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Cover: A bag worm with its beautiful heap of junk. Acrylics on 300 GSM paper by Dupati Poojitha based on a picture by Sanjay Molur.

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ARTICLE

Patterns and economic impact of livestock predation by large carnivores in protected areas of southern Kashmir, India

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Abstract: Livestock predation by carnivores in and around protected areas poses a significant threat to the livelihoods of pastoralists and presents a major challenge to carnivore conservation efforts. In Kashmir, livestock predation by the Asiatic Black Bear *Ursus thibetanus* and the Leopard *Panthera pardus* has been documented, but its substantial impact on communities living near protected areas has remained understudied. We assessed livestock predation patterns in three protected areas of southern Kashmir: Overa-Aru Wildlife Sanctuary, Rajparian Wildlife Sanctuary, and Achabal Conservation Reserve. Using an exponential non-discriminative snowball sampling method, followed by a questionnaire survey of affected individuals, we documented predation incidents across all three protected areas, with varying intensity. We identified Sheep *Ovis aries*, Cattle *Bos taurus*, and Domestic Horse *Equus caballus* as the primary prey species. Both the Asiatic Black Bear and the Leopard predominantly preyed on Sheep. The Asiatic Black Bear also targeted Cattle, and the Leopard showed a preference for Domestic Horse. Most predation events occurred during the summer, primarily during the day and within forest areas. However, the Leopard also attacked livestock penned in corrals. Most respondents expressed a positive attitude towards wildlife conservation; a minority advocated for lethal control of the carnivores involved in livestock predation. To mitigate this negative interaction, we propose a comprehensive interaction management strategy aimed at reducing the financial burden on local communities and fostering the long-term conservation of carnivores.

Keywords: Achabal Conservation Reserve, Asiatic Black Bear, carnivore, conservation, human-wildlife interaction, Leopard, mitigation, Overa-Aru Wildlife Sanctuary, Rajparian Wildlife Sanctuary, seasonal variation.

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Author contributions: LR—writing original draft, validation, visualization, methodology, investigation, formal analysis, data curation, conceptualization, software. BAB—writing, review & editing, validation, supervision, methodology, conceptualization, project administration, resources.

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INTRODUCTION

Human-carnivore negative interaction is one of the most pressing challenges in global carnivore conservation (Khorozyan et al. 2015; Dhungana et al. 2019). This interaction is largely driven by the intrinsic traits of large carnivores, including their size, carnivorous diet, and extensive territorial range (Pooley et al. 2017; Kuiper et al. 2021). In agricultural landscapes, carnivores often resort to preying on ungulates or livestock to meet their high-protein dietary needs (Inskip & Zimmermann 2009; Thorn et al. 2012). Although humans and large predators have coexisted for thousands of years, this interaction has intensified in recent decades, particularly in regions where human and wildlife habitats overlap (Morehouse et al. 2020). Growing intolerance towards large carnivores has been fueled by frequent livestock predation and occasional attacks on humans (van Eeden et al. 2018; Khosravi et al. 2024). Consequently, retaliatory killings have emerged as the foremost threat to many carnivore species (Woodroffe et al. 2007; Le Flore et al. 2019; Kichloo et al. 2024).

A significant portion of large carnivore species share their habitats with economically vulnerable human communities, with over a third of their territories overlapping these areas (Braczkowski et al. 2023). This overlap intensifies human-carnivore interaction, especially in and around protected areas, which often harbour large and potentially disruptive mammal species (Karanth & Nepal 2012; Karanth et al. 2013; Hanson 2022). The socio-economic impact on rural livelihoods is profound, primarily due to predation on livestock by these carnivores. These losses pose a substantial obstacle to balancing rural development and biodiversity conservation efforts (Gusset et al. 2009; Loveridge et al. 2010; Khorozyan et al. 2015).

