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Diel Activity Patterns of Himalayan Ibex and Livestock in the Trans-Himalayan Landscape of Himachal Pradesh, India

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Abstract: Understanding the activity patterns of coexisting species is essential for advancing our comprehension of species ecology and aiding in the development of effective conservation strategies. This holds true for ungulates that inhabit areas beyond protected zones, where human activities pose threats to their survival. Moreover, livestock grazing ranks among the most prevalent human activities in terms of land utilization. In the Lahaul-Spiti districts of Himachal Pradesh, situated in the trans-Himalayan landscape of India, a total of 241 camera traps were strategically positioned. These camera traps captured bimodal activity patterns in both the Himalayan Ibex (*Capra sibirica*) and livestock, encompassing crepuscular and diurnal behaviors. Nonetheless, the overlap coefficient, exceeding 0.7, signified a significant degree of overlap between Himalayan Ibex and livestock during both seasons. This study unveiled the striking similarity in activity patterns between wild Himalayan ibex and livestock, indicative of their comparable resource utilization. Consequently, the findings of this study emphasize the necessity for well-devised conservation planning aimed at fostering the long-term survival of wild ungulates.

Keywords: Diel activity pattern, Activity overlap, Himalayan Ibex, *Capra sibirica*, Livestock

Wildlife experiences adverse effects stemming from the multifaceted anthropogenic activities. Large terrestrial mammals, especially herbivores, are considered highly vulnerable species due to the significant population declines (Craigie et al 2010, Ceballos et al 2017, Atwood et al 2020, Bhandari et al 2022). These declines can be attributed to the continuous and extensive anthropogenic pressure resulted habitat loss and fragmentation (Bhandari et al 2022). Consequently, livestock grazing stands as the most prevalent human activity in terms of land utilisation and sharing habitats with wildlife on a global scale (Steinfeld et al 2006, Robinson et al 2014, Schieltz and Rubenstein 2016). In the past few years, there has been a substantial surge in livestock populations, primarily attributed to the exponential expansion of the cashmere industry (Berger et al 2013, Salvatori et al 2021). Over one fourth of the terrestrial land area on Earth is used for the purpose of grazing, resulting in a substantial disparity in population between the wild ungulates and livestock, with the latter outnumbering the former by multiple magnitudes (Berger et al. 2013, Robinson et al 2014, Bleyhl et al. 2019). In certain geographical areas across the globe, the phenomenon of overgrazing has undeniably resulted in a decline in the richness and total biomass of both flora and fauna populations (Schieltz and Rubenstein 2016). This has consequently led to a reduction in overall biodiversity and has caused significant modifications to landscape heterogeneity, ecological succession, deterioration of forage plants, habitat shift of wild ungulates, transmission of diseases and cycling of nutrients (Mishra et al 2001, Kauffman and Pyke 2001, Shrestha and Wegge 2008, Chirichella et al 2013, Krishna et al 2016, Schieltz and Rubenstein 2016). The potential detrimental influence of livestock overgrazing on indigenous ungulate populations in Asia has garnered considerable attention in scientific discourse (Shrestha and Wegge 2008). While some pastoral systems facilitate coexistence and preserve habitats for wild ungulates, the majority of cases indicate that multifaceted struggle with livestock poses a significant threat to large ungulates, especially in resource-limited places like dry lands or mountainous terrain (Riginos et al 2012, Ekernas et al 2017).

In the Himalayas and Trans-Himalayas, pastoralist practises including migratory livestock grazing are common (Axelby 2007, Bhasin 2011). Several studies illustrated the occurrence of multiple livestock diseases and parasitic infestations in Indian Himalayan rangelands, which are major concern to wildlife. These include haemorrhagic septicaemia, foot and mouth disease (FMD), peste des petits ruminants (PPR), swine fever, and gastrointestinal nematodes (Dixit et al 2009, Muthiah et al 2013, Khanyari et al 2022).

