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Cover: Life and death in one night - wolf hunting the hare. Mixed media—gouache, acrylics, pen & colour pencils. © Dupati Poojitha.

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ARTICLE

Negative interaction or coexistence? Livestock predation and conservation of wild carnivores in Kazinag National Park and adjacent region in the Kashmir Himalaya, India

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Abstract: Livestock predation by wild animals poses a significant challenge to communities residing in and around protected areas. This study aimed to assess the extent and patterns of livestock predation by Asiatic Black Bears and Leopards in villages around Kazinag National Park and adjoining areas: Limber Wildlife Sanctuary, Lachipora Wildlife Sanctuary, and Naganari Conservation Reserve, in Kashmir, India. Semi-structured questionnaire surveys and interviews conducted with residents and herders camping in the study area were used to collect data on livestock predation. A total of 72 livestock kills were documented for the years 2021 and 2022, involving Leopards and Black Bears. Statistical analysis revealed significant differences in predation patterns based on age class, livestock type, time & place of events, injury pattern, and body part affected. Sheep were most frequently targeted, with total economic loss estimated at >USD 15,000. Asiatic Black Bears primarily attacked at night and preferred cattle and sheep, while Leopards targeted goats and horses, peaking in summer and late autumn. The main factors influencing predation were grazing within the park and adjacent protected areas, and poorly constructed corrals. Mitigation strategies recommended include building robust corrals and designating specific grazing zones away from core wildlife habitats. The study emphasizes the need for comprehensive, context-specific approaches to ensure the long term human-wildlife coexistence in the region.

Keywords: Animal damage, Asiatic Black Bears, economic losses, leopards, livestock, management, predation, protected areas.

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Author contributions: UD—conducted fieldwork, collected data, performed formal analysis, curated data, and drafted the original manuscript. BAB—designed the study, supervised the research, provided resources, reviewed and edited the manuscript, and handled correspondence.

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INTRODUCTION

Human-wildlife negative interactions arise when the actions of wildlife have a negative impact on humans, or vice versa (Mekonen 2020). This conflict has serious consequences for both humans and wild animals, as well as the environment, by causing damage to crops, disturbance and destruction of habitats, predation on livestock, and killing of both wildlife and humans (Mekonen 2020; Merkebu & Yazezew 2021; Dwamena 2023). The perceived threats posed by wild animals to human economic assets like crops and livestock are considered a significant factor in the decline of many large mammalian species globally (Woodroffe et al. 2005; Pillai & Pillay 2016; Nyhus 2016). The establishment of protected areas (PAs) has played a crucial role in the conservation of wildlife (Ekka et al. 2022), yet these ecologically sensitive zones are facing increasing pressure from human-induced activities (Manral et al. 2016; Mengist 2020; Akrim et al. 2021).

The PAs are expected to achieve diverse conservation, social, and economic objectives (Job et al. 2020; Mengist 2020). However, increased livestock predation within these areas has a major negative impact on their perceived benefits (Parker et al. 2022; Lamichhane et al. 2023). Livestock predation is a significant issue in the PAs (Kuiper et al. 2021) due to shared resources between humans, livestock, and wild animals (Shrestha et al. 2022). Communities residing in and around PAs, often economically disadvantaged, depend on forests for sustenance (Mengist 2020; Gonçalves et al. 2022). Imposing restrictions without providing adequate benefits further strains their relationship with conservation efforts (Parker et al. 2022). Hence, ensuring viable alternatives for local communities is essential for effective conservation.

Big cats such as leopards and tigers in Asian countries are primarily responsible for the predation of livestock (Ramesh et al. 2020) but wolves, brown bears, and black bear also contribute substantially (Maheshwari & Sathyakumar 2020; Singh et al. 2024). The predation of livestock poses a substantial threat to the socio-economic fabric of agro-pastoral communities (Chinchilla et al. 2022). While large carnivores, humans, and livestock have coexisted for millennia, recent decades have witnessed an increase in human-wildlife conflicts (Woodroffe et al. 2005; Göttert & Starik 2022). This escalation is attributed to factors such as habitat fragmentation, human population expansion, diminished wild prey, and increased predator numbers due to the conservation laws (Alexander et al. 2016; Suryawanshi et al. 2017; Khanal et al. 2020).

Effective implementation of suitable mitigation measures is crucial for minimizing livestock predation and fostering coexistence between carnivores and agricultural communities. Mitigation approaches used globally, include eradicating or translocating the problem carnivore, zoning, aversive conditioning, shifting from small to large livestock, increasing wild prey availability, and employing livestock-guarding dogs and protective collars (Linnell et al. 2012; Chinchilla et al. 2022). Similarly, compensation for livestock losses due to predation is useful to increase public acceptance of predators (Ravenelle & Nyhus 2017), but may not always incentivize proactive conflict prevention (Braczkowski et al. 2020), and can be expensive and controversial. In contrast, incentive-based systems and insurance programs can encourage producers to adopt more effective mitigation strategies while being economically sustainable (Jacobs & Main 2015; Badola et al. 2021).