We explored livestock predation by the Asiatic Black Bear *Ursus thibetanus* and the Leopard *Panthera pardus* in and around some protected areas of Kashmir. These two carnivore species are increasingly involved in negative interactions with humans, frequently preying on livestock (Charoo et al. 2011; Dar & Bhat 2022; Dawood et al. 2025). This situation is particularly challenging for communities living near protected areas, where socioeconomic conditions are often fragile, and livelihoods heavily depend on livestock rearing and agriculture (Bhat et al. 2022; Islam et al. 2023). Despite the frequency and significant impact of these events, the issue has not received adequate attention in Kashmir. Farmers frequently endure livestock losses without compensation or support, which can lead to resentment and, in some cases, retaliatory killings of Asiatic Black Bears and Leopards, both of which are already in global decline (Garshelis & Steinmetz 2020; Stein et al. 2020).

To address this issue, it is essential to explicitly understand the patterns of livestock predation to identify regions and periods with high levels of predation. Both the ecological and social aspects of predation incidents, along with the economic losses they incur, need to be thoroughly assessed (Goodrich 2010; Dhungana et al. 2018, 2019). We investigated livestock predation across three protected areas in southern Kashmir: Overa-Aru Wildlife Sanctuary, Achabal Conservation Reserve, and Rajparian Wildlife Sanctuary. We focused on the ecological and social dimensions of livestock predation, without overgeneralizing the interaction aspect. Our objective was to evaluate the economic impact of livestock predation and to identify the spatial patterns of these events, which can provide a foundation for developing effective management strategies in the region.

Study Area

The study was carried out in and around three protected areas in southern Kashmir: Overa-Aru Wildlife Sanctuary, Rajparian Wildlife Sanctuary, and Achabal Conservation Reserve. These three study areas were selected based on varying levels of human-wildlife interactions, the number of villages in the vicinity, diverse land cover types, and differences in the socioeconomic status of the surrounding communities. Overa-Aru Wildlife Sanctuary, located in Anantnag District of Jammu & Kashmir, is nestled between the Zanskar and Pir Panjal mountain ranges, approximately 96 km south of Srinagar (Figure 1A). It spans an area of 425 km^2, with elevations ranging 2,000–5,425 m (Islam et al. 2023). It is surrounded by eight villages situated in and around its boundaries.

Achabal Conservation Reserve is also located in Anantnag District, with elevations ranging 1,636–2,434 m (Figure 1B). The reserve is about 65 km south-east of Srinagar and has nine villages within its buffer zone (Farooq et al. 2021). Rajparian Wildlife Sanctuary, also known as Daksum Wildlife Sanctuary, is located in Anantnag District of Jammu & Kashmir at an elevation ranging 2,360–4,270 m (Figure 1C). Located about 41 km south-east of Anantnag along the Anantnag-Semthan-Kishtwar National Highway 1B, the sanctuary covers an area of 48.27 km^2 (Bhat et al. 2023). There is only one village in the vicinity of the sanctuary, however, livestock from nearby villages are often grazed within the protected area.

MATERIAL AND METHODS

Data on livestock predation by the Asiatic Black Bear and the Leopard in villages in and around three protected areas were collected using the exponential non-discriminative snowball sampling method (Noy 2008; Akrim et al. 2023). Initially, we obtained information on livestock loss incidents from the village heads and subsequently verified with other residents. Where possible, we cross-checked incidents by visiting the sites and authenticating the kills. Monthly visits to village heads were conducted over a two-year period to gather information on any new incidents.

We interviewed affected livestock owners using semi-structured questionnaires to collect data on their socioeconomic status, details of the attacked livestock such as age, gender, time, and date of attack, the predator species involved, and the location of the attack. We visited incident sites and recorded coordinates using a handheld Garmin Oregon-750 GPS device. In cases, where the sites were difficult or dangerous to access, we inferred coordinates using Google Earth (Zarco-González et al. 2013). Additionally, we obtained data on the total livestock owned by village inhabitants from the Veterinary Department of Jammu & Kashmir.