Capra sibirica, commonly known as the Himalayan Ibex, represents a true species of mountain goat within the taxonomic classification of the Bovidae family. The Capra genus comprises a diverse array of ungulate species, with *Capra sibirica* standing out as particularly noteworthy due to its larger size (Fedosenko and Blank 2001). *Capra sibirica* demonstrates a wide-ranging distribution across diverse mountainous areas, *viz.* Afghanistan, Kazakhstan, Tajikistan, Pakistan, India, China, Uzbekistan, Mongolia, Russia and Kyrgyzstan and one among the least studied species (Otgonbayar et al 2017). In India, this species distributed in the Western Himalayan states, mainly in the Himachal Pradesh, Jammu Kashmir, and Ladakh highlands. The Himalayan Ibex lives in a region with rough terrain and steep inclines, where it must rely more on strength than speed to survive (Bhatnagar 1997). Himalayan Ibex are sexually dimorphic, the male and female morphological traits differ significantly (Roberts 1977, Prater 1980). The International Union for Conservation of Nature (IUCN) Red List has classified the Himalayan Ibex as a species of "Near Threatened" status and as Schedule I species in Wildlife (Protection) Act of 1972 in India considering the various threats to the species (Reading et al 2020).

Diurnal activity patterns are an evolutionary response to the fluctuating environmental conditions during the day. These patterns represent a multifaceted trade-off between several factors including as social interactions, competition, foraging, predator avoidance, resting, and environmental limitations, all of which ultimately influence an organism's fitness (Halle and Stenseth 2012, Kronfeld-Schor et al 2013, Vazquez et al 2019). Terrestrial mammalian activity patterns can be classified into four categories crepuscular, cathemeral, diurnal, and nocturnal (Bennie et al 2014). The activity patterns of the mammals have mostly been studied by direct/visual observation or camera trap surveys (Koprowski and Corse 2005, Li et al 2022). The utilisation of camera trapping is prevalent within the fields of ecology and conservation, since it serves as a valuable tool for the examination of species' ranges, the estimation of population densities, inventorying of biodiversity and activity patterns of species (O'Connell et al 2011, Steenweg et al 2017, Frey et al 2017). Temporal data derived from camera trap with time stamps have yielded initial analyses of activity patterns exhibited by animals (Gerber et al 2012, Bu et al 2016). In recent time, there has been a growing interest among researchers in examining the more detailed temporal data obtained from time-stamped camera-trap images (Ridout and Linkie 2009, Rowcliffe et al 2014). The primary aim of this study is to elucidate the activity patterns of Himalayan Ibex and livestock, while also examining the extent of activity overlap between these wild and domesticated ungulates within the study landscape.

MATERIAL AND METHODS

Study area: The valley is characterized by its snow-capped mountains, picturesque valleys, vibrant local community, and the captivating presence of Buddhist hymns, which contribute to the charming atmosphere. Additionally, the valley provides ample habitat for species, allowing for their successful survival. The geographical region of Lahaul and Spiti, located in the Trans-Himalayan range, spans from latitudes 31.7492° to 32.9992° N and longitudes 76.7747° to 78.6928° E (Fig. 1). These districts encompass 24.86% (13,841 km^2) of the overall geographical expanse of the Himachal Pradesh state, hence constituting the largest district within this state. This landmass situated between the Pir Panjal Mountain range of the Trans and Greater Himalaya (Aswal and Mehrotra 1994). The elevation range of this district extends from 2301 to 6580 metres above sea level. The present landscape exhibits distinctive physical features, including majestic mountains adorned with snow-capped peaks, as well as rugged and sloppy terrains. The predominant land cover types in the area are subalpine vegetation, agricultural land, rolling grassland meadows, and permafrost areas. Due to the trans Himalayan characteristic, this landmass has less vegetation cover which made this landscape challenging for various life forms. The Spiti region is endowed with three distinct Protected Areas, namely the Kibber Wildlife Sanctuary, Chandratal Wildlife Sanctuary, and Pin Valley National Park, however, the Lahaul valley does not currently possess any designated protected areas within its boundaries. The Trans- Himalayan Mountain slopes exhibit a distinctive ecological profile characterised by severe climatic conditions, limited precipitation, and a brief period suitable for plant growth. Consequently, the vegetation cover in this region is notably low, measuring less than 20%. However, this challenging environment serves as a habitat for an amazing diversity of indigenous plant and animal species (Joshi et al 2006).