The Himalayan subtropical pine forest region falls within a high human-wildlife interaction zone (Sharma et al. 2020). The northwestern Himalaya is a prominent example of an area where diverse wildlife populations coexist with human communities, leading to frequent conflicts (Singh et al. 2024). Therefore, it is essential to shift from human-wildlife negative interactions to coexistence, which requires an extensive understanding of the reasons and spatial factors of the conflicts (Kuiper et al. 2021). We conducted this study to understand the livestock predation in and around Kazinag National Park (KNP) in the Kashmir Himalaya due to black bear and leopard. The main objective of the study was to provide a clear understanding of the pattern, and ways to mitigate livestock predation for long term conservation planning in the region.

Study Area

The current study was conducted in the KNP and adjacent areas: Limber Wildlife Sanctuary (LiWS), Lachipora Wildlife Sanctuary (LaWS), and Naganari Conservation Reserve (NCR). The KNP is situated within an altitude range of 2,100–4,305 m and falls between 34.178–34.2646 ^{0}N & 73.9971–74.2397 ^{0}E. The LiWLS lies between 34.2064–34.2129 ^{0}N & 74.1818–74.1990 ^{0}E. LaWLS lies between 34.1414–34.2043 ^{0}N & 74.0205–74.1238 ^{0}E, and NCR lies between 34.2064–34.2129 ^{0}N & 74.1818–74.1990 ^{0}E. Established in 2007, KNP was formed by integrating the core regions of LiWS, LaWS, and NCR. The survey was conducted in 10 villages, five from LiWS (Bodrali, Babagayl, Limber, Choolan, Kharaad, and Suchen), three from NCR (Naganari, Muqam, and

Zehanpoora), and two from LaWS (Lachipoora-A and Lachipoora-B).

Located approximately 70 km away from Srinagar near the Line of Control, the KNP is characterized by dense forests. It serves as a habitat for the 'Near Threatened' Markhor *Capra falconeri* and spans an area of 89 km^2. The park boasts a rich biodiversity, hosting a variety of wildlife, including 20 mammal species and 120 bird species (Farooq et al. 2021). Notably, it is also home to the Western Tragopan *Tragopan melanocephalus*, an avian species classified as 'Vulnerable' by the International Union for Conservation of Nature (IUCN) Red List. Asiatic Black Bears *Ursus thibetanus* and Leopards *Panthera pardus* are often involved in conflict with humans in the adjacent landscape of the KNP.

METHODS

Data on livestock populations were obtained from the Animal/Sheep Husbandry Department of Jammu & Kashmir and village heads (Table 1). Data on livestock predation by the Asiatic Black Bear and the Leopard were collected from KNP, LiWLS, LaWLS, and NCR using semi-structured questionnaires, following the approach outlined by Dhungana et al. (2019). The chain-referral sampling method (Noy 2008; Akrim et al. 2023) was employed, wherein village heads initially provided information about predation incidents in their communities. Afterward, the owners of the affected livestock were interviewed using purposive non-probability sampling to gather detailed information. This included the species of livestock killed, the sex and age of the animal, the feeding pattern, the time and date of the incident, the predator responsible, and the geocoordinates of the predation site. The questionnaire was originally prepared in English, which was translated into the local languages, i.e., Kashmiri and Urdu, for understanding of the local population in the study area.

Where possible, information on livestock predation incidents was further cross-verified by other residents. Monthly visits to the village heads were carried out over a two-year period (January 2021 to December 2022) to document any new predation incidents. A total of 62 individuals were contacted during the study, out of which 42 provided complete responses. This targeted approach ensured that data were drawn from direct conflict incidents rather than general perceptions, which could introduce unrelated variables. Limiting the sample to directly impacted households mitigates potential study bias by focusing on genuine conflict cases.

We categorized livestock into specific age classes as follows: neonates (newborn to a few months old), juveniles (beyond the neonate stage but not yet fully grown), sub-adults (close to maturity), adults (fully mature), and pregnant females. Seasons were also categorized: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November). In order to analyse the temporal patterns of livestock predation, each incident was categorized based on the time of occurrence. The timing categories were defined as follows: morning (0500–1000 h), day (1000–1600 h), evening (1600–2100 h), and night (2100–0500 h).

The economic valuation of livestock losses was conducted using current local market prices from key markets in the Kazinag region, including Baramulla and various village-level markets (Supplementary Table 1). This valuation took into account the type of animal, along with its age and gender, to provide an accurate estimate of the financial impact on affected households. Notably, no substantial pricing variations were observed between the larger urban markets and the local village markets.

