Human-sloth bear conflict in Nepal – case study from an unprotected Churia forest

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Abstract

Human-sloth bear conflict is common throughout most areas where sloth bears coexist with humans. Though similar reports are available from different parts of Nepal's lowlands, comprehensive studies that can inform human safety and conflict mitigation are highly lacking. We used data from questionnaire-based interviews with conflict-affected people and witnesses to provide detailed information about human-sloth bear conflict (1990-2021) in the Trijuga forest, an important but unprotected area for sloth bear conservation in Nepal. The data were analyzed using descriptive statistics, chi-square tests, and regression analysis. For the time period, 66 conflict incidents involving 69 human individuals were recorded, with an annual average of 2.06 (SD = 1.48) incidents and 1.80 (SD = 1.32) attacks. The attacks injured 59 people with a fatality rate of 8.47% among those that were injured. Conflicts primarily impacted people from minority ethnic groups and mostly affected men. Victims were generally of working age group (25 – 55), engaged in farming, and frequented the forest regularly for resources. Conflicts typically occurred between 0900 and 1500, inside forests, and in places of poor land cover visibility. Poor visibility was also a significant positive determinant of bear attacks on humans. Despite statistically insignificant variation in conflicts across seasons or months, they tended to be more prevalent during the monsoon and post-monsoon seasons. Victims of bear attacks frequently had serious injuries, especially to the head and neck area of the body. Serious injuries were more likely to occur to lone individuals than to people who were in groups of two or more. Taking into account sloth bear ecology and the socio-demographic profile of the conflict victims, we discuss measures that can promote coexistence between humans and sloth bears in light of the findings.

Keywords: Bear attacks, Churia forest, human-bear conflicts, *Melursus ursinus*, Nepal, sloth bear

Introduction

Large carnivores' predatory, competitive, and aggressive nature in general plays an important role in shaping the structure and function of ecosystems that they inhabit [1–3]. As a result, large carnivores' population management is a major priority in today's conservation scenario, particularly in human-dominated settings where carnivore populations are diminishing [4]. Large carnivore management in human-dominated environments, on the other hand, poses a slew of problems, the most pressing of which is arguably human-carnivore conflict [4,5]. Direct attacks on humans by large carnivores, among other types of conflict, can have serious and far-reaching implications for both carnivores and humans [6,7]. On the contrary, reliable information on the characteristics of such incidents might assist people in avoiding or minimizing such circumstances [8,9]. This, in turn, can help garner support from general public to protect and coexist with large carnivores, which is especially useful in areas where humans are present on a regular basis in carnivore habitats [9–11].

The sloth bear (*Melursus ursinus*), despite exhibiting no predatory or territorial behavior [12], has evolved into one of the most aggressive large carnivore species on the Indian subcontinent [13,14]. This development is most likely a protective adaptation for coexisting with large and seemingly dangerous mammals, such as the Asiatic elephant (*Elephas maximus*), Bengal tiger (*Panthera tigris*), one-horned rhinoceros (*Rhinoceros unicornis*), and common leopard (*Panthera pardus*) [12,14,15]. Because of the widespread human intrusion in sloth bear habitat [16], sloth bears' violent defense behavior has become a severe problem for human safety, as humans are routinely attacked, injured, or killed by sloth bears [17–19]. As a result, many people are afraid of sloth bears and often refuse to undertake or support conservation efforts that are aimed at them [16,20].

Researchers are increasingly looking into the features of human attacks by sloth bears in order to lessen the severity of the problem. However, the majority of such studies are only available from India or Sri Lanka [18–22]. As site-specific natural as well as anthropogenic factors can bring about changes in conflict patterns involving sloth bears [19,20], there is a need to study human-sloth bear conflicts in other range areas of the species to aid in the development of more effective and site-specific conflict minimization measures [23].

Though sloth bears are a conflict-prone wildlife species in Nepal's southern region [24–26], literatures are limited to provide comprehensive information that can be utilized to inform

human safety and conflict mitigation. People around the protected areas (PAs) may be better equipped to deal with wildlife conflicts, such as those involving sloth bears, due to the availability of different conflict addressing measures, and periodic awareness campaigns by the authorities [27]. Non PAs, on the other hand, have a significant lack of conflict management resources with local authorities, such as Division Forest Offices, making them more vulnerable to human-wildlife conflict [28]. This highlights the need of delivering evidence-based, reliable conflict mitigation measures to local communities in the unprotected areas of Nepal.

This study was designed to fill the research gap on human-sloth bear conflict in the Trijuga forest, one of the most critical sites for sloth bear conservation in southeast Nepal [24,29]. According to preliminary research, sloth bears are the primary species involved in human casualties in certain portions of this region [26], and they may only be second to elephants in terms of human attacks across this region [30]. In this study, we provide comprehensive information about human-sloth bear conflict from 1990 to 2021 by surveying entire areas surrounding the Trijuga forest to identify and interview those affected by the conflict. Our objectives were to (1) document the socio-demographic characteristics of conflict affected people, (2) determine the spatial and temporal patterns of conflicts, (3) investigate the characteristics and circumstances associated with the conflict, (4) categorize the injuries resulting from attacks, and (5) identify potential factors predicting attacks.

Materials and Methods

Study area

The Trijuga or Triyuga forest, which occupies an area of around 430 km^2, is situated in the southeast of Nepal (Figure 1). It is one of the largest remaining patches of Churia or Siwalik forest and an important area for the biodiversity conservation outside of Nepal's PAs [31]. The forest is stretched east-west across the nine municipalities of the Udayapur and Saptari districts. It has a network of community forests across its periphery, with the central section designated as a national forest. *Shorea robusta* dominated dry deciduous forest predominates along the Trijuga forest's northern boundary. Along the southern boundary mixed deciduous forest is prevalent with *Dalbergia latifolia*, *Acacia catechu*, *Terminalia tomentosa*, and *Semecarpus anacardium* as important species. The forest is bordered on nearly all sides by agricultural lands and human settlements, resulting in a heavy reliance of the neighboring

human communities for forest resources [29]. Apart from sloth bears, other major mammalian species found in this area include the common leopard, Asiatic elephant, barking deer (*Muntiacus muntjak*), wild boar (*Sus scrofa*), jungle cat (*Felis chaus*), golden jackal (*Canis aureus*), Bengal fox (*Vulpes bengalensis*), rhesus macaque (*Macaca mulatta*), Tarai gray langur (*Semnopithecus hector*), and Chinese pangoliln (*Manis pentadactyla*). The study area is described in more detail elsewhere [29,32].

