle (Marinho *et al*., 2020). The published literature reports that the crab-eating fox was nocturnal-crepuscular, beginning its activity at dusk, continuing through the night, and reaching its peak around dawn. Some residual activity continued into the early morning hour (Marinho *et al*., 2020).

In the current study, we observed the activity pattern of yellow throated marten being like that already reported for the pine marten. A high overlap was observed amongst the pair-wise comparison of temporal activity rhythms of Indian-crested porcupine, and red foxes. Mori and Menchetti (2019) had reported that the pine marten was the only diurnal crepuscular and the crested porcupine avoided moonlit nights throughout the year They reported the temporal overlap in terms of moon phases, and showed a niche segregation between the crested porcupine, mostly active in dark nights (Mukherjee *et al*., 2018), and its main local predator (Lucherini *et al*., 1995), the red fox, which increased its activity patterns in bright moonlit nights (Penteriani *et al*., 2013). In our study, we also found red fox being more active at nighttime and Indian-crested porcupine also followed the same pattern.

Our findings have shown that common leopards are mostly active at nighttime. This could be because in the habitat of common leopard , the areas visited frequently by the local people (for their daily activities) and the tourists and visitors walking on foot and on vehicles, might have forced common leopard using the night-time instead to avoid human disturbance associated with local resource collection. A pattern of temporal avoidance similar to our findings was observed in Thailand by Ngoprasert *et al*. (2007) where local people were active at more camera trap locations than tourists, who were taken on selected paths in the forest.

The common leopard in the current study did exhibit relatively high temporal overlap with several prey species, especially the wild boar (*Sus scrofa*). It seems likely that common leopard is deliberately active when wild boar is active, so that the activity patterns and temporal niche

of these two species overlap in the study area. Earlier on Gashe and Yihune (2020) showed that during the activity time budget, there were two foraging peaks throughout the wet season: Early in the morning (6:00–10:00 h) and late in the afternoon (16:00–18:00 h). Contrarily, taking a nap frequently occurred between 10:00 and 11:00 and 14:00 and 15:00. Asiatic jackals were demonstrated the similar activity pattern during our study. The amount of time spent foraging was reduced during the dry season, and as a result, more time was spent relaxing between 10:00 to 14:00. However, virtually little resting was done between the h of 6:00 and 8:00 and 16:00 and 18:00. Golden jackals were mostly active in the early morning hour of 6:00–8:00 and the late afternoon hour of 16:00–18:00, according to their activity pattern.

Temporal niches are important for maintaining biodiversity during the course of evolution. Because it is believed to influence which species and how many may coexist in a group, niche overlap is a key topic in community ecology. As a result of the competitive exclusion principle, which argues that two species employing the same resources and/or conditions cannot coexist, niche overlap has gained attention. For their existence, the majority of animal species avoid overlapping, they compete with one another for food and shelter, as is well known.

The current study highlights that common leopards were mostly nocturnal and crepuscular, like barking deer and fox, and that they were least active in the middle of the day. In terms of their predatory tendencies, like the related Sunda clouded leopard (Hearn *et al*., 2013). While red fox, barking deer, and wild boar are potential prey for common leopards. and there was a lot of niche overlap between them. Spatial and temporal overlaps between the Asiatic jackal and red fox were also impacted by human activities. Both species displayed greater nighttime behaviours in agricultural environments, which led to higher temporal overlaps (Tsunoda *et al*., 2018) than those seen in mountain forests (Tsunoda, 2020). Their nighttime activities can be related to their behaviour of avoiding humans during the day (Gaynor *et al*., 2018), which causes both species to have narrower windows of daily activity (Shamoon *et al*., 2018). To prevent interaction, both species in our study are nocturnal and active primarily in the evening and at night. Both species avoid predators in the districts of Rawalpindi and Islamabad, as well as human interactions in the districts of Chakwal and Attock. Between them, there was some overlap. According to Zhou *et al*. (2008), masked palm civet activity is primarily nocturnal; this was also true of the civets in our investigation. The majority of the time, wild boars were nocturnal, and there was no seasonal, age-, or sex-related variance. Boitani *et al*. (1994) observed that wild boar activity is nocturnal and demonstrated that wild boars exclusively exhibit activity at night.

Yellow-throated martens were generally nocturnal, however on evenings with full moons, some nocturnal activity was seen. In Indonesia, camera trapping revealed that yellow-throated martens were crepuscular (Van Schaik and Griffiths, 1996). Jackals were observed to be active from dawn until late in the morning, and yellow-throated Moorhens were observed to be active from late afternoon till evening hour. As a result, these two species had separate niches.

CONCLUSION

The findings of the current study provide the baseline data on the activity patterns of the mammalian species (carnivores and herbivores) and the patterns of the temporal niche overlap between predators and prey species in the Pothwar Plateau, Pakistan. The main results show that the temporal niche overlap between fox and barking deer is very high and the niche overlap between Asiatic jackal and red fox, and between Asiatic jackal and common leopard were similar (delta = 0.5) and the niche overlap between these species were partially segregated as well. The study recommends that the disturbance by the visitors and tourists in some parts of the study area such as Margalla Hills National Park (MHNP) Islamabad, Ara Basharat National Park, Chakwal district etc. should be controlled and minimized so that the animal species present may not need to make adjustment to avoid the tourists and visitors.

DECLARATIONS

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Statement of conflict of interest

The authors have declared no conflict of interest.

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