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Research Article

An Emerging Issue of Human-Leopard Conflict in the Human-Dominated Landscape of Mid-Hills: A Case Study from Tanahun District of Nepal

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Information on the spatial and temporal patterns of losses caused by leopard (*Panthera pardus*) in terms of human attacks and livestock depredation in the human-dominated landscape of the mid-hills of Nepal is essential in formulating and implementing effective mitigation measures. This study aimed to assess the spatial and temporal patterns of leopard attacks on humans and livestock and the economic losses incurred by livestock depredation between 2015 and 2019 in the Bhanu municipality of Tanahun District. We adopted a household survey ($N = 110$), key informant ($N = 10$), and focus group discussion ($N = 4$) for this study. We purposively chose two conflict wards: 2 and 4, based on the severity of the attacks by the leopard. Within each ward, we selected the households randomly and conducted a semistructured questionnaire survey in September 2020. A total of 8 incidents of human attacks and 142 incidents of livestock depredation were recorded, with six human casualties in ward 2 and 1.45 incidents of livestock depredation per household in ward 4. The maximum attack was observed during 2019 both on humans ($n = 6$) and livestock ($n = 67$). Leopards mostly attacked children below 9 years, living within 200 m of the nearest forest edge, with the highest attack during the autumn months (62.5%). During the five years, leopard killed goats that represent 83.1% of total livestock loss categories. A significant difference was found in the frequency of attacks on livestock over the years ($\chi^2 = 87.60$, df = 4, and $P \leq 0.01$), months ($\chi^2 = 16.53$, df = 11, and $P = 0.12$), and time of day ($\chi^2 = 48.47$, df = 3, and $P \leq 0.001$) with the highest attack during the year 2019 (47.18%), July (14.08%), and daytime (42.96%), respectively. Households living nearer to the forest edge (<200 m) lost more livestock (72.54%). The monetary value of a total of 8142 USD (74 USD per household) was lost due to livestock depredation, with major monetary loss at a distance >400 m from the forest edge. We suggest adopting mitigation measures like predator-proof livestock corals while stall feeding and strengthening conscientious livestock herding practices during grazing, encouraging livestock insurance schemes, educating local communities about leopard behavior, caring for and protecting children intensively in the leopard attack sites, improving the prey base in the wild, and timely management of man-eater leopard to reduce the conflict in the study area and the country.

1. Introduction

Human-wildlife conflict (HWC) refers to interactions between humans and wildlife that cause negative impacts on human livelihoods, wildlife, and their environment [1, 2]. HWC often results from human encroachment or loss of natural habitats, leading to increased human-wildlife interactions from competition over shared resources [3–5].

These conflicts include human injury, death, livestock depredation, crop-raiding, property damage, and retaliatory killing of wildlife [6, 7]. Although such conflicts may involve any wild animal, there are more common with large carnivores due to their diet and overlapping home ranges with human settlements [8]. Among different HWC incidents, human casualties, and injuries, fear of wildlife attacks and livestock depredation is considered one of the most serious problems across the world [9–12]; resulting in reduced support of local communities for wildlife conservation [13]. HWC threatens the existence of wildlife as well as the livelihoods of people [14, 15]; hence, it is considered one of the major conservation challenges worldwide [16–19].

In Nepal, HWC cases have increased in recent years due to the large carnivores such as Tiger (*Panthera tigris*), common leopard (*Panthera pardus*), snow leopard (*Panthera uncia*), Asiatic black bear (*Ursus thibetanus*), brown bear (*Ursus arctos*), wolf (*Canis lupus*), and wild dog (*Lycaon pictus*) [13, 20]. According to Chetri et al. [20], about 585 livestock were killed by carnivores including common leopards during the years 2013 to 2014 in Manaslu Conservation Area (MCA) and Annapurna Conservation Area (ACA). Common leopard (or "leopard" throughout the text) and tiger were the two major predators of domestic livestock in Bardiya National Park [21] and Chitwan National Park (CNP) in Nepal [13]. During the years 2012–2016 in CNP, tiger, leopard, and sloth bear (*Melursus ursinus*) attacked 119, 36, and 147 people, respectively [13]. In addition, Baral et al. [22] reported leopard as the principal predator followed by the golden jackal (*Canis aureus*), jungle cat (*Felis chaus*), yellow-throated marten (*Martes flavigula*), and Asiatic black bear in the mid-hills of Nepal.