Camera trap direct observation: As part of a research endeavour aimed at documenting endangered vertebrate species in the Indian Himalayan region, camera traps were strategically positioned across the study landscape. During the period from July 2018 to October 2020 and from August 2021 to August 2022, a comprehensive deployment of 241 camera traps was conducted across various study grids. These camera trap had been positioned with a wide variety of elevations, spanning from 2120 m to 5411 m. The trail cameras used included the SPYPOINT FORCE-11D (GG Telecom in Canada, QC), SCOUTGUARD (SG562 D) and Browning 940 Defender. The cameras were operational continuously for a duration of 24 hours each day, with minimal intervals between captures. Additionally, each capture consisted of three quick photos, each accompanied by a time and date stamp. Photographs were regarded as independent records in cases where the time lapse between each record exceeded 30 minutes (Oliveira et al 2018). In addition, we meticulously recorded our direct observations of the Himalayan Ibex, as well as the presence of livestock. Each entry in our documentation includes precise geographical coordinates, the date and time of the sighting, and the specific location where the wild ungulates and livestock were encountered.

RESULTS AND DISCUSSION

In this present study, a total of 41 individual captures of the Himalayan Ibex were documented through camera trap, accompanied by 42 direct observations. In contrast, a total of 44 incidents of livestock captures were documented through camera traps, while 64 instances of Livestock recorded through direct observation. The livestock comprised a diverse range of ruminant and equine species, including goats, sheep, cows, and horses. In the summer season, a total of 44 individual observations were recorded for the Himalayan Ibex, while during the winter season, 39 individual observations were recorded for the same species. Moreover, a total of 77 individual observations were recorded for livestock during the summer season, whereas only 31 observations were recorded during the winter season for the livestock. The Himalayan Ibex and livestock were generally crepuscular and diurnal (Fig. 2). The analysis of activity patterns during the summer season indicates that the wild ungulate exhibits peak activity during 6:00. Additionally, another peak in activity is observed approximately 16:00. Notably, the activity levels of wild ungulates show a relatively high peak just after 18:00 (evening hours) (Fig. 2). During the winter season, the highest activity peak of Himalayan Ibex observed during 12:00, and before 18:00 (Fig. 2). The activity of livestock is observed during the summer season, started from after 6:00 and highest peak observed before 12:00 (approximately 11:00), after 12:00 (approximately 14:00), and before 18:00 (approximately 17:00) (Fig. 2). During the winter season, the occurrence of the highest peak is observed at 12:00, followed by subsequent peaks around 16:00. Furthermore, the overlap pattern indicates a significant degree of overlap between Himalayan Ibex and livestock populations. During the summer season, the computed Δ_4 value was 0.71 (Fig. 3). Conversely, in the winter season, the overlap index indicated a value of 0.74 between the Himalayan Ibex and livestock (Fig. 3). Study conducted in India found that the activity pattern of the Himalayan Ibex primarily follows a bimodal pattern during the winter season (Fox et al 1992). This pattern is characterised by a significant peak in activity observed around sunrise, as well as a minor peak around sunset and consistent with our findings. Additionally, our analysis revealed a notable shift in Ibex activity patterns following periods of significant snowfall. Specifically, noticed an increase of activity throughout the mid-day hours, with a particularly high peak occurring at 12:00. The observed phenomenon may be attributed to the decrease in temperature, which causes Himalayan Ibex to remain in a bedded state until mid-morning, followed by a rise in activity prior to sunset. Our study recorded that the activity patterns of Himalayan Ibex exhibit seasonal variations and corroborated with previous studies (Prater 1980, Fox et al 1992).

The livestock activity pattern is mostly regulated by the attention of the shepherd and villagers. During the summer