Data analysis

We conducted all the statistical analyses using the R software 4.2.2 (R Core Team 2022). Since the data was categorical, we used Pearson's chi-square test of independence to investigate statistical differences between the incidents of Asiatic Black Bears and Leopards with respect to (i) age classes; (ii) livestock type; (iii) months; (iv) place of event; (v) time of event; (vi) village; (vii) gender; (viii) injury pattern; (ix) feeding pattern; and (x) body part affected.

In addition to assessing statistical significance with the chi-square test, we examined over-represented and under-represented categories to gain deeper insights into the patterns of predation incidents. By comparing observed counts within each category combination (e.g., age class, livestock type, and time of event) to

Table 1. Total livestock holding across the study areas. (Source: Animal/Sheep Husbandry & Fisheries Department of Jammu & Kashmir and village heads).

Study area	Villages (n)	Sheep	Goat	Cattle	Horse
Limber Wildlife Sanctuary	6	2486	720	389	56
Lachipora Wildlife Sanctuary	2	1498	365	63	30
Naganari Conservation Reserve	3	997	381	377	16

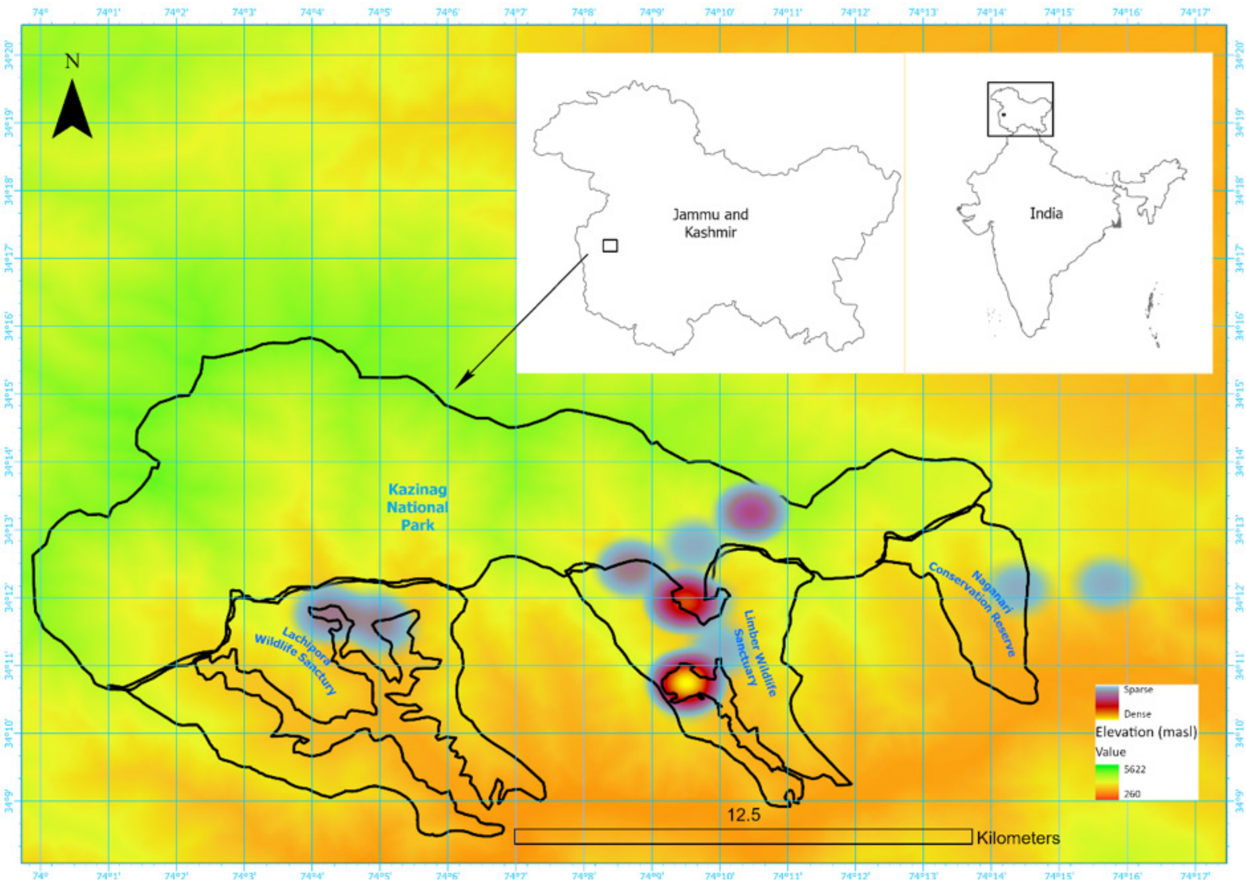

Figure 1. Study area showing livestock predation sites.

the expected counts, we identified specific scenarios where predation was higher or lower than anticipated. We expressed Pearson's residual scores as the degree of deviation between observed and expected counts using the "vcd 1.4-8" package (Meyer et al. 2020). This analysis is relevant as it highlights specific factors or conditions (such as certain livestock types or times of day) that may influence predator behaviour, aiding in identifying risk factors for livestock predation.