Leopard is one of the most prevalent carnivores [23], distributed throughout Southern Asia, India, and sub-Saharan Africa [24]. It is categorized as vulnerable by the IUCN (2016) due to >30% of its global population decline over three generations caused by habitat loss, hunting, prey depletion, and conflict with humans [25, 26]. This species preys on medium-sized ungulates (1–45 kg) [27, 28] and often lives in habitat edges near human settlements [25]. It prefers to mate in January and February, although it has no fixed breeding season [29]. Among the 14 recognized subspecies of leopard [30], *Panthera pardus pernigra* is found in Nepal [31]. Their habitat is greatly reduced from their original distribution [32]; however, their population is now increasing after the implementation of community forestry in the 1990s, which provided additional habitat for leopards [33, 34].

Human-leopard conflict (HLC) is one of Nepal's most frequently recorded serious human-carnivore conflicts [13, 32, 35]. It is directly affecting very poor local communities [10, 36–40]. An average of 25 people per year were killed by leopard from 1994 to 2004 [41], and 18 were killed and three injured between 2011 and 2014 in Baitadi District [42]. According to DNPWC [43], leopard was the principal predator for depredation on 78% of the livestock in Nepal. HLC results in the killing of leopards [10, 44], and also they are facing increasing risks of mortality [45]. Among the 51 dead leopards from 2006 to 2013 in Nepal, about 65% of them were killed by humans [46]. There is an increasing incidence of HLC, even in areas with no previously reported incidents [3, 33].

Leopard attacks livestock while grazing in the forest as well as inside human settlements, posing risks to human lives [47]. Six children were killed and 57 livestock were depredated by leopard in one and half years in Bhanu Municipality, Tanahun [48]. Due to increased instances of attacks, the District Administration Office (DAO), Tanahun, as per Section 9 (4) of the Local Administration Act (1971), had directed the locals to kill leopards if they enter human settlements [49]. All the damages stated above are evident in the study area, but no research related to such conflict issues has been conducted to date. The major objectives of our study were: (a) identify the spatial and temporal patterns of livestock depredation and human casualties between 2015 and 2019 in the Bhanu municipality of Tanahun District and (b) quantify the economic loss faced by households due to livestock depredation. Further, this study tried to answer research questions: (a) When and where the livestock and human attack incidents occurred in recent years? (b) How does the economic loss vary accordingly to spatial location, time, and livestock categories? These research outputs will support concerned authorities in designing and implementing effective mitigation measures and safeguarding the livestock of inhabitants, particularly residing nearby the forest.

2. Materials and Methods

2.1. Study Area. The study was conducted in the Bhanu municipality, where the attack of leopard on humans and livestock was frequently reported (Figure 1). It lies in the northern part of the Tanahun District of Gandaki Province, Nepal, with latitude and longitude of 28°01′12.3″N and 84°25′25.4″E, respectively; comprising a total population of 6298 within 1800 households [50]. Most of the people are involved in agriculture—crop cultivation and livestock farming for their major sources of income. The livestock rearing practice mainly involves stall feeding within the livestock shed, while seasonally grazing in the private farmland during the winter months after harvesting crops. Sal (*Shorea robusta*), Chilaune (*Schima wallichii*), and Katus (*Castanopsis indica*) are the major plant species in this area. common leopard, Asiatic black bear, rhesus monkey (*Macaca mulatta*), barking deer (*Muntiacus muntjak*), porcupine (*Hystrix brachyuran*), golden jackal and so on are the major fauna species found in this area.

2.2. Data Collection. A preliminary survey was carried out to know the general information and existing situation of leopard-related incidents in the study area before the actual data collection. First, we conducted a focus group discussion including staff of the Division Forest Office (DFO), the municipality, the Federation of Community Forestry Users Nepal, local elites, and women to identify the human-leopard conflict hotspot in the Tanahun District. We recorded the registered lists of conflict incidents in DFO from 2015 to 2019 and selected wards no. 2 and 4 for our