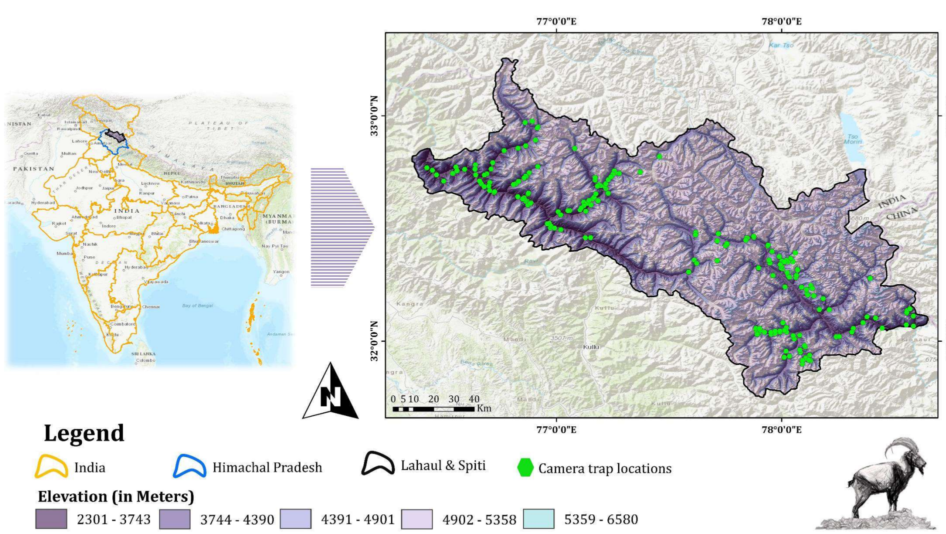

Fig. 1. Map of study area showing the camera trap locations distributed in the study landscape

season, there is a significant migration of livestock primarily originating from the lower regions of Himachal Pradesh, particularly from the Kangra and Chamba districts to this study area due to wide range of available grazing grounds. Thus, significant degree of overlap between the Himalayan Ibex and livestock within the area, however, this indicates a clear similarity in habitat choice between the Ibex and livestock species (Bagchi et al 2004). Migratory shepherds avoid the area in the winter because of the snowfall, which also hinders the growth of plants and local livestock supplemented by stall feeding; however, villagers do take their livestock outside for a brief period which illustrates the observed overlap between the Ibex and livestock during the winters. In rugged mountainous terrain like Lahaul -Spiti landscape, the presence of diverse resources and their distribution over space and time can potentially contribute to the coexistence of competing species). This is due to the fact that the relationship between the species growth rates and the resource densities is likely to be non-linear in such environments (Armstrong and McGehee 1980). However, the presence of wild ungulates has a significant impact on the ecosystem functionality and structure, making them as a valuable indicator of the overall health of terrestrial ecosystems (Gordon et al 2019, Sharief et al 2022). Wild ungulates play a crucial role on vegetation composition. Their trampling, grazing, browsing and defecation activities (Lillian

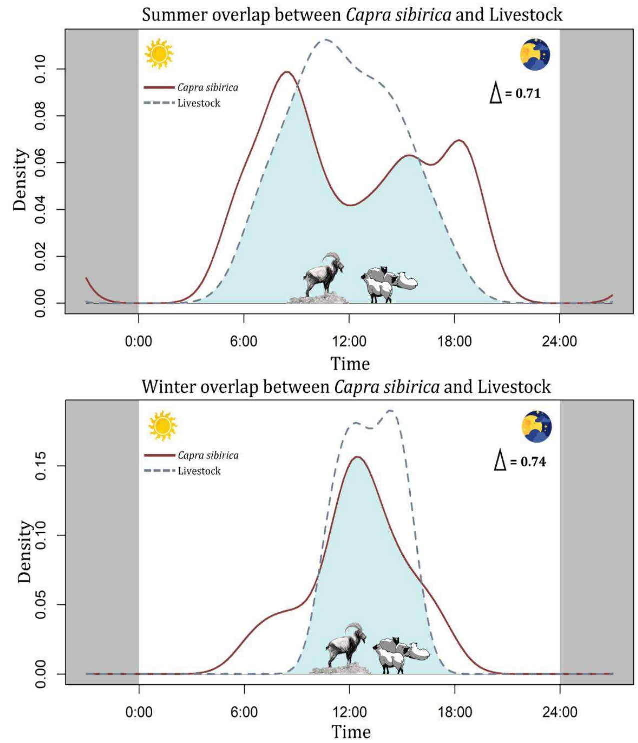

Fig. 3. The overlap coefficient used (Δ) as a means to quantify the extent of the Himalayan Ibex (*Capra sibirica*) and livestock density estimations in summer and winter season, as shown by sky colour