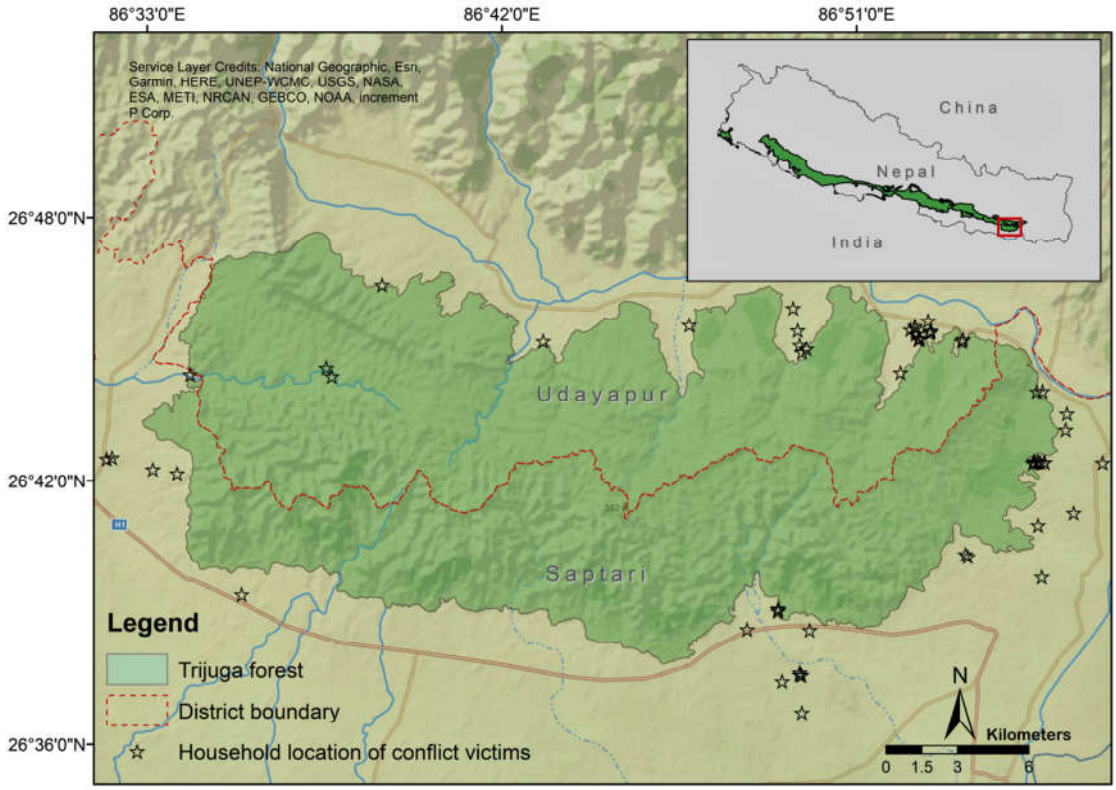

Figure 1: Map of Trijuga forest showing district boundary and household location of conflict victims. The blue lines indicate rivers and double lines indicate major highways. Inset map shows the location of the study area in reference to the predicted distribution range of sloth bears in Nepal, adapted from IUCN Red List 2020

Data collection

In accordance with Hopkins et al. [33] vocabulary of terminology and concepts developed for human-bear study and management, we define human-sloth bear conflict as any incident in which humans and bears come into close proximity, prompting the bear to react aggressively, resulting in the human taking evasive action and/or the bear making physical contact with the person. Therefore, we also took into account the incidents where the people were not attacked but were at considerable risk of being attacked and injured by the bears [9,19].

Data on human-sloth bear conflict was collected between 15th July and 23rd September 2021 using a three-stage approach. In the first stage, we viewed records of relief applications or payments held by the forest offices, including division, sub-division and community forests. This provided us with a preliminary list of people around the Trijuga forest who had been affected by conflict with sloth bear. However, due to the Nepal government's relatively recent initiation of relief payments for wildlife conflicts outside PAs [28], and limited awareness among the local population about the relief mechanism, there was a high chance of conflicts going unreported to the authorities. Additionally, we were also interested in documenting unreported incidents where the encounters did not result in an attack but people were at significant risk of being attacked. In order to account for this, in the second stage we visited all the administrative divisions (2 Municipalities in Udayapur and 7 Municipalities in Saptari), that Trijuga forest is a part of, and spoke with the officials of local administrative bodies (Wards) and villagers to identify any remaining persons affected by sloth bear conflict. We set the upper limit for documenting conflicts at 1990 because we were able to identify only a small number of people ($n = 3$) who were involved in conflict before that year, and information provided for much older incidents was less likely to be reliable. In this way, we compiled a comprehensive catalogue of conflict victims from 1990 to 2021, and while the sampling strategy used was purposive, we believe it is representative of the study site for the time period.

In the final stage, we performed interviews with the conflict affected people, or in absence of such person, had closely witnessed the event ($n = 10$). A questionnaire containing a mix of closed-and open-format questions (Appendix S1) were used to collect data during the interviews [34,35]. Before interviews respondents were made clear about the purpose of the study and verbal consent was obtained from each of them to start the interview [34]. Interviews were conducted in Nepali language, and in cases where the respondent could not speak or understand Nepali properly, a local field assistant helped in language translation. The questionnaire was divided in two sections. The first section had questions asking respondents of: (a) temporal data (time, month and year of conflict); (b) spatial data (approximate spatial location, major land cover features and visibility conditions); (c) characteristics and circumstances associated with conflict (human and bear activity before encounter, human and bear behavioral response to encounter); (d) bear demographics (number, age, sex) and human companions (number, approximate distance) data; and (e) injuries from bear attacks (type of injuries and organs affected). The second section of

questionnaire was focused in extracting socio-demographic information of conflict victims and had questions about the (a) ethnicity; (b) gender; (c) age; (d) occupation; (e) education level; (f) family size; (g) duration of residency; and (h) frequency and purpose of forest visit made by respondent, at the time of conflict. We also recorded household location of the respondents with the help of a Garmin Etrex 10 handheld GPS device.

Data preparation and analysis

Microsoft Excel 2010 (Microsoft Redmond, USA) was used to enter and prepare the interview data for analysis. Five key categories were used to categorize respondents' characteristics, including their age, ethnicity, level of education, and duration of residency in the area (Table 1). The respondents' occupation at the time of the conflict was divided into eight categories, and their frequency of visits to the forest was divided into four main classes (Table 1). Due to the rapid nature of the majority of human-sloth bear confrontations, it is acknowledged that human companions who are more than 50 meters away from a victim of a conflict have a relatively negligible effect on the outcome of the encounter [20]. As a result, the number of companions only included those who were within 50 meters of the victim. Likewise, it has been demonstrated that land cover visibility plays a significant role in determining the occurrence of human-bear confrontations, including for sloth bears [9,23]. We followed Smith and Herrero [9] and Sharp et al. [23] qualitative classification of land cover visibility as: (1) poor (densely vegetated place or rough terrain with short sight distances, as well as periods of low light levels, such as dawn, dusk, or night); (2) moderate (areas with small patches of vegetation and limited tree cover allowing increased visibility than those rated poor); and (3) good (poorly vegetated open areas, such as wide sandy riverbanks and grasslands with short grasses).