We conducted a regression analysis to examine the relationship between the number of animals predated as a dependent or response variable and several factors as independent or predictor variables, including the distance from human habitation, distance from the forest, the gender and age class of the predated animal, the season of the predation incident, and the time of the incident. For the regression models, we calculated the variance explained (i.e., $R_{adj.}^2$) and the associated statistical significance at P ≤0.05 level (i.e., 5% level of significance).

RESULTS

Livestock Types and Losses

Across the study area, four main types of livestock were reared: sheep, goat, cattle, and horse. During the study period, a total of 72 livestock kills in 42 incidents were documented in the villages surrounding KNP, with an equal number of cases attributed to Leopards (n = 36) and Asiatic Black Bears (n = 36). Notably, eight of these incidents involved mass killings, with each event resulting in the predation of 2–10 livestock in a single attack. The total economic loss due to these predation events was estimated at USD 15,887 over the two years.

Analysis of Predation Patterns

Significant differences (χ^2 = 31.89, df = 3, p <0.001) were observed in the types of livestock preyed upon by each predator species. Incidents involving Asiatic Black Bears were predominantly higher for cattle and sheep, whereas Leopard-related attacks were more frequent on goat and horse (Figure 2). Among different livestock types, sheep were the most frequently preyed upon, accounting for 45.83% of total kills by both predator species.

Further analysis showed that the age of livestock significantly influenced predation patterns (χ^2 = 13.16, df = 4, p = 0.015). Asiatic Black Bear attacks were disproportionately high among neonates, and pregnant females, while Leopard attacks were more common among juveniles, and sub-adults. Additionally, significant differences were observed in predation patterns across age classes within each livestock species killed by both predators (χ^2 = 31.8, df = 12, p = 0.012). For Cattle, both predators primarily targeted younger age groups, as well as pregnant females; sub-adults and adults were less frequently attacked. Predation on goat was mainly concentrated among sub-adults. Horses were more commonly targeted in sub-adult age group. In contrast, sheep experienced a higher incidence of predation among adults and pregnant females.

Seasonal and Temporal Patterns

The study found distinct seasonal trends in predation. Asiatic Black Bear attacks were more common in spring (97%), while Leopard attacks showed bimodal peaks during spring (44%) and summer (33%) (Figure 3). These seasonal differences were statistically significant (χ^2 = 24.38, df = 3, p <0.001).

Temporal variations were also observed, with most predation incidents (56.6%) occurring at night. Asiatic

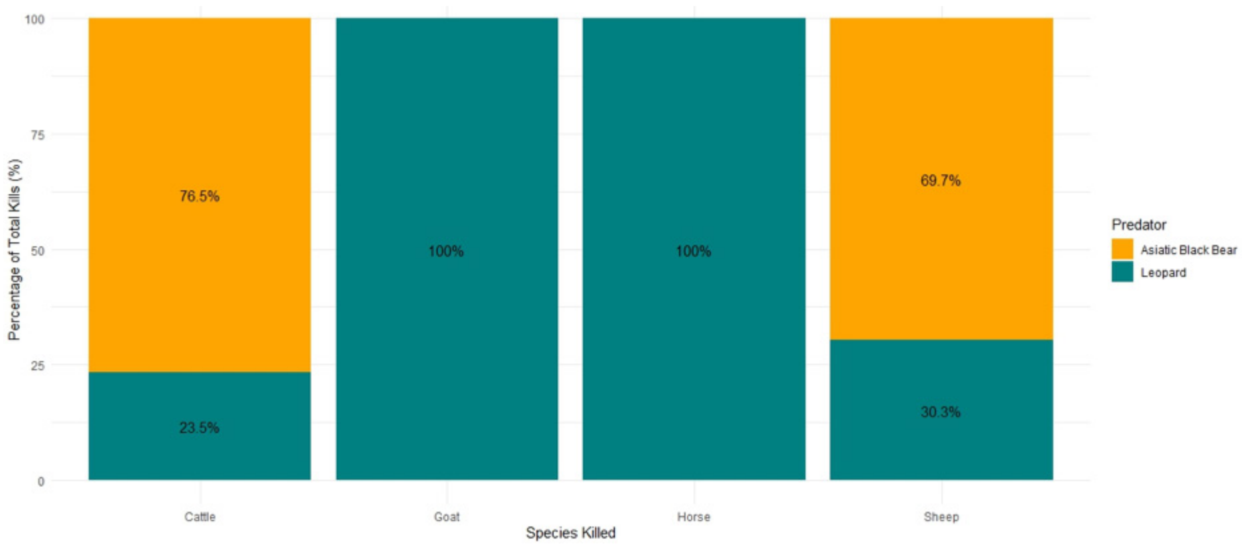

Figure 2. Livestock type killed by predators.