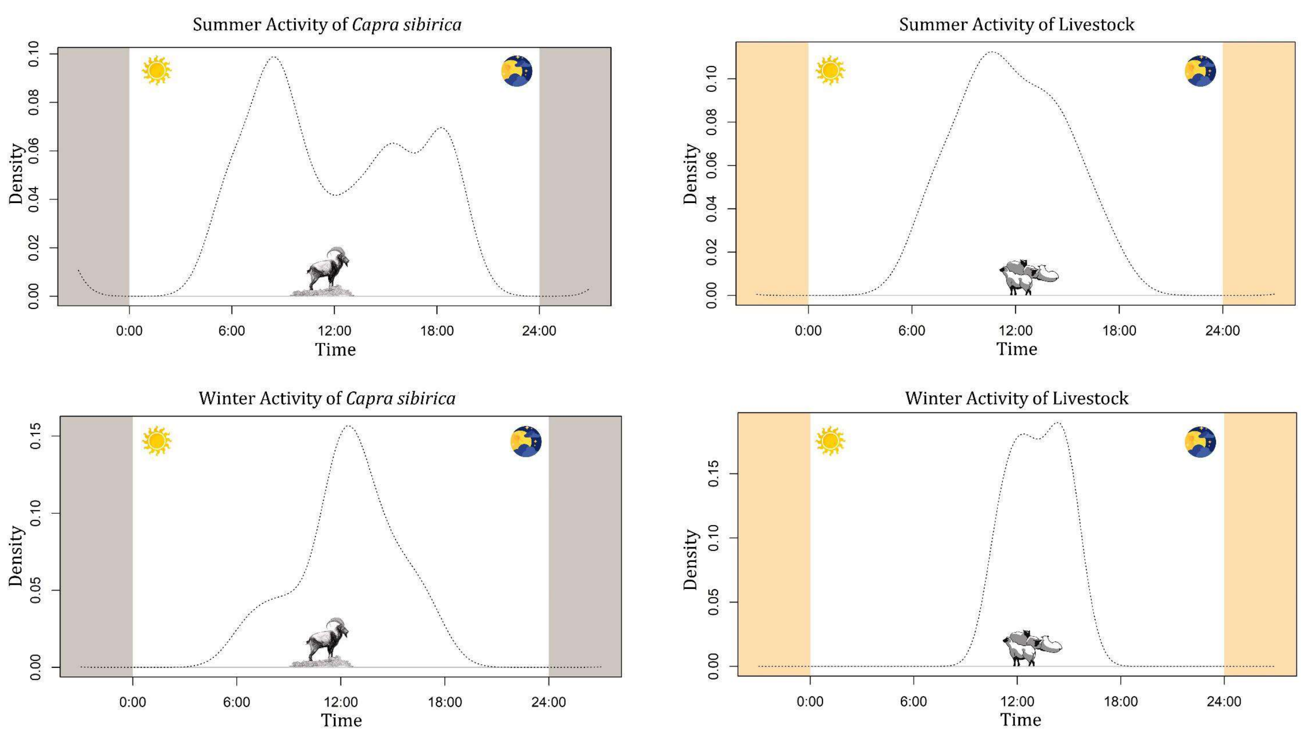

Fig. 2. Diel activity patterns of Himalayan Ibex (*Capra sibirica*) and livestock in summer and winter season from acquired data

et al 2019), have the potential to alter plant communities. These actions affect not only the distribution and structure of the vegetation, but also the flow of nutrients and responses of other related species (Rooney et al 2009, Schulze et al 2014, Kasahara et al 2016). The snow leopard (*Uncia uncia*) is an apex predator inhabiting the uppermost trophic level in the Trans Himalayan ecosystem, exhibits a strong reliance on Himalayan Ibex, serving as a pivotal constituent of its dietary preferences (Suryawanshi et al 2017, Sharief et al 2022, Khanyari et al 2022). Furthermore, the presence of pastoralism poses a significant threat to the population of large carnivores, this threat arises from a series of interconnected and intricate effects (Ekernas et al 2017, Salvatori et al 2021). These effects primarily involve the decrease in the number of wild prey available for carnivores, leading to an increased predation on livestock. Consequently, this situation triggers conflicts between humans and carnivores, resulting in retaliatory killings. These processes are widely recognised as the main factors contributing to the negative impact of pastoralism on large carnivores (Snow Leopard Network 2014, Mishra et al 2016, Salvatori et al 2021). The rangelands in this region experience significant grazing pressure from livestock, which poses conservation challenges for wild ungulates, therefore, effective management policies for this terrain requires the integration of both social and ecological factors (Bagchi et al 2004, Ghoshal 2017, Khanyari et al 2022). The findings of this study underscore the importance of understanding and addressing the overlapping activity patterns of Himalayan Ibex and livestock, highlighting the need for effective conservation planning. This study's implications extend to species conservation and management, particularly in areas with a high prevalence of Ibex activity, and it paves the way for in-depth habitat ecology analysis in these regions.

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