Table 1: Socio-demographic profile of people affected by human-sloth bear conflict around the Trijuga forest

	District		**Total**
	Saptari	**Udayapur**	
Number of respondents	38	31	69
Gender			
Male	35	28	63
Female	3	3	6
Age group			
10-24	4	3	7
25-39	12	13	25

40-54	17	12	29
55-69	4	3	7
70+	1	0	1
Ethnicity			
Tarai indigenous (Tharu)	10	15	25
Brahmin & Chhetri	10	10	20
Dalit	11	1	12
Ethnic hill migrants	3	4	7
Madhesi and Muslim	4	1	5
Education level			
Illiterate	26	16	42
Primary	2	7	9
Lower secondary	7	5	12
Secondary	3	1	4
Higher secondary	0	2	2
Residency			
Since childhood	25	15	40
>20 Years	12	12	24
10-20 Years	1	2	3
5-10 Years	0	1	1
Visitor to relative	0	1	1
Major occupation			
Farmer	16	24	40
Labor	9	4	13
Firewood & NTFPs seller	6	0	6
Forest ranger/guard	1	1	2
Carpenter	1	1	2
Driver	2	0	2
Student	1	1	2
Livestock holding	2	0	2
Frequency of forest visit			
Daily	28	21	49
Weekly	8	2	10
Monthly	0	6	6
More rarely	2	2	4
Municipality			
Chaudandigadhi	-	26	26
Saptakoshi	17	-	17
Agnisair Krishna Savaran	9	-	9
Surunga	6	-	6
Triyuga	-	5	5
Kanchanrup	3	-	3
Khadak	2	-	2
Tirahut	1	-	1

Since the date of conflict provided by the respondents was according to the Bikram Sambat calendar which is different from the Gregorian calendar, we used an online date converter tool (https://www.hamropatro.com/date-converter) to covert the dates to Gregorian calendar system. Further, the majority of respondents were able to recall the year and month but not the day of the conflict. To account for the fact that the Nepali months coincide with two English months (For example, the first month *Baishak* of the Bikram Sambat calendar runs from April 14 to May 14), we asked respondents whether the conflict occurred near the start, middle, or end of the Nepali month and selected the appropriate English month for the analysis. Based on the month of conflict we divided seasons as: (1) winter (December – February); (2) summer (March – May); (3) monsoon (June – September); and (4) autumn/post-monsoon (October – November).

To identify the approximate spatial location of the conflicts, we first divided the Trijuga forest into 4-km^2 grid cells. The grid cells were the same as those that were used in our earlier study to understand sloth bear habitat usage through occupancy-based sign surveys. We asked respondents for the name of the community forest (if applicable) where the conflict occurred, as well as the direction and distance to the conflict location from their home or from easily mapped features such as streams. In order to help respondents pinpoint the location of the conflict more precisely, we also showed printed satellite photographs of the study area that were obtained from Google Earth Imagery. Although exact coordinates could not be determined, the information provided for 58 conflicts was adequate to locate them within the 4-km^2 grid cells. We mapped the number of conflicts according to grid cells and prepared a conflict hotspot map using ArcGIS 10.4.

In order to determine the pattern of injuries to human body from a bear attack, we divided the surface area of human body according to the Wallace's "rule of nines" method [36] into six categories as: (1) Head-neck region (9% of body surface); (2) back (18%); (3) front (chest & abdomen; 18%); (4) arms (9% each); (5) legs (18% each); and (6) perineum (1%). Additionally, we used criteria developed by Ratnayeke et al. [20], to determine the severity of injuries sustained during sloth bear attacks. These were grouped into four categories: (1) minor injuries (injuries that did not result in deep punctures and only had minor scratches or superficial lacerations); (2) moderate injuries (injuries that resulted in deep punctures that took longer to heal and left few permanent scars); (3) moderately serious injuries (fractures of

the hands or feet, punctures to the head, several lacerations or punctures that resulted in significant bleeding); and (4) serious injuries (injuries that resulted in fractured bones in the head or neck, loss of scalp, the removal of facial components (such as the eyes, nose, and ears), or the permanent impairment of one's vision, hearing, or speech.

We computed descriptive statistics (mean, median, standard deviation, range, and frequencies) to summarize the data. The disparity between observed and expected frequencies across various categories of a variable was examined using a Chi-square goodness-of-fit test. We specifically investigated whether conflict rates differed by ethnic group, frequency of forest visits, year group, months, seasons, and time of the day. We also looked at whether the frequency of injuries varied according to the four severity classes and whether some body parts were more vulnerable to injuries than others. Further, we performed a chi-square test of independence to determine if there is an association between human group size and the severity of the injuries sustained due to bear attacks. The strength of association was calculated using Cramer's V. Significance level for all the chi-square analysis was determined at $\alpha \leq 0.05$.

Furthermore, we used non-parametric linear regression using the 'Rfit' package [37] in R to assess the trend of human-sloth bear conflict across years by taking year as an explanatory variable and the number of conflicts as a response variable. Additionally, we selected four variables (Table 2) that could potentially predict the outcome of a human-bear encounter (attack or non-attack, coded as 1 or 0, respectively). In order to assess the relative importance of variables we built regression models using the firth's bias-reduced logistic regression through the use of R package 'logistf'. Firth's logistic regression is believed to effectively take into consideration the problem of statistical separation and small sample size in our data [38]. Small sample size-corrected Akaike Information Criterion (AICc) was used for comparison and selection of the candidate models [39], using the R package 'MuMIn'. Model selection uncertainty was accounted for by model averaging the competing models (ΔAICc $\leq$ 2), and estimates of regression coefficients (β estimates) were generated to determine the direction and magnitude of influence of the variables on the probability of bear attack. The numerical variables were standardized and checked for correlation using the Spearman's rank correlation (r_s) prior to the analysis. The two variables (i.e., human group size and bear group size) were found to have a very weak correlation ($r_s = 0.08$).

Table 2: Variables devised to test their influence on the probability of a sloth bear attack

Variable	**Type**	**Description/categories**
Human group size	Numeric	Number of people within 50 m of the conflict victim
Bear group size	Numeric	Number of bears engaged in conflict
Land cover visibility	Categorical	Poor (yes) or not poor (no)
Making noise	Categorical	Victim or companion engaged in making noise before encounter (yes) or not engaged in making noise (no)

Results

We documented 66 incidents of human-sloth bear conflict during a 32-year period (1990–2021). Of the total, 56 events (84.84%) resulted in human attacks, while the remaining ten did not result in any form of physical contact. The conflicts involved 69 human individuals from eight administrative divisions (Table 1), with two people encountering bears twice.

Socio-demographic characteristics of conflict victims

Males made up the vast majority (91.30%, n = 63) of those affected by conflict. Average age of respondents at the time of conflict was 40.76 (SD = 13.59) years (range 11-77, median = 40) and average family size was 6.18 (SD = 2.30) individuals (range 2-14, median = 6). When compared to other ethnic groups, people from indigenous Tharu community (36.23%, n = 25) were affected more than expected (χ^2 = 21.072, df = 4, p = 0.0003). Most people (60.87%, n = 42) facing conflict were illiterate and the majority (57.97%, n = 40) were living in the area since childhood. The majority of people (57.97%, n = 40) were engaged in farming as their primary occupation, however those engaged in other occupations were also inclined to visit the forest to some extent. People who reported visiting the forest on a daily basis made up the biggest number (71.01%, n = 49) of conflict victims (2.84 times more than expected; χ^2 = 79, df = 3, p < 0.00001) than those who visited less frequently. Affected people were higher in number from Saptari district than from Udayapur district, but looking at the data based on administrative divisions, nearly two-fifth (37.68%, n = 26) of the conflict victims were from Chaudandigadhi Municipality of Udayapur district alone (Table 1). People from Chaudandigadhi Municipality (n = 10) and Saptakoshi Municipality (n = 11) were involved in the majority of recent events (21 out of 29) from 2010 to 2021. When compared to previous decades, this indicated a nearly four-fold rise in the number of conflicts involving residents of Saptakoshi Municipality (Figure 2).