We conducted all statistical analyses using R software (R Core Team 2022) and employed Pearson's chi-square test to analyse data related to patterns of Asiatic Black Bear and Leopard predation, including the livestock species attacked, as well as the time, place and seasons of attacks. Differences between Leopard and Asiatic Black Bear regarding these patterns were also examined using Pearson's chi-square test. We used a polynomial regression model to determine if carnivores showed a preference for any particular age group of the prey. We performed linear regression to investigate whether livestock losses were proportional to their relative availability in the selected villages. Additionally, we generated a livestock predation map, showing the predation sites of Asiatic Black Bear and Leopard using ArcMap 10.5.

RESULTS

From January 2021 to December 2022, we surveyed a total of 50 respondents from three protected areas, encompassing 29 in Overa-Aru Wildlife Sanctuary, 19 in Achabal Conservation Reserve, and two in Rajparian Wildlife Sanctuary. They all had experienced at least one case of livestock predation during this period. The majority of respondents (80%) earned their income from farming or daily labour, followed by those involved in business (6%), government jobs (6%), tourism (4%) and private jobs (4%). They primarily kept Sheep *Ovis aries*, Domestic Goat *Capra hircus*, Cattle *Bos taurus* followed by Domestic Horse *Equus caballus,* except in Overa-Aru Wildlife Sanctuary, where Cattle were more common (Table 1).

A total of 92 livestock losses were reported by respondents, encompassing 59 in Overa-Aru Wildlife Sanctuary, 30 in Achabal Conservation Reserve, and three in Rajparian Wildlife Sanctuary (Figure 2). In Overa-Aru Wildlife Sanctuary, there were 32 incidents of livestock predation. The Leopard was responsible for 53.12% of the attacks, the Asiatic Black Bear for 34.37%, and 12.5% of the attacks were of unknown origin. Of the 59 livestock lost, most were Sheep (64.41%), followed by Domestic Horse (16.95%), Cattle (15.25%), and Domestic Goat (3.39%). Both predators primarily preyed on Sheep, with the Asiatic Black Bear also targeting Cattle and the Leopard preferring Domestic Horse. Notably, neither Asiatic Black Bear attacks on Domestic Horse nor Leopard attacks on Cattle were reported.

In Achabal Conservation Reserve, 20 incidents of livestock predation were reported. The Leopard was responsible for 85% of the attacks and the Asiatic Black Bear for 15%. The 30 livestock lost included Cattle (50%), Sheep (43.33%), and Domestic Horse (6.67%). The Asiatic Black Bear exclusively attacked Cattle, while the Leopard primarily targeted Sheep, followed by Cattle. In Rajparian Wildlife Sanctuary, only two incidents were reported, resulting in the loss of three Cattle over a two-year period. Respondents identified the Asiatic Black Bear as responsible for both attacks.

A significant difference was observed in the livestock species attacked in Overa-Aru Wildlife Sanctuary (χ^2 = 19.052; $p < 0.001$; Cramer V = 0.594) and in the livestock species attacked by the Leopard in Achabal Conservation Reserve (χ^2 = 8.222; p = 0.016). There was also a significant difference between the livestock species attacked by Asiatic Black Bear and Leopard across the

Table 1. Total livestock kept by residents in three protected areas: Overa-Aru Wildlife Sanctuary (OAWS), Achabal Conservation Reserve (ACR), and Rajparian Wildlife Sanctuary (RWS).

Protected area	Cattle	Domestic horses	Sheep and domestic goats
OAWS	2,665	862	2,421
ACR	1,265	30	1,420
RWS	275	8	300