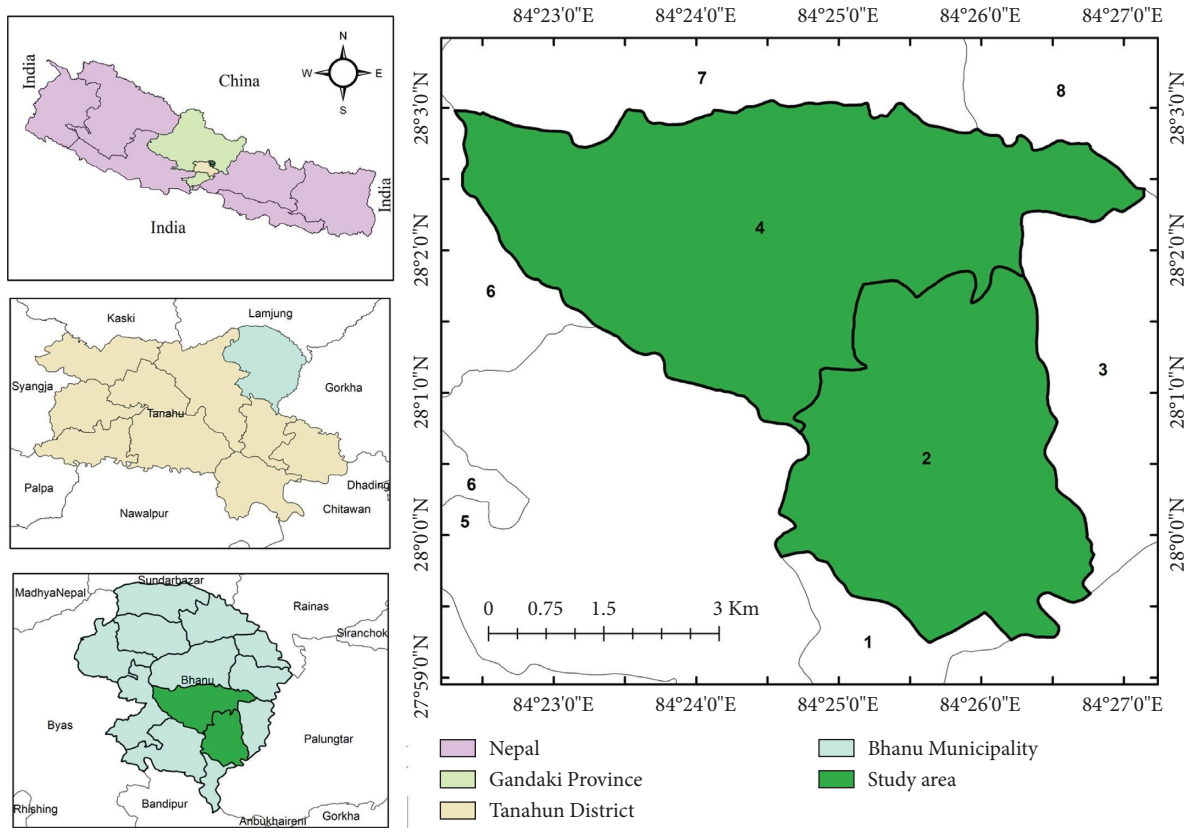

Figure 1: Map of the study area (wards no 2 and 4 of Bhanu municipality, Tanahun, Nepal).

study based on the higher number of leopard attack incidents (Figure 1). The "ward" refers to the smallest administrative unit of local government in Nepal. The actual field study was conducted in September 2020. Since the socioeconomic characteristics (economic well-being and livelihood strategies) of the households were not much diverse; therefore, we randomly selected only 110 households ($n = 55$ from each ward) out of 1800 households following the method suggested by Koirala et al. [35] and Baral et al. [22] for the questionnaire survey. We assume that the selected households are not spatially correlated and could represent the different extent of human-leopard conflict in the study area. We used both structured and semistructured questionnaires that were divided into two major sections. The first section included the demographic and livestock status of respondents, including the value of livestock owned. While the second part contained incident details such as time and place of attack, frequency of attack, severity of human and livestock attack (casualty/injury), category of livestock depredation, and economic losses incurred based on the monetary value of different categories of livestock. Similarly, a separate checklist with open-ended questions was prepared to aid in providing additional information on the existing situation as well as the past five-year trend (2015–19) of livestock depredation and human casualties by a leopard, and the status of livestock holdings, and the retaliatory killing of leopard. We selected 10 key local stakeholders who were familiar with the leopard attack incidents within the study area. The representatives from local bodies include; Division Forest Officer ($n = 1$), rangers ($n = 3$), local political leaders ($n = 2$), elites ($n = 2$), and the secretary of each ward ($n = 2$). In addition, four focus group discussions ($n = 2$ in each ward) were carried out each consisting of leopard attacked victims ($n = 10$), executive members of Community Forest User Groups ($n = 2$), and ward members ($n = 2$) to supplement and validate the information obtained from key informant interviews and household surveys. Each focus group discussion was performed for about 3 hours. Information about the general trend of the leopard conflict, the consequences of the attacks on the victims' livelihood those of and their family members, and the economic loss incurred from livestock depredation were discussed and recorded through the memory recall method. This method assumes that the respondents could reproduce precise information [35]. Further, incident sites were identified by the participatory method including local people. GPS coordinates for each incident site were taken, and the distance to a water source, forest, settlements, and road was calculated from ArcGIS 10.8 for spatial analysis of conflict data. The condition of livestock sheds in the affected households was also thoroughly observed.