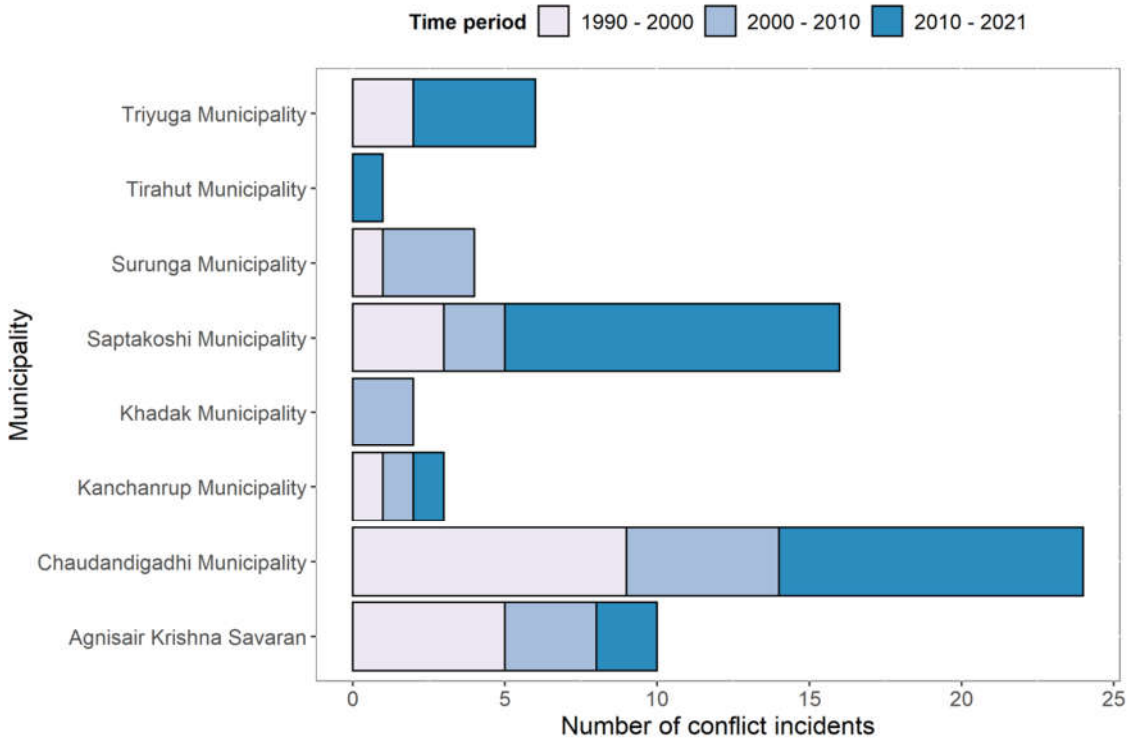

Figure 2: Variation in the frequency of human-sloth bear conflict across the past three decades based on the administrative divisions of conflict victims around the Trijuga forest

Spatial and temporal patterns of conflict

Conflict incidents almost always (95.45%, n = 63) took place inside the forest apart from a few (n = 3) that occurred in plantation areas (*e.g.* rice field, mango orchard) located between human settlements and forests. In 74.24% (n = 49) of the conflict incidents visibility condition was poor while remaining had moderate (21.21%, n = 14) to good (4.55%, n = 3) land cover visibility. Human-bear confrontations most typically occurred in narrow gullies (n = 21), followed by hill slopes (n = 12), riverbank (n = 10) and forest trail (n = 6), according to location data (n = 49) for incidents that occurred in the forest. Conflict incidents mapped using of 4-km^2 grid cells (n = 58) indicated that human-sloth bear conflict is primarily concentrated in the east section of the Trijuga forest with sporadic events documented in the western part (Figure 3).

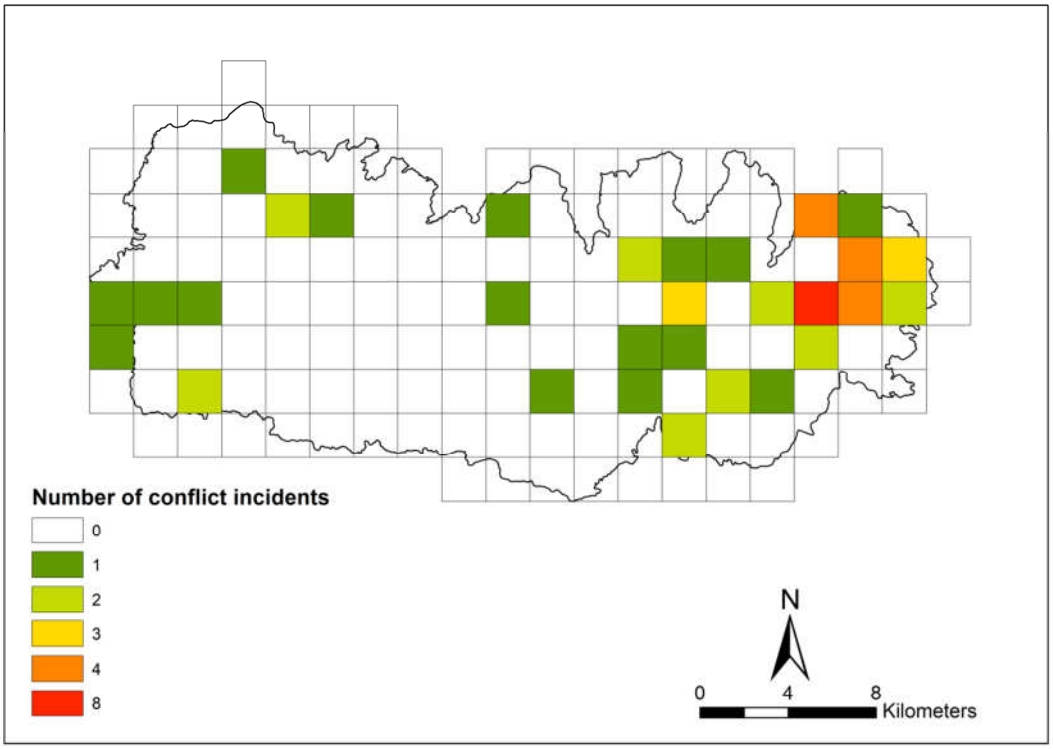

Figure 3: Incidents of human-sloth bear conflict in the Trijuga forest between 1990 and 2021 mapped using 4-km^2 grid cells based on the location data (n = 58) provided by the interviewees

There was an insignificant marginal increment ($0.03 \pm 0.02_{SE}$) in conflict events over the given time period with an annual average of 2.06 (SD = 1.48) conflicts and 1.80 (SD = 1.32) human attacks. Slightly declining trend of conflict was observed for the period of 1990-2000 ($1.91 \pm 1.38_{SD}$ events/year) and 2000-2010 ($1.6 \pm 1.78_{SD}$ events/year), whereas the trend was observed to be increasing in the last decade (2010-2021; $2.64 \pm 1.21_{SD}$ events/year; Figure 4). There was, however, no significant difference in the observed and expected proportions of conflicts between the three time periods (χ^2 = 3.90, df = 2, p = 0.14). Human-bear confrontations occurred almost throughout the year with an average of 5.5 ± 3 per month and 16.5 ± 4.12 per season having no significant variation in terms of months (χ^2 = 11, df = 10, p = 0.35) or seasons (χ^2 = 3.09, df = 3, p = 0.37). Nevertheless, a peak (31.82%, n = 21 events) was observed during the monsoon season, whereas October had the highest number of incidents by month and no incidents reported on July (Figure 5). Distribution of conflict events was not even throughout the day (χ^2 = 20.212, df = 4, p = 0.0004) and occurred most commonly between 1200 and 1500 (36.36%, n = 24: Figure 6).