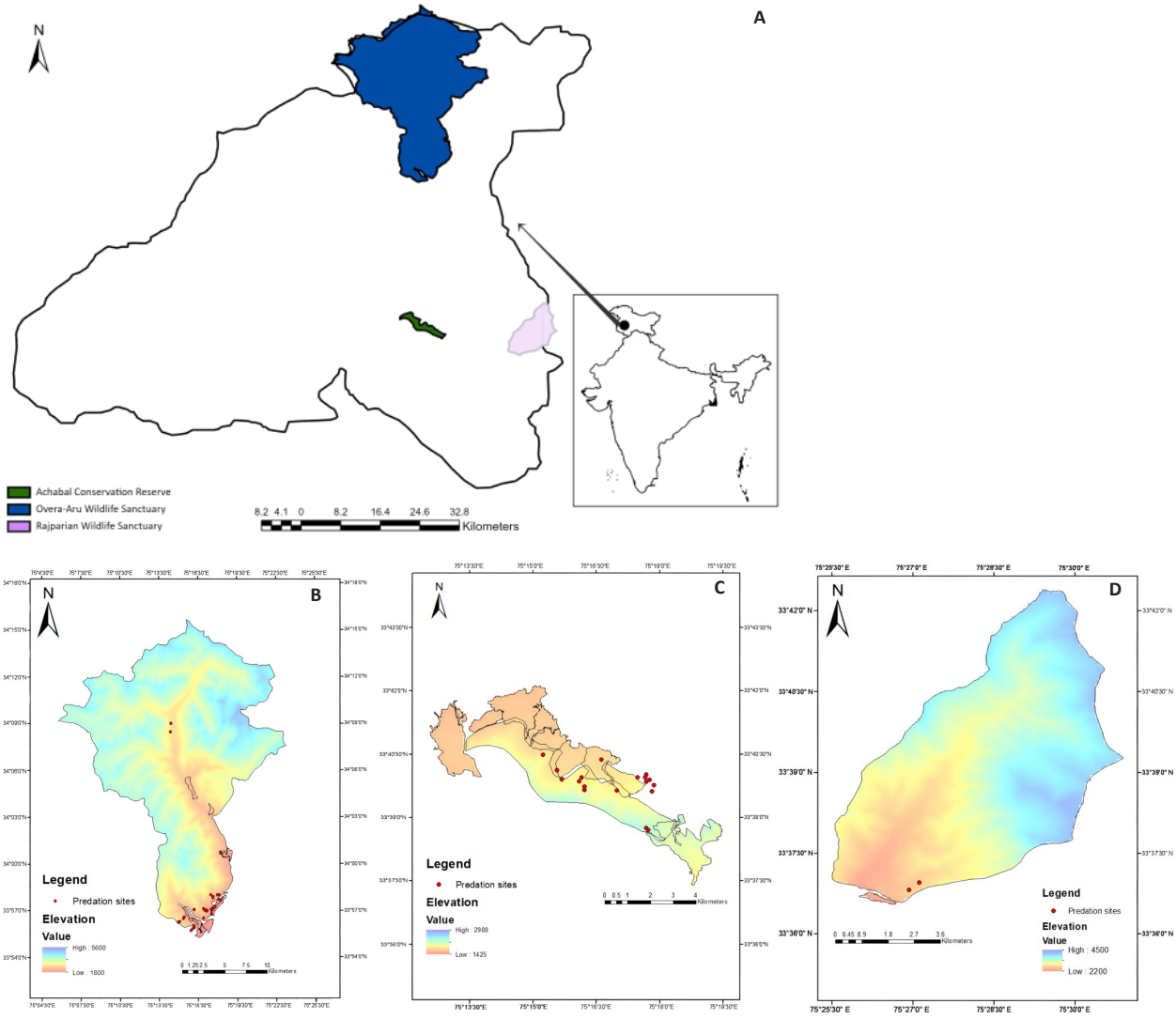

Figure 1. A—Selected protected areas of southern Kashmir | B—Overa-Aru Wildlife Sanctuary | C—Achabal Conservation Reserve | D—Rajparian Wildlife Sanctuary.

three protected areas (χ^2 = 12.186; p = 0.007; Cramer V = 0.374).

The ages of the livestock attacked ranged from less than 1–7 years for Sheep, 2–6 years for Domestic Goat, less than 1–8 years for Cattle, and less than 1–11 years for Domestic Horse. Regression analysis revealed that the predators did not significantly prefer any specific age group, although the 4–6 years age group experienced slightly more attacks (Figure 3).