2.3. Data Analysis. MS Excel 2016 and Statistical Package for Social Sciences [51] were used to analyze data. Descriptive statistics such as mean, percentage, frequency, and cross-tabulation were used to interpret the result. Further, we classified livestock depredation by leopard into 5 categories:

goat, buffalo, cattle, chicken, and pig, since these livestock were the major financial source for their livelihoods at the household level. Although other pets like dogs and cats were also attacked, they did not contribute to the household economy in rural settings: we did not consider them for this study. The chi-square tests of independence were applied to compare the frequency of livestock attacks by a leopard with time (year, month, and time of day), location (house, farmland, or forest), and distance from the forest at a 5% level of significance. Further, we categorized the months; Dec–Feb, Mar–May, June–Aug, and Sept–Nov as winter, spring, summer, and autumn seasons, respectively. Similarly, we divided the 24 hours of the day into 4 equal classes (time of day): morning (4 am–10 am), day (10 am–4 pm), evening (4 pm–10 pm), and night (10 pm–4 am) for a relative comparison of attack risks. In addition, the relative risk of livestock depredation was calculated for different categories of livestock concerning the numbers owned by the household in the study area. We did not account for retaliatory killings of leopard and further analysis as there were no official records of such event in the Divisional Forest Office.

2.3.1. The Monetary Value of Livestock. The existing market value of all types of livestock was estimated by interviewing villagers and local livestock traders. It was found that the average value for each category of livestock is similar in both wards of Bhanu municipality through consultation with respondents. The local selling prices were considered for an individual animal. The rate of each category of animal was fixed as a goat (weight and sex), cattle and buffalo (age or milking or not), and pig and chicken (weight) (Table 1). During the survey, each respondent was asked to provide the sex, weight, age, and condition (milking or not) of particular depredated livestock, which was verified through the records kept at DFO and the respective ward office. Finally, we converted all the monetary value into USD (1 NRS = 0.0086 USD).

Table 1: Monetary value of different types of livestock.

Livestock category	Rate (USD)
Goat (male)	6.85 per kg
Goat (female)	4.28 per kg
Cattle (milked)	128 per individual
Cattle (male)	74.34–92 per individual
Young cattle	25.68–42 per individual
Buffalo (milked)	428–770 per individual
Buffalo (male)	96–110 per individual
Young buffalo	42.80–128 per individual
Chicken	6.85–8.56 per kg
Pig	3–3.42 per kg

3. Results

3.1. Current Status of Livestock Holding. One hundred and ten households of these two wards owned 2630 livestock individuals, including goats, cows, buffalo, chickens, and pigs. The chicken was the most common (63.33%; $n = 1665$) of total livestock, followed by goat (28.82%; $n = 758$), buffalo (3.22%; $n = 85$), cattle (3%; $n = 79$), and pig (1.63%; $n = 43$). The number of livestock held per ward was higher in ward no. 2 ($n = 1462$, average per household = 26.58) than in ward no. 4 ($n = 1168$, average = 21.23) (Table 2).

3.2. The Pattern of Human Casualties

3.2.1. Extent and Nature of Human Casualties. A total of eight incidents occurred during 2015–2019, out of which, half of the cases resulted in death and half were of minor injury (Table 3). Five of the eight victims were male and three female, with six of the victims being children <9 years old. In half of the eight cases, attacks occurred when the person was by themselves. This appeared to be a strong indicator of whether the person was killed or not (3/4 attacks on lone people resulted in death, while 1/4 attacks on people accompanied by friends resulted in death (Table 3).

3.2.2. Spatiotemporal Attacks on Human. Out of the total attacks, 7/8 of attacks occurred in ward no. 2 and the rest in ward no. 4. Similarly, 7/8 of cases happened in and near home and the remained on the village road (1/8). All of the attacks occurred within 200 m distance from the forest edge.

During the five years from 2015 to 2019, the maximum number of cases ($n = 6$) happened in 2019, followed by 2018 ($n = 2$) with no attacks in 2015, 2016, and 2017. The highest number of attacks took place in October ($n = 3$), followed by November ($n = 2$), June ($n = 1$), July ($n = 1$), and August ($n = 1$). Similarly, most of the attacks (87.5%) occurred in the evening and 12.5% during the morning.

3.3. The Pattern of Livestock Losses

3.3.1. Extent and Nature of Livestock Losses. Out of 110 households, 73 (66.4%) lost one or more types of livestock between 2015 and 2019. Leopards killed a total of 142 individuals of livestock, including goats, pigs, cattle, and chickens. Ward no. 4 had more livestock losses (80 individuals) than Ward no. 2 (62 individuals). Leopards primarily killed goats (83.1%), followed by chickens (10.6%), cattle (4.2%), and pigs (2.1%) (Table 4). Livestock losses to leopards varied significantly among species ($\chi^2 = 357.78$, df = 5, and P value <0.05).