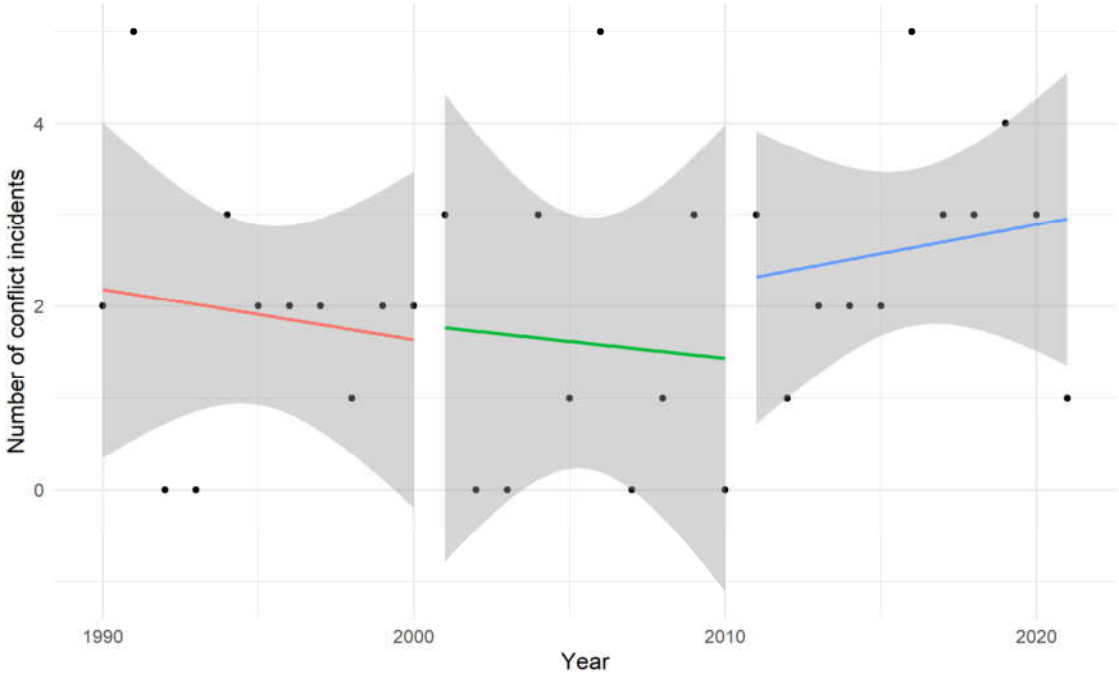

Figure 4: Trend of human-sloth bear conflict in the Trijuga forest across the past three decades

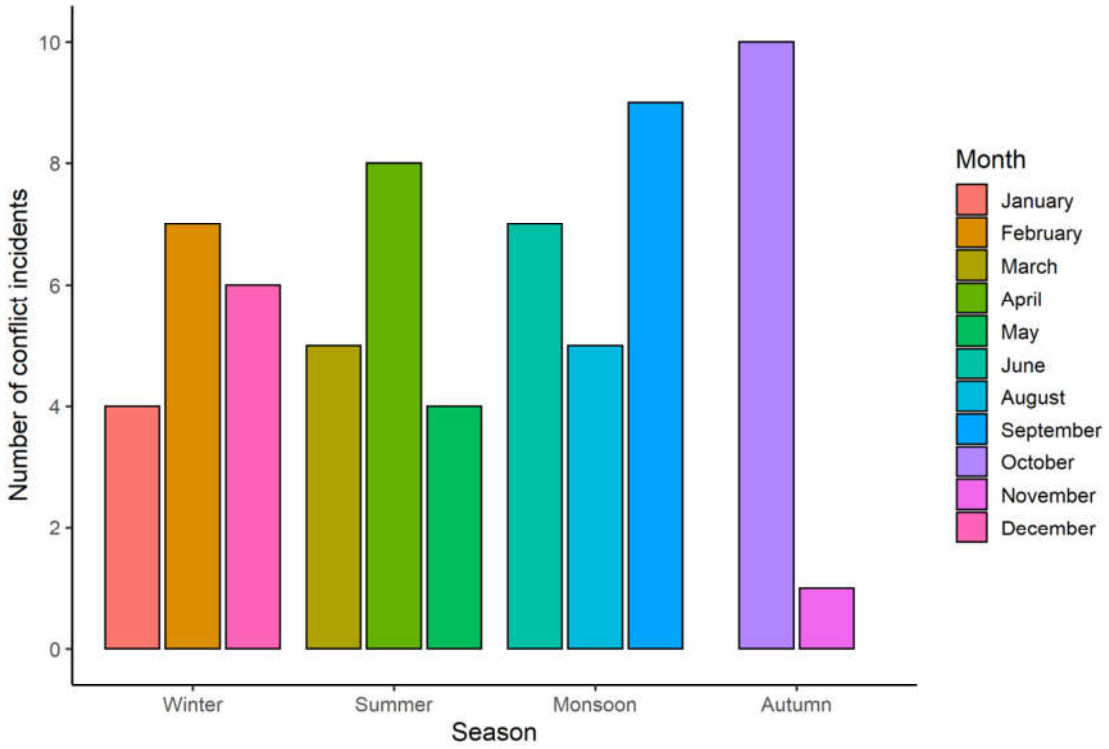

Figure 5: Seasonal and monthly variation in human-sloth bear conflict in the Trijuga forest between 1990 and 2021