Asiatic Black Bear attacks in three protected areas occurred predominantly during the day (62.5%), followed by unknown times (25%), night (6.25%), and morning (6.25%). Leopard attacks were most common during the day (70.59%), followed by night (20.59%), evening (5.88%), and morning (2.94%). There was no significant difference in the timing of attacks between the Asiatic Black Bear and the Leopard (χ^2 = 3.819; p = 0.282). Most Asiatic Black Bear attacks (92.59%) occurred inside the forest, with 7.41% just outside it, and none near the respondents' homes or livestock pens. In contrast, the majority of Leopard attacks (61.67%) occurred in the forest, followed by 33.33% inside corrals or near the respondents' homes, and 5% just outside the forest. The difference in attack locations between the Asiatic Black Bear and the Leopard was statistically significant (χ^2 = 11.687; p = 0.003; Cramer V = 0.366).

The majority of Asiatic Black Bear (85.19%) and Leopard attacks (45%) occurred during the summer. For the Asiatic Black Bear, this was followed by autumn (11.11%) and spring (3.7%), with no attacks in winter. For the Leopard, the subsequent seasons were spring (41.67%), autumn (8.33%), and winter (5%). There was

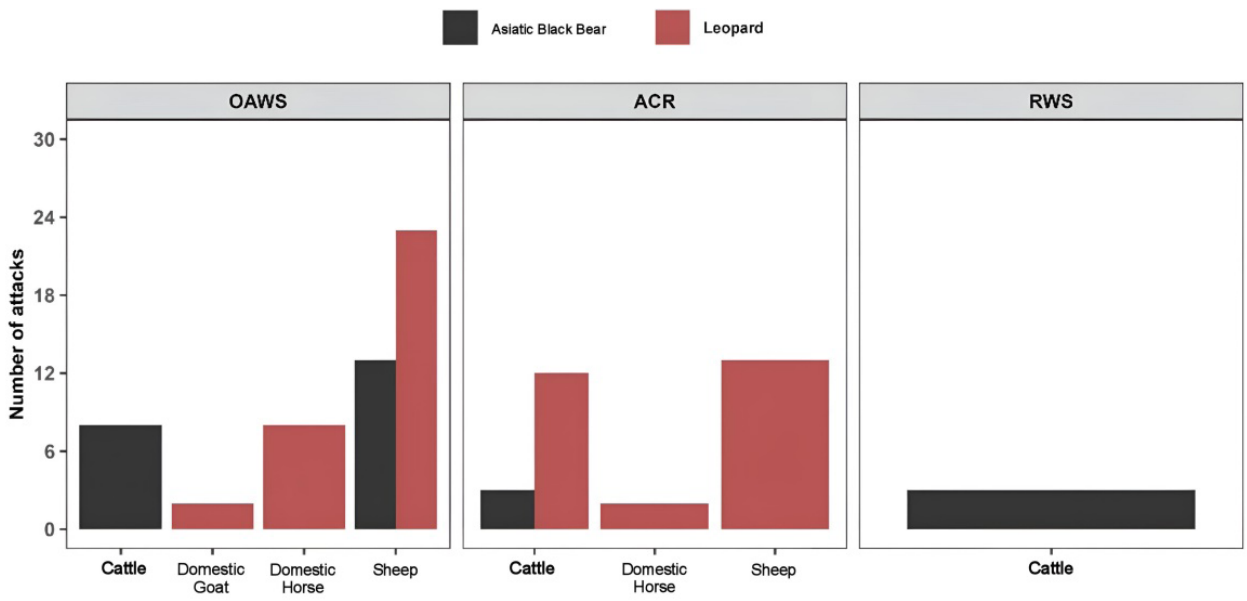

Figure 2. Livestock attacks by Asiatic Black Bear and Leopard in three protected areas during a two-year period from January 2021 to December 2022: Overa-Aru Wildlife Sanctuary (OAWS), Achabal Conservation Reserve (ACR), and Rajparian Wildlife Sanctuary (RWS).

a significant difference in the seasonal distribution of attacks between the Asiatic Black Bear and the Leopard (χ^2 = 15.718; p = 0.001; Cramer V = 0.425). Additionally, a significant difference was observed in the seasonal distribution of attacks for both Asiatic Black Bear (χ^2 = 32.889; p < 0.001) and Leopard (χ^2 = 32.533; p < 0.001). The livestock species attacked also varied significantly across seasons (χ^2 = 22.253; p = 0.008; Cramer V = 0.292) (Figure 4). However, no significant relationship was observed between the location of the attack and the seasons (χ^2 = 8.312; p = 0.216).