3.3.2. Spatial Pattern. A relatively high proportion of livestock predation was reported from ward no. 4, with an average of 1.45 livestock heads per household than ward no. 2 (1.13 livestock/household) (Table 4). According to respondents (victims), more than half of the livestock depredation by leopard (55.63%) was caused inside the livestock shed in the last five years period (Table 5). There were marked distance effects in depredation ($\chi^2 = 14.11$, df = 3, and $P = 0.002$) with maximum killings of about 72.54% of the livestock occurring at a distance of 0–200 m from the nearest forest, followed by 20–400 m (23.24%), and above 400 m (4.23%) (Figure 2).

Table 2: Current status of livestock holding per ward.

Type of livestock	Ward no. 2		Ward no. 4	
	Total individuals	Average/household	Total individuals	Average/household
Goat	367	6.67	391	7.11
Buffalo	39	0.71	46	0.83
Cattle	35	0.64	44	0.8
Chicken	1005	18.27	660	12
Pig	16	0.29	27	0.49
Total	1462	26.58	1168	21.23

Table 3: Injury severity of attacks by sociodemographic characteristics of victims.

Factors	Minor	Serious	Death	Total
Gender				
(i) Male	3	—	2	5
(ii) Female	1	—	2	3
Age categories (years)				
(i) Minor (below 9)	4	—	2	
(ii) Teen (10–17)	2	—	—	
(iii) Adult (18–59)	—	—	—	
(iv) Senior (above 60)	—	—	—	
Social association				
(i) Alone	1	—	3	
(ii) With friends	3	—	1	
Activity during attack				
(i) House working/sleeping/playing	7	—	3	
(ii) Farming	—	—	—	
(iii) Grazing the livestock	—	—	—	
(iv) Collecting resources	—	—	—	
(v) On the road/walking trail	1	—	—	
(vi) Fishing	—	—	—	

Table 4: Number and percentage of livestock loss during the five years (2015–2019).

Ward no	No. of households	Goat	Buffalo	Cattle	Chicken	Pig	Total	Average/household
2 (livestock owned)	55	367	39	35	1005	16	1462	26.58
2 (livestock depredated)		52	0	2	7	1	62	1.13
Relative risk		14.17	0	5.71	0.7	6.25	4.24	
4 (livestock owned)	55	391	46	44	660	27	1168	21.23
4 (livestock depredated)		66	0	4	8	2	80	1.45
Relative risk		16.88	0	9.09	1.21	7.41	6.85	
Total	110	118	0	6	15	3	142	1.29
%		83.1	0	4.2	10.6	2.1	100	

Table 5: Depredation location of different categories of livestock during the study period.

Livestock type	Incident sites		
	Livestock shed	Farmland	Forest
Goat	59	29	30
Cattle	2	4	0
Buffalo	0	0	0
Chicken	15	0	0
Pig	3	0	0
Total	79	33	30

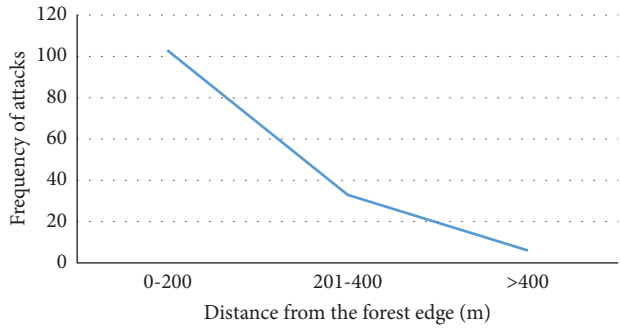

Figure 2: Number of livestock killed by leopards concerning distance from the forest.

3.3.3. Temporal Pattern. The extent of livestock losses varied from year to year. On average, leopards killed 28.4 livestock heads per year during 2015–2019. Our result showed an increasing trend of livestock depredation from 2016–2019 ($\chi^2 = 87.60$, df = 4, and $P \leq 0.01$). The number of livestock kills dropped from 2015 ($n = 22$) to 2017 ($n = 14$), then again increased and peaked in 2019 ($n = 67$) (Table 6). Similarly, the highest depredation on livestock was found in July ($n = 20$), followed by June ($n = 16$), and the lowest in January ($n = 6$) (Figure 3). Although some fluctuations were observed, we could not find any significant differences between the frequency of livestock depredation over the months ($\chi^2 = 16.53$, df = 11, and $P = 0.12$). The highest livestock depredation events were found to have occurred during the daytime (42.96%) followed by nighttime (32.39%) (Figure 4). Likewise, there was a significant effect of time of day on the frequency of attacks ($\chi^2 = 48.47$, df = 3, and $P \leq 0.001$).