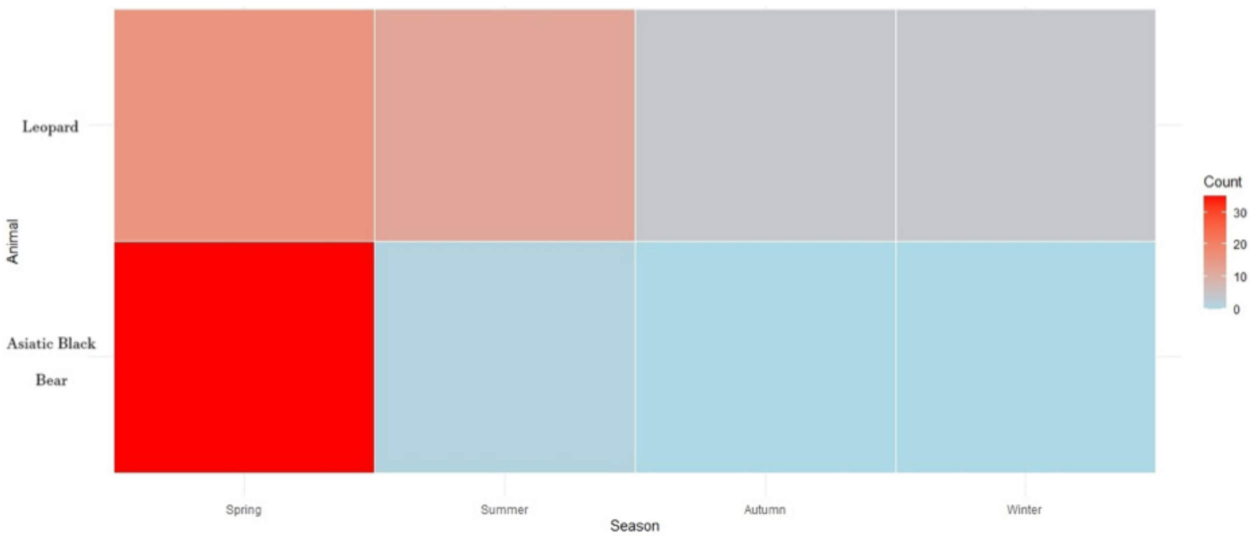

Figure 3. Livestock predation by the two large carnivores across different seasons in the study area.

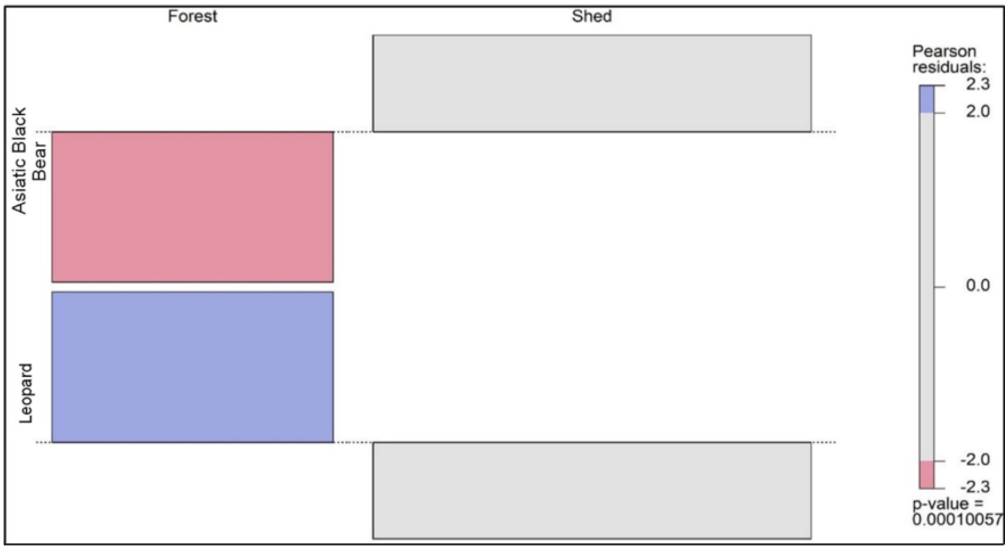

Figure 4. Pearson's residuals for the number of animals killed by the two predators against place of event.