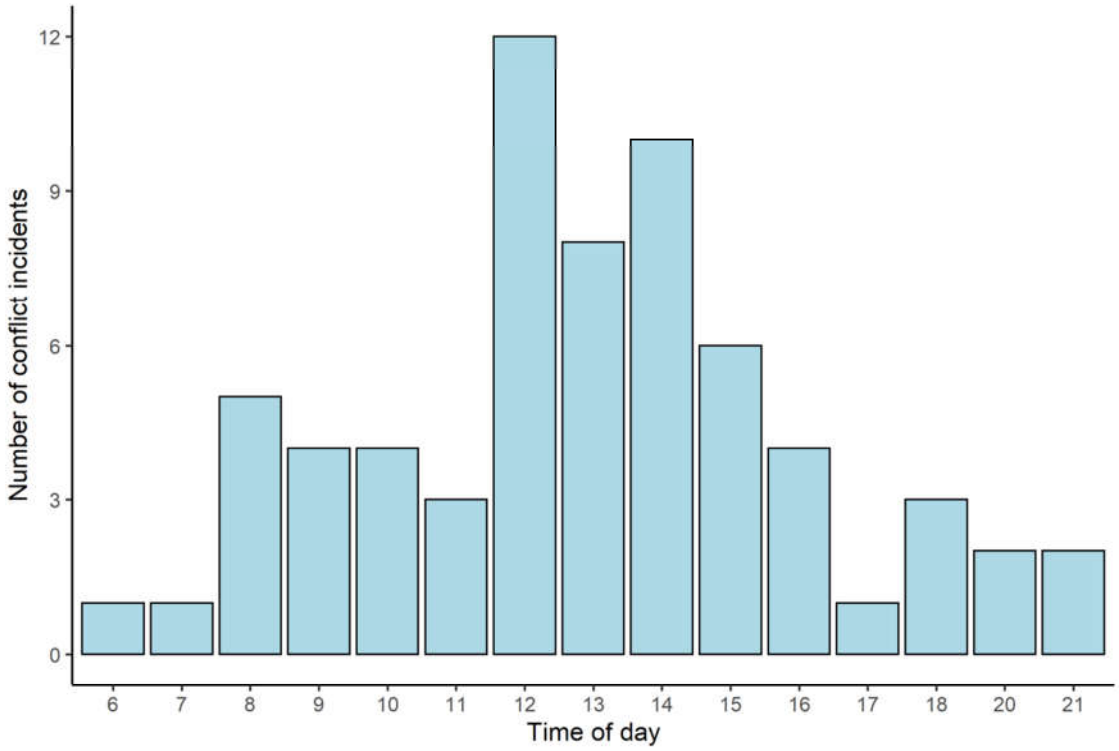

Figure 6: Variation in human-sloth bear conflict by time of the day in the Trijuga forest between 1990 and 2021

Characteristics and circumstances associated with the conflict

Single bears' were involved in the majority of conflict incidents (46.03%, *n* = 29), compared to female with offspring and similar-sized pairs (Table 3). Apart from the cases (20 out of 63) where people were unsure about bear activity before encounters, bears were most commonly (26.98%, *n* = 17) reported to be resting, either alone, in pair, or with cubs (Table 3).

Table 3: Groupings of bears engaged in conflicts and their activities immediately before conflicts

Bear group size (*n* = 63)	**Number of events**
Single bear	29
Female with cubs	23
Similar sized pair	11
Bear activity at time of encounter (*n* = 63)	**Number of events**
Uncertain	20
Resting	17
Walking	10
Already attacking	8
Foraging	7
Running	1

The primary motive for most persons (33.82%, *n* = 23 individuals) visiting the site of conflict was to harvest fodder, but when people encountered sloth bears, they were walking in the majority of cases (64.52%, *n* = 40 events; Table 4). They made no talks or noise prior to the encounter in 69.70% (*n* = 46) of cases (Table 4). There was data on the availability and number of human companions with conflict victims for 64 conflict incidents. There were no companions in half of the events (*n* = 32). In 18.75 % (*n* = 12) of the events, there was only one companion, and in 31.25 % (*n* = 20) of the events, there were two or more.

Table 4: People's purpose of visit to the site of conflict and their activities immediately before conflicts

Reasons for visit to the site of conflict (*n* = 68)	**Number of people**
Fodder collection	23
Livestock grazing	17
NTFPs collection	16
Firewood collection	8
Forest patrolling	2
Recreation	2
Human activity at the time of encounter (*n* = 62)	**Number of events**
Walking	40
Collecting fodder	8
Collecting NTFPs	4
Sitting	3
Standing	3
Collecting firewood	1
Cycling	1
Drinking water	1
Fishing	1
Making noise/talking (*n* = 62)	**Number of events**
Yes	16
No	46

Sloth bears' major behavioral responses during events that resulted in attacks (*n* = 56) were to loudly vocalize before and during the attack (82.14 %, *n* = 46), charge the person by running on all four legs (82.14 %, *n* = 46), and attack by standing on hind legs (80.36 %, *n* = 45). Bears used claws in 80.36 % (*n* = 45) and teeth in 50 % (*n* = 28) of the occasions. When it came to non-attack incidents, bears' most prevalent response was to vocalize (*n* = 9) when they encountered humans. In addition, bears rushed aggressively towards human (*n* = 4) and

stood up on hind legs (n = 3), but in almost all cases (n = 9) bears walked away, except in one case where the bear chased the person for a brief time before departing the area.

We were able to gather information regarding human behavior during conflict from only 48 incidents. People fled after encountering bears in eight of the occasions, whereas they fled after being attacked by bears in two of the occasions. When people attempted to flee after encounters, the majority were pursued (n = 6) and attacked (n = 5). People reported jumping down from the hill slope in both cases where the bears did not chase them. When humans were attacked by bears and fled, they did so after the bear began attacking their companion (n = 1) and when the bear stopped attacking and began to move away (n = 1) after the person laid down facing the ground. The bears chased the fleeing victim in both occasions, although only for a brief time. People mentioned climbing trees to escape from attacking bears in two conflict events: one person climbed tree when the bears became more aggressive after the person started fighting, and another person tried climbing tree initially but was dragged down and mauled by the bear.

Half of the ten events (n = 5) in which humans shouted after encountering bears did not result in an attack. People who fell down due to a bear attack stayed in the position with their faces facing the ground in six cases, and none of the victims reported further injuries by the bears. People engaged in active bear fighting in 17 of the 56 attack episodes studied, and they hit the bear once or twice in 9 of them. People reported hurting bears with metal weapons or other objects, such as stones or sticks, in many of these incidents (15 out of 26). The rest of the instances (11 out of 26) had persons hitting bears with only their body parts (hands and legs).

Injuries resulting from attacks

Humans were injured in 54 out of 56 attack events (number of humans injured = 59) and bears were injured to some degree in 19 events. The majority (44.07%, n = 26) of people received serious injuries from bear attacks (χ^2 = 13.203, df = 3, p = 0.004) compared to moderately serious (25.42%, n = 15), moderate (13.56%, n = 8), and minor injuries (16.95%, n = 10). Of all the people bearing injuries, 8.47% (n = 5) died within a few hours of attack, whereas two people died between 1 and 3 years because of complications developed from the wounds. Injuries from bear attacks were most commonly (35.09%, n = 40) recorded in the head-neck region of the body. This resulted in people losing either one or both of their eyes causing partial or complete blindness (n = 16), loss of scalp (n = 14), injuries in ear (n = 7), mouth (n = 5) and damage of other facial structures (n = 17). Followed by head-neck region,

other parts of human body that was injured were hands and arms (28.07%, n = 32), legs (19.30%, n = 22), chest (6.14%, n = 7), back (5.26%, n = 6), stomach (5.26%, n = 6) and perineum (0.88%, n = 1). The observed difference was statistically significant ($\chi^2 = 60.421$, df = 5, $p < 0.00001$) with injuries in head-neck region being twice more than expected; arms 1.68 times more than expected; legs 1.15 times as much as expected. Injuries in the rest of the body parts were all less than expected. A moderate level of association was found between human group size and level of injuries received ($\chi^2 = 10.997$, df = 3, $p = 0.01$; Cramer's V = 0.43), with people having no companions being more likely to receive serious injuries compared to those having one or greater number of human companions (Figure 7).