3.4. Economic Loss from Livestock Depredation. Overall, livestock depredation by leopard resulted in a total economic loss of USD 8142 (USD 1628 average/year) during the study. The average economic loss per household due to livestock depredation was USD 73 from 2015 to 2019. The majority of losses was incurred by goat depredation (89.42%), followed by cattle (5.59%), chickens (2.93%), and pigs (2.06%). The annual overall depredation was highest in the year 2019, with the highest economic loss of USD 3605; whereas, it was lowest in the year 2016. The mean monetary loss in the last five years in ward no. 4 is equal to USD 4551 (USD 83 average/household), while it is USD 3522 (USD 64 average per household) in ward no. 2 (Table 7). The economic loss was higher near the forest area than in the area far from the forest. The mean economic loss of households located within 200 m of the forest (USD 91) was higher in comparison to those far away from the forest (Table 8). About half a percentage of economic losses occurred in corral, followed by forest (23.03%) and farmland (23.03%) (Table 9).

4. Discussion

Leopard is one of the most feared species that causes the highest number of human mortalities in Gandaki Province. Our study reveals that children were the most common victims of human casualties in the study area, comprising 75% of all cases. Similar results have been reported by Athreya et al. [9] in Maharashtra of India. While attacking human, leopard shows a waiting nature and whenever it gets the best opportunity, it attacks and kills human [52]. Thus, the cases of human attacks when alone were more than those accompanied by friends in our study area.

In context to the wards, the proportion of livestock depredation reported from ward no. 4 was relatively high with an average of 1.45 livestock heads per household than ward no. 2 which has more livestock. This shows high susceptibility of ward no. 4 to leopard attacks than ward 2 and the reason could be the higher coverage of the nearby community forest which might have supported the larger population of leopard; therefore, the frequency of attacks might have been increased. However, a detailed field survey using standard scientific protocol should be performed to prove this assumption. After the successful drive of the community forestry program in the mid-hills of Nepal, it can be argued that leopards have increased in these habitats [11]. Most forest patches of the mid-hills are close to human settlements [53], and studies have shown that leopards can live in human-dominated landscapes [10, 54], and human-leopard conflict is mostly induced by the depletion of natural prey populations, the lack of water and poor livestock herding and guarding practices [10].

Although chickens were the major livestock category comprising nearly 75% of total livestock, leopard attacked majorly on goats which only shared one-fourth portion of the total livestock categories. This event alone comprises 89.42% of the total loss which is similar to the findings of Rahalkar [55] who also accounted for 80% of depredation in goats as a result of the leopard attack. This may be due to the preference for smaller-sized hoofed animals such as goats, sheep, and calves by leopards [56]. Goat belongs to the preferred prey size range (25–50 kg) for leopard as a result they can be killed and dragged to a safe place easily [10, 35, 57]. Further, goats in our study were typically free-ranging, and attacks on free-ranging livestock by large carnivores are more common [58, 59]. This is similar to the findings of Kabir et al. [10] who have reported goats as the most depredated livestock species even when it was the second most abundant livestock. Research carried out in the Pokhara Valley by Adhikari et al. [60] and the buffer zone of Chitwan National Park by Lamichhane et al. [13] and Dhungana et al. [34] also reflected goats as the major

Table 6: Number of livestock losses for each category of livestock during the study period.

Year	Livestock type					
	Goat	Cattle	Buffalo	Chicken	Pig	Total
2015	21	0	0	0	1	22
2016	10	1	0	0	0	11
2017	13	1	0	0	0	14
2018	22	1	0	5	0	28
2019	52	3	0	10	2	67
Total	118	6	0	15	3	142

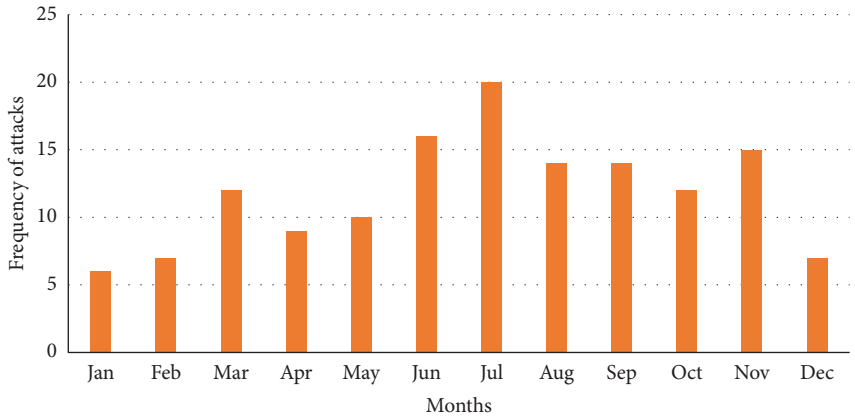

Figure 3: Monthly pattern of livestock loss.

depredated livestock. Over the 5 years (2015–2019) in this study, there was some evidence that human-leopard conflict might be increasing with the highest level being recorded in 2019. However, without additional data in the time series, it is impossible to be sure if this reflects a real trend or a single-year effect restricted to 2019. Moreover, particular historical events such as huge hail storms and post-earthquake were also taken as references for capturing the information on real incidents of leopard attacks in a particular year through the memory recall method [35]. And also, this increment might be due to the greater resilience and adaptability of leopards in comparison to other carnivores which allow them to survive in human-dominated landscapes [10]. Koirala et al. [35] and Ghimirey [31] also reported the increasing damage trend by leopard in the ACA even after the establishment of the Annapurna Conservation Area Project (ACAP) office. Likewise, studies of human-carnivore conflict conducted in Bhutan and Pakistan also reported leopards to be the main predator of livestock [57, 61].