Linear regression analysis showed a significant correlation between the frequency of livestock killings and their relative availability (r^2 = 0.71, p = 0.018) (Figure 5).

The estimated economic loss resulting from livestock predation by Leopard and Asiatic Black Bear over two years was substantial across the three surveyed protected areas. In Overa-Aru Wildlife Sanctuary, the total loss amounted to 1,295,500 INR, representing an annual loss per respondent of 22,336.21 INR (1,861.35 INR/month/respondent). In Achabal Conservation Reserve, the total loss was 878,000 INR, averaging 23,105.26 INR per respondent annually (1,925.44 INR/month/respondent). In Rajparian Wildlife Sanctuary, the losses were relatively lower, totalling 160,000 INR, with an average of 40,000 INR per respondent annually (3,333.33 INR/month/respondent).

When asked about mitigation measures, most respondents favoured the translocation of predators to other areas (24%), followed by compensation (22%), while some offered no specific suggestions (18%). Other proposed measures included fencing of protected areas (16%), habitat restoration for wildlife (12%) and the elimination of problematic individuals (8%).

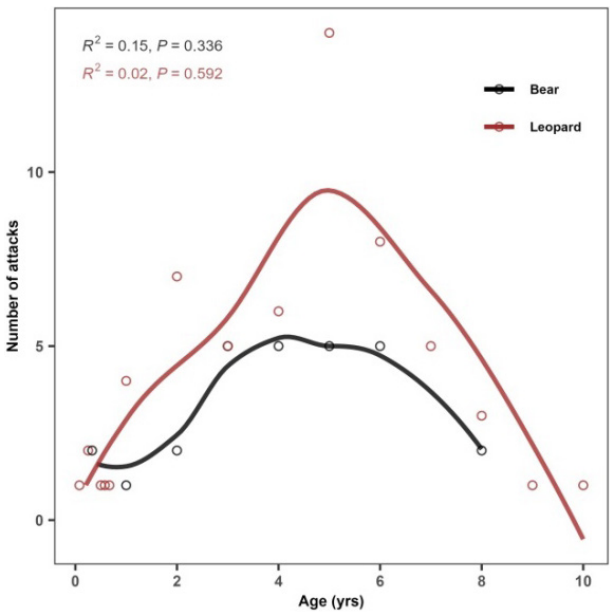

Figure 3. Quadratic polynomial regression illustrating the relationship between the ages of livestock and the frequency of attacks by Asiatic Black Bear and Leopard.

Table 2. Total livestock lost to predation in three protected areas: Overa-Aru Wildlife Sanctuary (OAWS), Achabal Conservation Reserve (ACR), and Rajparian Wildlife Sanctuary (RWS).

Predator	OAWS				ACR			RWS	Total
	Sheep	Cattle	Domestic Horses	Domestic Goats	Sheep	Cattle	Domestic Horses	Cattle	
Asiatic Black Bear	13	8	0	0	0	3	0	3	27
Leopard	23	0	8	2	13	12	2	0	60
Unknown	2	1	2	0	0	0	0	0	5
Total	38	9	10	2	13	15	2	3	92