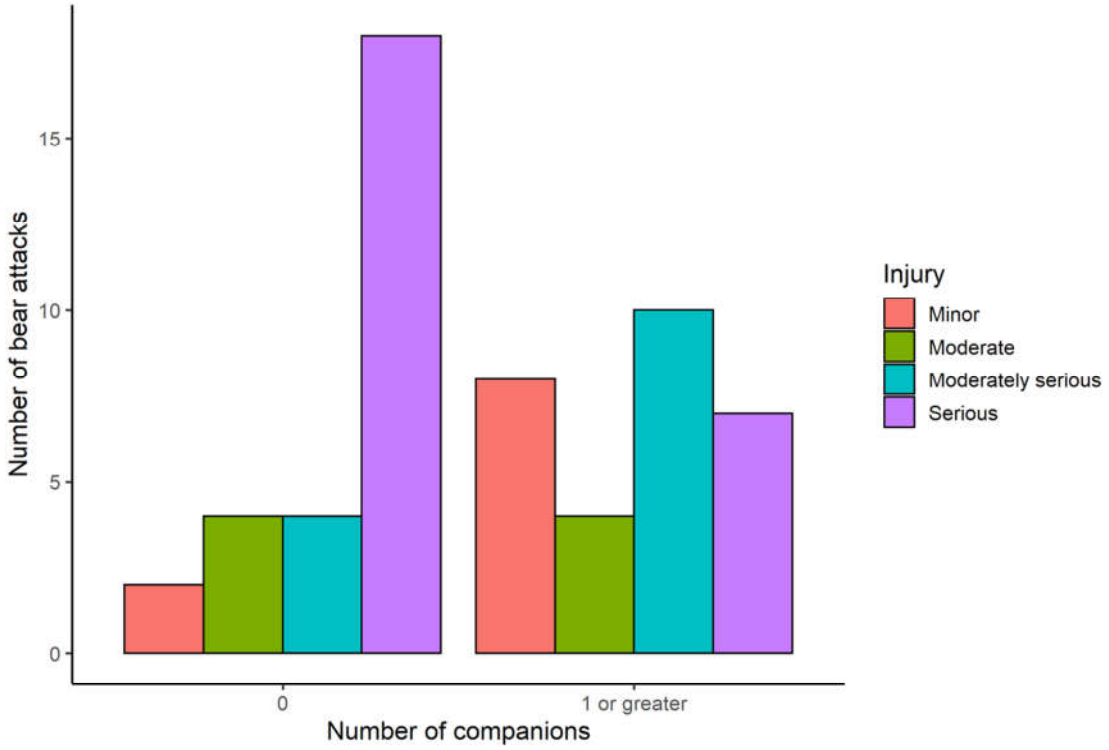

Figure 7: Frequency of bear attacks grouped by number of companions with conflict victims and level of injuries received from attacks

Predictors of human attacks

The top model for predicting human attacks by bear included an additive combination of human and bear group sizes (AICc weight = 0.194; Appendix S2). However, no single model was dominant and all the four variables were represented in the competing models (models with ΔAICc < 2). Among the four variables, highest cumulative weight was attained by human group size (Summed AICc weight = 0.692), followed by bear group size (0.543), noise (0.243), and poor visibility (0.241). According to model averaged regression coefficients, the size of the bear group and low visibility were shown to be positive predictors of sloth bear attack, while the size of the human group and noise were found to be negative predictors (Table 5). The influence of visibility was strong and significant, with the 95% CIs not containing 0, while the CIs for human group size marginally overlapped 0. CIs of the remaining two variables more strongly overlapped 0, showing that their influence, based on our study, was only indicative and not conclusive (Table 5).

Table 5: Weighted β estimates, standard errors, and 95% confidence intervals of the variables devised to test influence on sloth bear attack probability

Variables	***β***	***SE*(*β*)**	**LCI**	**UCI**
(Intercept)	1.7861	0.6214	0.5682	3.0040
Bear group size	0.5467	0.4372	-0.3102	1.4036
Human group size (≤50m)	-0.2542	0.1554	-0.5588	0.0504
Making noise (Yes)	-0.4693	0.767	-1.9726	1.0340
Poor visibility (Yes)	2.5803	0.8066	0.9994	4.1612

Discussion

This study uncovers important findings about human-sloth bear conflict in the human-dominated Churia habitat of Nepal. We identify vulnerable populations facing the conflict and provide a thorough understanding of conflicts' circumstances, spatiotemporal dynamics, as well as potential predictors of attacks and human injuries caused by attacks. The information can easily be incorporated to design conflict mitigation and human safety guidelines that can form as a basis for human-sloth bear coexistence in this and other parts of the country. It also emphasizes the significance of conducting similar research in other parts of the country in order to strengthen the coexistence mechanism between humans and sloth bears on a national scale.

Increased vulnerability of the forest-dependent local communities, particularly those from marginalized or tribal groups, to human-wildlife conflict, is commonly acknowledged across many developing nations [17,20,28,40]. The victims of sloth bear conflict in the Trijuga forest followed a similar pattern. Conflicts primarily affected members of the indigenous Tharu tribe, while 71% of all persons involved came from socially disadvantaged communities in Nepal (Tharu, Ethnic hill migrants, Dalit, Madhesi, and Muslims). These incidents mostly involved persons of working age (25 - 55) that visited the forest on a regular basis for activities such as resource collection and livestock grazing. Most of them had minimal or no formal schooling. It means that reducing the local population's dependency on the forest and educating them on the underlying mechanisms of conflict are crucial if we want to reduce the rate of conflict with species like sloth bears [17,25]. There were also local forest department employees engaged in the conflicts, which adds to the evidence for the need to train staff and strengthen institutional capabilities of forest offices to manage conflicts outside of Nepal's PAs [28].

In accordance with this study, male biased gender pattern in conflict with sloth bears as well as other large mammals (e.g., tiger, elephant) has been frequently reported in Nepal and elsewhere in the Indian subcontinent [17,20,21,30,41,42]. The reasoning of males being more likely to go alone and spend longer periods of time in forest than women, making them more susceptible to confrontations with wildlife [20,42], applies equally to our study region.

We did not record conflicts from two administrative divisions surrounding the Trijuga forest (Rupani Municipality and Shambhunath Municipality of Saptari district), but we did record one person from Tirahut Municipality, which is not bordering the Trijuga forest. We discovered that residents of the Chaudandigadhi Municipality in Udayapur and the Saptakoshi Municipality in Saptari were mostly engaged in confrontation with sloth bears, which has become more common in recent years. Conflicts mapped using 4-km^2 grid cells further confirmed that forested areas of these divisions had more confrontations than others. Many grid cells in this part of the Trijuga forest were predicted to have a greater probability of being used by sloth bears due to the availability of important ecological resources for bears [29]. Because human activities were also significant in this part of the forest [29], the considerable overlap in sloth bear and human use of the forest should have contributed to a high number of human-bear encounters. There are growing body of literatures on human-wildlife management, including bears, that have identified increased human disturbances in natural habitat to be associated with the increased frequency of wildlife-related human

casualties [13,43–45]. One important approach to reducing human-sloth bear conflicts in human-dominated unprotected areas, such as the Trijuga forest, could therefore be to identify and limit human activity in regions that bears are more likely to make use of.

Despite the fact that the Trijuga forest is surrounded on most sides by agricultural lands and settlements, we only documented a few conflicts in these areas, and incidents mostly happened within forests. Ratnayeke et al. [20] documented similar findings for Sri Lanka. However, in areas of rather fragmented and degraded forests in central [41], eastern [21], and western [18] India, sloth bear attacks have been frequently documented often close or within human usage areas. Despite ongoing human disturbances, the overall forest cover has remained more-or-less consistent over the decades in the Trijuga forest [45], which could have helped to meet sloth bear habitat needs to a certain extent, limiting their presence in areas of human use. Studies have shown that sloth bear occurrence is positively associated with forest cover [46,47]. Adequate cover provide sloth bears a measure of safety from humans and predators, and protection from high daytime temperatures in the tropics [48]. It further generates necessary conditions for termites (sloth bears' important food source) to thrive [48], as many termite species are particularly dependent on plant tissues for nourishment [49,50]. However, with ongoing levels of human disturbances, the forest cover and associated benefits to sloth bears might be declining rapidly in the Trijuga forest [29,32]. If disturbances are not controlled, the persistent scarcity of ecological resources may drive bears to venture into human-use areas in search of them in the future.