In addition, the highest depredation on livestock by leopard in terms of the month was found in July, followed by June and November. In another study by Lamichhane et al. [13] in the buffer zone of Chitwan National Park, the highest livestock depredation by leopard was reported in December, followed by June and November. During the summer months, people make their movement in the forest and pasture land for livestock grazing, where they lack well-structured shelters for their livestock, and also, they graze their livestock there for a long period making them more vulnerable to leopards [10]. Thus, leopard kills on livestock become maximum during the daytime in our study area. Similar to our study, Dar et al. [57] in Machiara National Park also found a majority of livestock depredation due to leopards during the summer months. It is because, in the winter months, the leopard has enough prey species in its natural habitat due to less disturbance by local villagers, so, they might not enter into a human settlement in search of food. Similarly, Sijapati et al. [62]; reported the highest livestock depredations during summer and spring in the eastern and western areas of Bardiya National Park. It is because livestock was kept inside small-sized low-wall corals during winter to shelter them from cold weather. This constrained their movements and further accelerated the likelihood of livestock depredation when confronted by leopards. However, another research by Consolee et al. [63] in the natural reserve of China showed the highest livestock depredation by leopards during spring, followed by summer, autumn, and winter, respectively. This is likely because, in spring, the ice melts favoring the growth of grass; as a result, the livestock roams around the reserve looking for green pasture. In the same way, the resident ungulates also disperse to pastoral lands outside protected areas where most livestock are found due to actively growing grasses, and together with reduced wild prey base and large home ranges, predators are turned towards livestock. In contrast to our study, Koirala et al. [35] reported the highest depredation during the winter months followed by spring and summer in ACA of Nepal. This is because people along with their livestock migrate from high altitudes to the lower region to avoid the extreme cold and on the way; they get attacked by the

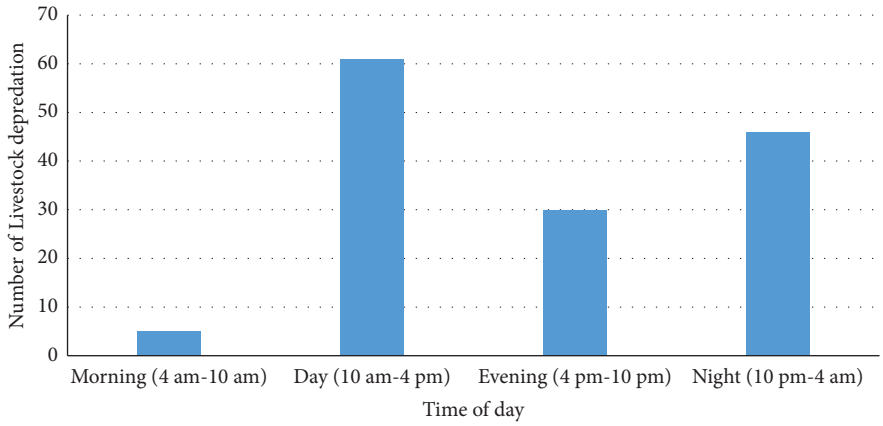

Figure 4: Number of livestock depredation during the time of day.

Table 7: Monetary loss (USD) per species during the five years.

Year	Goat	Cattle	Buffalo	Chicken	Pig	Total	Average monetary loss/household
2015	1513.60	0	0	0	86	1599.60	
2016	516.00	86.00	0	0	0	602.00	
2017	722.40	86.00	0	0	0	808.4	
2018	1324.40	129.00	0	73.10	0	1526.50	
2019	3203.50	154.80	0	165.12	81.70	3605.12	
Total	7279.90	455.80	0	238.22	167.70	8142	
%	89.42	5.59	0	2.93	2.06		
Ward no							
2	3384.1	68.8	0	124.7	12.9	3522	64.03
4	3895.8	387	0	113.52	154.8	4551	82.75

Table 8: Economic loss (USD) in relation to forest distance.