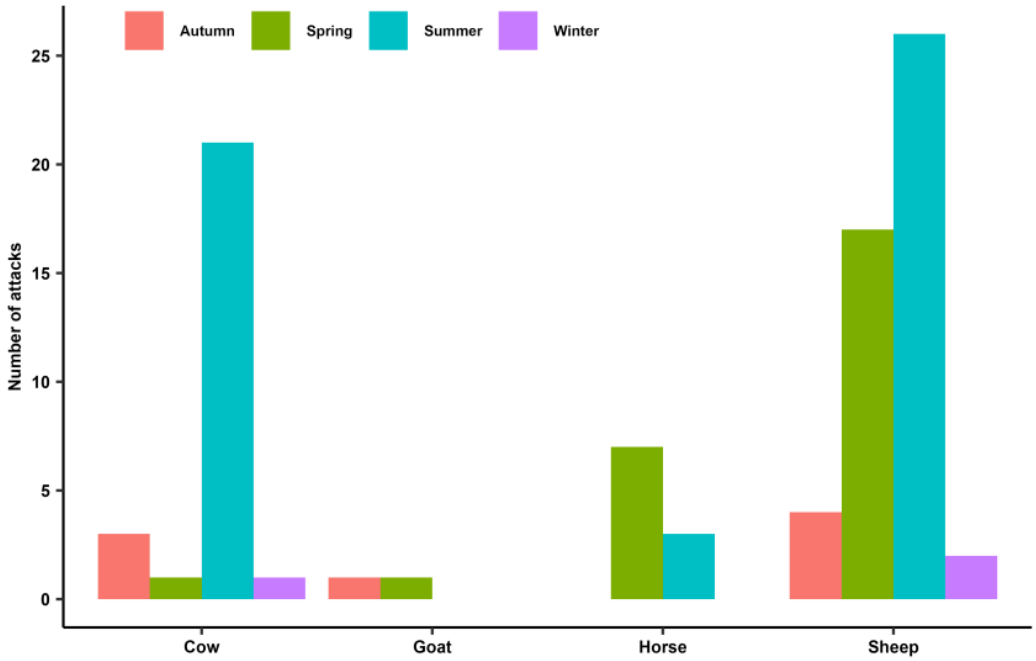

Figure 4. Livestock attacks by carnivores in different seasons across three protected areas.

DISCUSSION

Livestock predation was reported across all three surveyed protected areas, though cases in Rajparian Wildlife Sanctuary were minimal. This may be attributed to the proximity of Rajparian Wildlife Sanctuary to only one village, resulting in fewer livestock grazing inside the sanctuary. Additionally, a well-guarded sheep farm within the sanctuary possibly deterred predator movements in the area. Notably, no cases of livestock predation were reported in Aru and Mandlan villages in Overa-Aru Wildlife Sanctuary, and in Sahibabad, Jogigund, Khundroo, and Sombroona villages in Achabal Conservation Reserve. This suggests reduced predator activity in the Mandlan-Aru stretch of Overa-Aru Wildlife Sanctuary compared to the Khelan-Dahwatoo stretch, and, similarly, less activity in the Sahibabad-Sombroona stretch of Achabal Conservation Reserve. Most incidents were recorded in Andoo village in Achabal Conservation Reserve and Nala Overa in Overa-Aru Wildlife Sanctuary likely due to their proximity to forests, making them more vulnerable to predator incursions.

Sheep were the most frequently preyed upon livestock by both the Leopard and the Asiatic Black Bear. The Asiatic Black Bear primarily preyed on cattle, while the Leopard targeted Domestic Horse in addition to sheep. The preference for Sheep can be attributed to their optimal size, non-defensive behaviour, ease of killing, and high availability. Surplus killing, where multiple individuals are killed in a single attack, was observed primarily by the Leopard, a behaviour also documented in other studies (Sangay & Vernes 2008). This phenomenon contributed to the majority of kills during the study being attributed to the Leopard. The