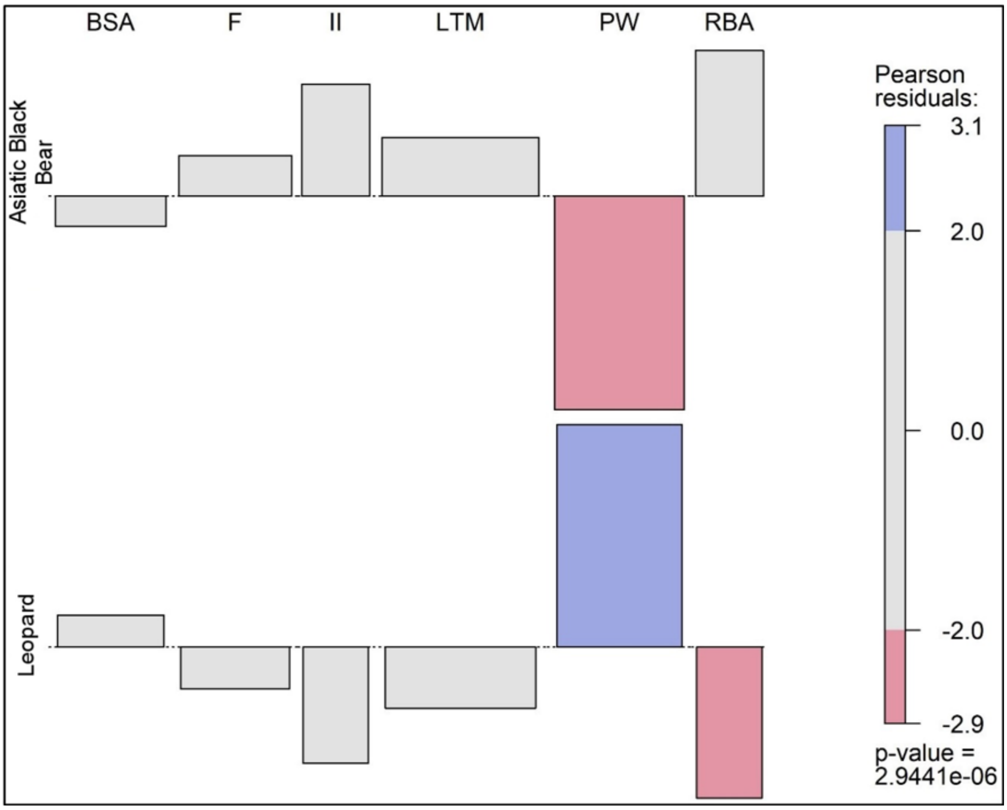

Figure 5. Pearson's residuals for the number of animals killed or injured by animal type against injury pattern. BSA—Bruises/Scratches/Abrasions | F—Fractures | II—Internal injuries | LTM—Lacerations/Torn Muscles | PW—Puncture wounds | RBA—Ripped Belly/Abdomen.

Black Bear attacks were predominantly nocturnal, while Leopard attacks occurred more often during the day (χ^2 = 16.7, df = 2, p <0.001).

Influence of Spatial Factors

The location of predation incidents also differed significantly (χ^2 = 13.18, df = 1, p <0.001) between the two predators: Asiatic Black Bear attacks were more

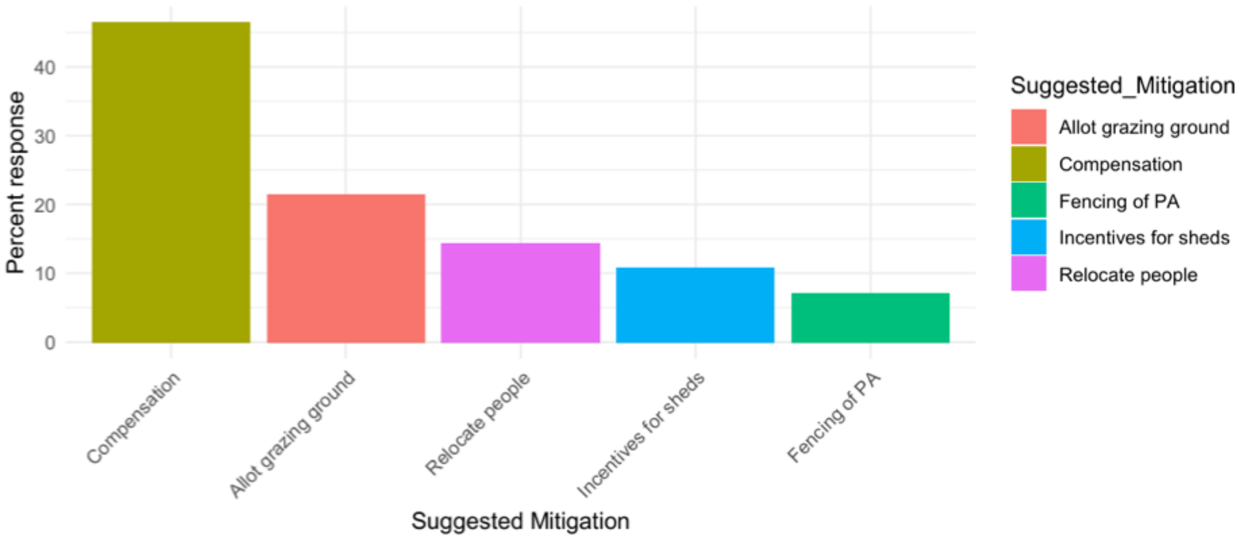

Figure 6. Suggested mitigation methods by respondents to alleviate livestock damage.

common in corrals or sheds during night-time, whereas Leopards were more likely to attack in forested areas during the day (Figure 4).