Forest distance category (m)	Total no. of incidents occurred in mentioned category	No. and category of livestock depredated	Mean	Minimum	Maximum	Total (USD)
0–200	103	Goat (83) Cow (6) Buffalo (0) Chicken (12) Pig (2)	59.09	17.2	567.6	6086.22
201–400	33	Goat (29) Cow (0) Buffalo (0) Chicken (3) Pig (1)	49.25	12.9	412.8	1625.4
>400	6	Goat (6) Cow (0) Buffalo (0) Chicken (0) Pig (0)	71.67	34.4	129	430
Total	142					

leopard, particularly in the pastures where livestock are often left unguarded. The carnivores are assumed to kill ungulates more frequently in winter due to harsh environmental conditions which cause ungulates to congregate [64, 65].

Most of the daytime attacks occurred in the grazing land when the livestock are left unattended to graze while their owners engaged with other work. However, Ahmed et al. [66] found nighttime to be the best for the leopard to attack livestock. The study further showed depredation of more than half of the livestock inside the livestock shed which suggests the need for better husbandry practices with predator-proof livestock corrals. The most killing of

Table 9: Economic loss (USD) in different places over five years.

Year	Total number of attacks incidents in			Monetary loss incurred		
	Corals	Farmland	Forest	Coral/ home	Farmland	Forest
2015	10	5	7	739.6	326.8	533.2
2016	3	5	3	172	344	86
2017	6	2	6	309.6	111.8	387
2018	19	5	4	881.5	369.8	275.2
2019	41	16	10	2168.92	911.6	524.6
Total	79	33	30	3796.9	1677	1806
%	55.63	23.24	21.13	52.16	23.04	24.81

livestock is reported at a distance of 200 m from the forest as the open and pasture land which is preferred by livestock for grazing, which is close to the forest.

Our study has shown an economic loss of USD 73.39 per household. A study by Consolee et al. [63] in Tieqiaoshan Provincial Nature Reserve of China has estimated the mean annual economic loss to range from USD 706.58–1413.17 per person. This loss is comparatively higher as compared to our study as the primary source of income of local people in and around this reserve was cattle keeping, accounting for about 57.1% of total income. Another study by Koirala et al. [35] in the ACAP area reported an economic loss of about USD 130 from the leopard. Further, in Trans-Himalaya of Ladakh, Namgail et al. [67] estimated an annual monetary loss of USD 190/household/year from livestock depredation, particularly of valuable livestock such as yak and horse, by Tibetan wolf, snow leopard, and lynx. Distance from forest or wildlife habitat is considered an important determinant of predator attacks on livestock [68] and the intensity of the economic loss [12]. Our results showed that the majority of the leopard attack incidents were within 0–200 m distance from the forest edge, with an average economic loss of 59 USD. Results from Bardiya National Park and Waza National Park, Cameroon also reported that the probability of an attack increases significantly from a closer distance to a core area [69, 70], which supports our study. In addition, Adhikari et al. [12] reported a significant amount of economic loss near forest edge (0–500 m) due to livestock depredation. In contract, our study showed that the economic loss is significantly high when the distance to the forest edge is >400 m; the reason could be the predation of only goat species which has high monetary value in response to other distance categories where livestock with low monetary value was also killed. Our result also showed that the majority of the livestock attack incidents were in corals, with an estimate of monetary loss equivalent to 3796 USD, followed by farm land. This finding is similar to that reported by Upadhyaya et al. [68], who also accounted for the most livestock attacks in corals.

This study reflects the scenario of human-leopard conflict that has been rising in recent years by putting humans and livestock at risk. This problem is common in other areas of the country, and no effective interventions have solved the situation yet. Although this is one of the case studies of the human-leopard conflict from the mid-hill region of Nepal, the findings are applicable for the concerned government authorities and managers to address the issues of leopard attacks on humans and livestock in other regions of the country. However, a detailed long-term study including several years and large spatial coverage is needed for predicting the conflict hotspots (risk zones) across the hilly region of the country. Further, a detailed scientific study on the prey abundance and other habitat parameters of the leopard, including its behavioral ecology is required to supplement lacking information and promote effective management of human-leopard conflict.

5. Conclusion

Based on our results, we can conclude that leopards primarily attacked goats, although chickens were the major livestock. The frequency of attacks on livestock was high in the daytime and summer months. Also, the attack on the human during being alone was higher than being with friends. Although the risk of wildlife attacks may not be eliminated, efforts must be directed toward minimizing them to a level that people can accept. Hence, we suggest making loud sounds, displaying flashing lights during the night, and constructing predatory-proof corals to reduce attacks on both humans and livestock. Furthermore, people should be made aware through sensitization programs about the opportunistic attacking behavior of the leopard; to prevent them from going to the forest alone as well as not leaving their children unattended outside the houses during the evening.

Data Availability

The data are made available in the data repositories https://www.re3data.org.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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