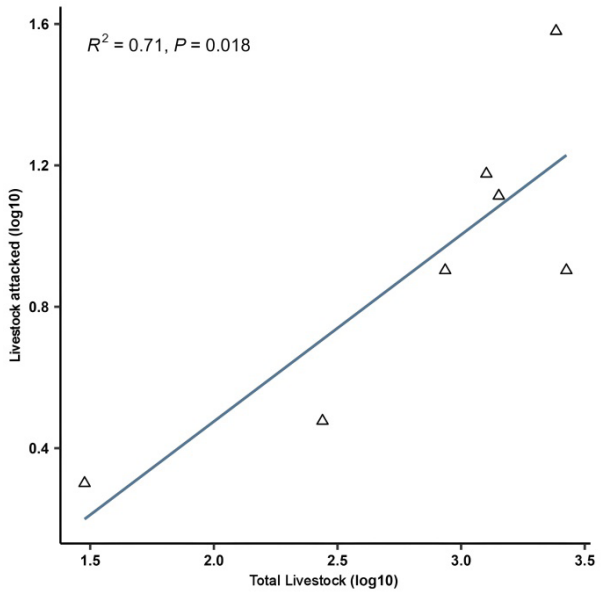

Figure 5. Linear regression illustrating the relationship between livestock attacks by Asiatic Black Bear and Leopard, and the total number of livestock present in three protected areas.

Leopard typically prefers prey species weighing 10–40 kg and 2–25 kg (Dhungana et al. 2019), while the Asiatic Black Bear has been reported to target all livestock species (Sangay & Vernes 2008; Jamtsho & Wangchuk 2016).

Both the Asiatic Black Bear and the Leopard were observed to attack livestock across various age groups, with a slight preference for the 4–6 age range. This age group might be more attractive due to the optimal size and vulnerability of the animals. A more detailed study with a larger dataset could provide clearer insights into age-related predation patterns.

Asiatic Black Bear attacks mostly occurred in the summer, followed by the autumn, with predation peaking in June and July. Most Leopard attacks were also reported in the summer, closely followed by the spring. No Asiatic Black Bear attacks were recorded during the winter, likely due to their inactivity in this season. In the summer, an abundance of forage in forests leads local communities to graze their livestock in these areas, increasing their vulnerability to predation (Akrim et al. 2023). Additionally, the peak cropping season keeps people busy, resulting in livestock being left unguarded and more susceptible to attacks (Sangay & Vernes 2008).

Livestock kills by both the Asiatic Black Bear and the Leopard were predominantly diurnal, with a smaller percentage occurring at night. This contrasts with results of similar studies conducted in Pakistan (Qamar et al. 2010) and India (Gujarat) (Mesaria et al. 2023), where Leopard attacks were mostly nocturnal. However, it aligns with findings from the Indian Himalayan Region, where livestock predation occurs more often during the day when livestock are taken for grazing and left unguarded (LeFlore et al. 2019; Naha et al. 2020).

Dense vegetation cover often leads to an increased risk of predation by large carnivores (Kolowski & Holekamp 2006; Beattie et al. 2020). We observed similar patterns in our study area, with the majority of Asiatic Black Bear and Leopard attacks occurring inside forests. While these incidents may not be classified as human-wildlife negative interaction (IUCN 2023), they still have a profound impact on the financial well-being of local residents, highlighting the need for focused attention and effective mitigation efforts. A significant proportion of Leopard attacks also occurred inside corrals, possibly due to its hunting behaviour and the multi-use nature of the landscape, which includes both forests and agricultural areas (Naha et al. 2020).

The perception of local people towards carnivores was generally positive, although a small portion advocated for their elimination. Given the hesitance of respondents to express their opinions more clearly, evidenced by 18% not suggesting any preventive measures, it can be inferred that more local people might hold this view. The negative attitude stems from substantial economic losses caused by livestock predation, which is especially significant for people from lower socioeconomic classes who depend on livestock for their sustenance, increasing the risk of retaliatory killings and posing a conservation concern.

Respondents suggested various mitigation measures, including translocation of predators, compensation for livestock losses, fencing of protected areas, and habitat restoration. While not all measures may be feasible, habitat restoration is particularly important as a healthy wild prey base can reduce conflicts (Khorozyan et al. 2015; Khan et al. 2018). A fair and speedy compensation scheme could minimize economic losses and support long-term wildlife conservation. Additionally, providing financial assistance to farmers for building better corrals and increased guarding of livestock, especially during summer, could significantly reduce predation rates (Le Flore et al. 2019; Akrim et al. 2023; Samelius et al. 2021; Ullah et al. 2024).

Authorities, in collaboration with local communities, should implement a comprehensive conflict management strategy to alleviate the financial burden on people living near protected areas and ensure the long-term conservation of wildlife.

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