Determinants of Livestock Predation

The results of the Poisson regression model indicated several significant predictors influencing the number of livestock predated. The intercept ($\beta = -2.270$, $p = 0.079$) suggests a baseline level of predation when all predictors are at their reference levels. Among the categorical variables, the age class of livestock significantly affected predation rates. Juveniles ($\beta = 2.108$, $p = 0.007$), sub-adults ($\beta = 1.678$, $p = 0.029$), and adults ($\beta = 1.71$, $p = 0.026$) were more likely to be predated. Similarly, the month of incidence showed a significant effect, with predation events being higher during spring ($\beta = 1.66$, $p = 0.004$). Other variables, such as gender, time of incidence, and distance from habitation or forest, did not show statistically significant effects on predation. We also found a strong positive correlation between the total number of livestock held and the number of animals lost to predation ($r^2 = 0.72$, $p = 0.019$).

Patterns of Injury

The types of injuries inflicted by the two predator species showed significant difference ($\chi^2 = 33.54$, df = 5, $p < 0.001$). Asiatic Black Bear attacks were more likely to cause fractures, internal injuries, lacerations, and ripped abdomens, while Leopard attacks commonly resulted in bruises, scratches, abrasions, and puncture wounds (Figure 5). Further analysis of the body parts affected by these attacks showed that Asiatic Black Bears inflicted injuries mainly on the abdomen, flank, head, limbs, and underbelly, whereas Leopards targeted the face, groin, nape, neck, and spine ($\chi^2 = 52.83$, df = 13, $p < 0.001$).

Community-Recommended Mitigation Strategies

The majority of respondents (46.42%) advocated for the provision of ex-gratia as a primary measure to compensate livestock losses caused by wild animals (Figure 6). Other suggestions included allocating government-designated grazing grounds (21.42%), providing financial assistance for building better livestock sheds (10.71%), relocating communities from high-interaction zones (14.28%), and implementing fencing around protected areas (7.14%).

DISCUSSION

Our study highlighted substantial predation on livestock by Leopard and Asiatic Black Bear in villages around Kazinag National Park, with seasonal and spatial variations in attack patterns. These findings align with previous research on livestock predation by carnivores (Akrim et al. 2023; Singh et al. 2024), suggesting that carnivore preference for certain livestock types and predation timings are likely influenced by ecological and behavioral factors. Although, the overall incidence of livestock predation was relatively low, and randomly distributed in our study area. A few herders bore the brunt of the losses, leading to a domino effect that exacerbated the impact on their livelihoods. The reported economic loss of USD 15,887, in the two-year study period is substantial for the communities around KNP, who are primarily dependent on the livestock and/or agriculture. This substantial loss has driven many people in the study area to abandon livestock rearing, which has profound implications for local economies and traditional ways of life.

Our study found that sheep were primarily predated by both predators, similar with findings of Khan et al. (2018) in Pakistan from similar landscape. This high rate of predation is likely due to the large sheep population in the study villages, making them more readily available as prey. Leopards showed a clear preference for goats, hunting them more often than expected based on their availability. This behaviour is similar to findings by Dhungana et al. (2019) in Nepal, where Leopards were found to prefer prey within a weight range of 10–40 kg. Conversely, Asiatic Black Bears preyed upon all types of livestock, with no specific livestock preference, illustrating the opportunistic nature (Bowersock et al. 2021) of Asiatic Black Bear predation.

In ecosystems with diverse resources and pronounced seasonal changes, large carnivores frequently adopt opportunistic foraging strategies, adjusting their prey preferences and hunting behaviors with the seasons (Davidson et al. 2013). Consistent with this, our study observed significant seasonal variations in predation patterns, with Leopard attacks showing bimodal peaks in summer and spring. The seasonal variation of Leopard predation can be related to the grazing cycle in the study area which involves moving livestock to higher altitudes (behaks) from May to June, followed by partly attended or unattended livestock grazing in summer pastures (July to August), and free grazing in and around village forests from September to April. During summer, livestock grazing pushes natural prey of Leopards away (Khan et al. 2018), resulting in increased predation on livestock during these months.

The increased livestock killings by Asiatic Black Bear in spring can be attributed to lesser availability of natural food. Asiatic Black Bears rely on high-quality food throughout the year, consuming soft mast such as berries in summer and hard mast like nuts and acorns in autumn (Bowersock et al. 2021). In spring, the scarcity of these food sources may drive Asiatic Black Bears to seek alternative foods, such as livestock, to fill their nutritional gap (Malcolm et al. 2014). This dietary shift underscores the bears' adaptability to changing food availability and points to a heightened risk of human-wildlife conflicts during periods of food scarcity. These findings underscore the seasonal dynamics in livestock predation incidents, emphasizing the necessity of considering temporal trends when devising and implementing effective management and mitigation strategies for human-wildlife conflict.