Poor land cover visibility significantly elevated the possibility of a sloth bear attack in the Trijuga forest, and most confrontations occurred in regions with rough terrain and dense vegetation (e.g., narrow gullies, hill slopes, and thickets of riverbanks). Previous researches on human-bear conflict have come up with similar conclusions [9,23], albeit no empirical testing similar to ours was undertaken to substantiate the findings. Sloth bears prefer rough terrain and dense vegetation for resting, especially during the day [48]. This is especially true for areas that lack natural caves or similar structures [23]. Moreover, because such places receive less sunlight, they tend to have damp soils, which may maintain a high termite population while also making soil conditions favorable for excavating termite colonies [48]. In the Trijuga forest similar observations have been made based on the indirect signs of sloth bears [29]. Given these insights into sloth bear ecology and our study's findings that resting and foraging were two of the most important known activities of sloth bears at the time of encounter, it is reasonable to conclude that people mostly surprised bears at a close range in

areas of poor visibility when bears were at resting or feeding sites [20]. In this context, reliable information on the denning ecology of sloth bears might as well prove useful for devising strategies that can minimize risky encounters with sloth bears in areas of regular human activities such as the Trijuga forest.

Though our research did not find a significant variation in the frequency of human-sloth bear conflicts in the Trijuga forest over the past three decades, it does provide a hint in the direction of an increase in conflict in recent years. The inclining trend of conflict is found to be even more pronounced for sympatric species like elephants in the region [30]. This, as well, must be associated to the widespread human disturbances undergoing throughout Nepal's Churia range, including in the Trijuga forest region [31,45]. The seasonal or monthly differences in conflict incidents involving sloth bears were also not supported statistically by our study. It might be because human activity in this area is somewhat constant throughout the year. Nevertheless, our documentation of more conflicts (48%) in the monsoon to post-monsoon season is comparable with findings from Northern Odisha and Chhattisgarh in eastern and central India, respectively [21,41]. However, it varies with studies from Sri Lanka, the Deccan Plateau in South India, the Kanha-Pench corridor in central India, and North Gujrat in western India, where more conflicts have been documented during drier seasons, such as winter and summer [17,18,20,23]. During the monsoon and post-monsoon, the vegetation productivity in the forest in our study area is greatly increased. A higher number of confrontations may have been observed during this time of the year due to the decreased visibility caused by the increased foliage cover [21]. There may also be an increase in individuals visiting the forest to collect NTFPs, such as bamboo shoots and fiddleheads at this time of the year.

Interestingly, however, we were unable to document any conflicts in July. The month of July marks the peak of paddy cultivation in this area, and since paddy is the most important crop for the locals, this is the time of year when they are most likely to be working in the fields. As an outcome, there may have been minimal human-sloth bear encounters during this month due to the lower regularity of people visiting the forest. Throughout the sloth bears' range, monthly variations in the frequency of conflicts dependent on the level of human activity within or close to bear habitat have been noted [17,20,23]. The same explanation should also be applicable in describing the influence of time of the day on conflict with sloth bears. Conflicts predominantly took place between 900 and 1500 (65%) coinciding with the time when humans tend to be more active in the forest in our study area.

Single bears were more involved in conflicts in our study than females with cubs or similar sized pairs, which is consistent with earlier studies on sloth bears [18,19,41]. However, the regression analysis indicated that in our situation, the probability of an attack rises as bear group size increases. The observed inference may be explained by analyzing the sociobiology of sloth bears. For instance, even though sloth bears are solitary in nature, family grouping of females with cubs is common, and to a lesser extent, coalitions of sub-adults have also been observed [12,15]. It has also been noted that during mating season, multiple male sloth bears may congregate around receptive females [12]. When with cubs, females are highly defensive, making them more prone to attack intruders [15]. Similarly, aggressive behavior and fights between males have indeed been documented during mating sessions, whereas the coalitions of young bears is suspected to be a tactic for defense against potential predators or adult male conspecifics [12,14]. Therefore, encounters with humans in either scenario may also increase the bears' propensity to attack. Moreover, since our study could not derive a strong support for this evidence, as indicated by the 95% CIs overlapping 0, future studies are clearly essential to support this hypothesis and gain more robust insights in this matter.

Studies other than ours have also provided evidence in favor of the effect of human group size in predicting the outcome of human-large carnivore encounters, including with bears [9,10]. In general, it is implied that humans in groups are less vulnerable to attacks by large carnivores like bears and that individuals acting alone are more likely to be involved in attacks that result in fatalities or serious injuries [9,10,48]. Not only did we find a higher number of solitary persons encountering sloth bears, but we also observed a link between human group size and the severity of injuries, with single people suffering more serious injuries, and all fatal attacks involved solitary persons.

Serious injuries by sloth bear attacks were almost always due to the wounds sustained in the head and neck region of the body. Hands and legs were other body parts that were frequently injured. Despite reports of sloth bears inflicting similar patterns of injuries in other range areas [9,18,20], the proportion of victims in our case who suffered severe injuries was higher than anticipated when compared to other studies [17–19]. We observed that in around 46% of bear attack cases people tried fighting or at least frightening the bears. Such conduct may put bears under more pressure to engage in attack for longer periods of time when their natural instinct is to flee the area unharmed [17–19]. This suggests that individuals in the study region need to be better informed about the precautions to respond to bear attacks and protect key body parts like the head and neck during attacks. Moreover, avoiding circumstances that

could result in encounters is the wisest course of action one can take while in bear habitat given the danger of suffering severe injuries if attacked [19].

Conclusions and management implications

Conflict with sloth bears affected people of diverse socio-demographic backgrounds around the Trijuga forest; however, the majority of these conflicts included people who practiced forest-based livelihood methods (e.g., farming) and generally belonged to minority ethnic groups, who were mostly males and working members of the population. Concerned authorities are suggested to focus on shifting forest-based livelihood practices, particularly among vulnerable socioeconomic groups, and strengthen their economic capability through alternative livelihood sources for conflict minimization with sloth bears. Training and awareness programs on human conduct and safety in sloth bear habitat should be customized in the most fundamental and simply understandable manner possible for increased effectiveness among the people who typically have minimal education. Further, the concentration of conflicts in the east section of the Trijuga forest, which often coincided with areas that were important for bear use, implies that this region be prioritized for conflict mitigation by limiting excessive human activities.

The dominance of conflicts during daytime when sloth bears are generally less active [12,51] and in places of low land cover visibility, implies that adopting certain practices can help minimize sudden encounters and attacks by bears. Based on the growing body of evidence, including our own, we mainly suggest people to 1) avoid or take extra precautions in areas of dense vegetation and rough terrain that may shelter bears or obscure visibility that can lead to sudden encounters, and 2) remain in a close-knit group rather than alone when in the forest. Aside from this, since the majority of encounters with sloth bears involved people who were not making noise, it is possible to alert bears to human presence by making noise [9], although this must be done with caution when they are encountered up-close.

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