Statistical analysis of spatial factors influencing livestock predation revealed distinct patterns between Asiatic Black Bears and Leopards. Asiatic Black Bears frequently attacked livestock housed in corrals during night-time, where confined spaces offer them a concentrated and easily accessible food source. As opportunistic feeders (Kozakai et al. 2020), Asiatic Black Bears readily exploit these enclosures, and insufficient night-time protection further increases the risk of predation. Night-time attacks in corrals often led to mass killings, severely impacting herders' livelihoods. Similar trends were observed by Samelius et al. (2021) in the Tost Mountains, South Gobi, Mongolia, where such incidents fostered negative attitudes towards conservation and sometimes led to retaliatory actions against wildlife. The prevalence of Asiatic Black Bear attacks at night underscores the importance of enhancing protective measures in corrals to mitigate economic losses and improve coexistence.

In contrast, Leopards showed a preference for forested environments, where they rely on stealth and camouflage to hunt. As solitary predators (Roex et al. 2022), Leopards use dense vegetation for concealment, allowing them to approach and ambush prey effectively, which aligns with their natural hunting strategies (Beattie et al. 2020). Leopard attacks were more frequent during the day, highlighting the importance of attended livestock grazing and regulated grazing in the forested areas to reduce predation risks.

The distinct injury patterns inflicted by Asiatic Black Bears and Leopards provide insight into each predator's hunting strategy and physical characteristics (Stirling & Derocher 1990; Pawar et al. 2018; Lin et al. 2020). Asiatic Black Bears caused more severe injuries, such as fractures and internal injuries, due to their larger size and powerful attacks. Leopards, in contrast, inflicted bruises, abrasions, and puncture wounds consistent with quick, immobilizing attacks aimed at disabling prey with minimal exertion, aligning with their ambush style (Pawar et al. 2018; Lin et al. 2020). These findings not only aid in identifying the predator responsible for attacks but also underscore the need for targeted veterinary interventions post-attack to improve livestock survival rates.

Ex-gratia compensation, suggested by nearly half of the respondents, has shown to mitigate negative attitudes by providing financial relief to affected communities (Braczkowski et al. 2020; Mekonen 2020).

However, compensation alone may not address the root causes of conflict; it is essential to couple financial support with preventive measures, such as secure corrals and designated grazing zones, to minimize predation. We identified two main factors responsible for livestock predation in the region: grazing within designated protected area boundaries and inadequately constructed corrals. Additionally, villages with larger livestock holdings were found to experience higher rates of predation, likely due to the increased availability of prey. Livestock rearing and agriculture are essential economic activities for local communities in the study area. Consequently, losses in these sectors affect not only the economic stability but also the mental and emotional well-being of these communities.

This study advocates for an integrated approach to mitigate livestock predation in the villages around KNP. Beyond financial compensation, effective conflict management requires preventive strategies tailored to the seasonal and spatial patterns identified in this study. Robust livestock enclosures, night-time monitoring, rotational grazing, and alternative grazing areas are recommended to reduce predation risks. Additionally, fostering community awareness on coexisting with wildlife and the ecological role of predators can contribute to long-term conservation goals.

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Supplementary Table 1. Market prices of livestock by species, age, and sex.

Species killed	Gender	Age (in years)	Market value
Cattle	F	1	18000
Cattle	F	1.5	20000
Cattle	F	2	25000
Cattle	F	3	70000
Cattle	F	4	70000
Cattle	F	5	65000
Cattle	F	6	60000
Cattle	F	7	50000
Cattle	F	8	45000
Cattle	M	0.4	5000
Cattle	M	0.5	5000
Cattle	M	1	15000
Cattle	M	2	25000
Cattle	M	3	35000
Cattle	M	4	45000
Cattle	M	5	45000
Cattle	M	6	40000
Cattle	M	7	40000
Cattle	M	8	30000
Goat	F	1	7500
Goat	F	2	8000
Goat	F	3	10000
Goat	F	4	8000
Goat	F	5	8000
Goat	F	6	7000
Goat	M	1`	7000
Goat	M	2	9000
Goat	M	3	12000
Goat	M	4	14000
Goat	M	5	11000
Goat	M	6	10000
Horse	M	1	20000
Horse	M	2	30000
Horse	M	3	45000
Horse	M	4	50000
Horse	M	5	55000
Horse	M	6	55000
Horse	M	7	55000
Horse	M	8	55000
Horse	M	9	55000
Horse	M	10	55000
Sheep	F	1	6000
Sheep	F	2	10000
Sheep	F	3	10000
Sheep	F	4	8000
Sheep	F	5	8000
Sheep	F	6	7000
Sheep	M	1	8000
Sheep	M	1.5	8000
Sheep	M	2	10000
Sheep	M	2.5	12000
Sheep	M	3	15000
Sheep	M	4	17000
Sheep	M	5	20000
Sheep	M	6	20000

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