

Patterns and determinants of Elephant attacks on humans in Nepal

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Abstract

Attacks on humans by Asian elephant (*Elephas maximus*) is an extreme form of Human-elephant conflict. It is a serious issue in southern lowland Nepal where elephants kill more humans than any other wildlife. Detailed understanding of elephant attacks on humans in Nepal is still lacking which affected in devising appropriate strategies and actions for human elephant conflict mitigation. This study documented spatio-temporal pattern of elephant attacks on humans, factors associated with the attacks and human/elephant behaviour contributing to deaths of victims when attacked. We compiled all the documented incidences of elephant attacks on humans in Nepal for last 20 years across Terai and Siwalik region of Nepal. We also visited and interviewed 412 victim families (274 fatalities and 138 injuries) on elephant attacks. Majority of the victims were males (87.86%) and had low level of education. One fourth of the elephant attacks occurred while chasing the elephants. Solitary bulls or group of sub-adult males were involved in most of the attack. We found higher number of attacks outside the protected area. People who were drunk and chasing elephants using fire-crackers were more vulnerable to the fatalities. In contrast, chasing elephants using fire was negatively associated to the fatalities. Elephant attacks were concentrated in proximity of forests primarily affecting the socio-economically marginalized communities. Integrated settlement, safe housing for marginalized community and community grain house in the settlement should be promoted to reduce the confrontation between elephants and humans. Conservation of elephant should be carried out in entire landscape, extending beyond the boundary of protected areas to reduce threats of elephant extinction.

Key words: Asian elephant, Attacks on humans, Spatio-temporal pattern, Terai-Siwalik landscape

1. Introduction

Asian elephant (*Elephas maximus*, referred to as 'elephant' hereafter) is a globally endangered megaherbivore (Williams et al., 2020). It is an umbrella species in tropical and subtropical forests of Asia, and has a strong cultural role in various Asian societies (Menon et al., 1996; Sukumar, 2003; Jadhav & Barua, 2012; Vasudev et al., 2020). Once widely distributed in the Asia, elephants are now confined to ca. 5% of their historical range in highly fragmented landscapes (Sukumar, 2006). In addition, the rapid development of linear-infrastructures including railways, highways, electric transmission lines and irrigation canals cause further obstruction to elephant movement. Elephants require large areas for their survival with long distance seasonal movements (Leimgruber et al., 2003; Goswami, 2017). However, increasing habitat fragmentation brings them in frequent confrontation with humans. As a result, human elephant conflict (HEC) is worsening and has become a prominent cause of elephant population decline (Sukumar, 2006). Attack on humans is the extreme form of HEC. Other effects upon local people from HEC includes loss of crops, damage to property, and safety threats (Dickman, 2010); and a large number of elephants are also killed in retaliation.

Nepal is a typical example of an elephant range country with a small but growing population of about 230 elephants in highly fragmented landscape (Ram & Acharya, 2020). Increasing encroachment and forest conversion in the lowlands of the Terai and Chure hills (Himalayan foothills) have destroyed the traditional migratory routes of the elephants. Whereas some residential solitary bulls living in protected areas have become habituated to visiting agricultural areas for a higher quality diet causing a high amount of damage (Koirala et al., 2016). Elephants cause the highest number of human deaths among the wildlife species in Nepal. Thus, HEC is a serious issue throughout the lowland Nepal (Acharya et al., 2016).

Few studies on human-elephant conflict have been carried out in Nepal primarily focusing on crop and property damage (Neupane et al., 2013; Graham et al., 2016; Pant et al., 2016). However, detailed studies of elephant attacks on humans are still lacking. This study attempts to document spatio-temporal pattern of elephant attacks on humans in Nepal, characteristics of the victims and attacking elephants, determine factors associated with the attacks, and identify human and elephant behaviour contributing to deaths of victims when attacked. We tested hypothesis 1) human activities are responsible for elephant attacks on humans; 2) elephant attacks are higher in the close proximity to forest; and 3) majority of the attacks on humans is caused by solitary bull elephants. The study results have long term implications for the conservation and management of elephants in the human dominated landscape of Nepal and beyond.

2. Material and Methods

2.1 Study area

The study was conducted across the Terai and Siwalik region of Nepal covering ca. 46,000 km² of elephant range in 24 districts (Figure 1). The Terai and Siwalik region of Nepal is densely populated with 391.5 persons/km² (CBS, 2014). About 51% of total population of Nepal reside in the region with agriculture and livestock husbandry as the primary occupation. About 42% of the study area is forested providing habitats and migration corridors for the Asian elephant (DFRS, 2015). Major cities, industrial areas and major highways fragment the forested areas. The region was intact till 1950s but afterwards it is under continuous human pressure from expansion of agriculture, settlements and built-up areas.

The study area comprises various habitats including highly productive alluvial floodplain grasslands, riverine forests and climax (*Shorea robusta*) forest supporting many rare and globally threatened species including tiger (*Panthera tigris*), dhole (*Cuon alpinus*), greater one-horned rhinoceros (*Rhinoceros unicornis*). The study area has a sub-tropical climate characterized by hot and humid summers (mid-March/mid-June), intense monsoons (mid-June/mid-September), and dry autumns/winters (mid-September/mid-March) (Lamichhane, Persoon, et al., 2018; Lamichhane, Subedi, et al., 2018). The maximum temperature on varies from 35–40°C during summer and 14–16 °C in winter (Jackson, 1994) . The mean annual rainfall ranges between 1138 and 2680 mm, with over 80% of the rain occurring during the 3 monsoon months (Lamichhane, Persoon, et al., 2018) -. Elephants in Nepal are found in four population clusters i.e. eastern (Koshi to Jhapa), Central (Chitwan to Mahottari), Western (Bardia to Dang), and Far Western (Kanchanpur & Kailali). Out of four population clusters of elephants, higher number of attacks on humans were recorded in eastern, central and western clusters. They frequently migrate through the Nepal-India transboundary forest connectivity in the East (Northern part of West Bengal), West (Uttarakhand) and some places in the South (Bihar and Uttar Pradesh).

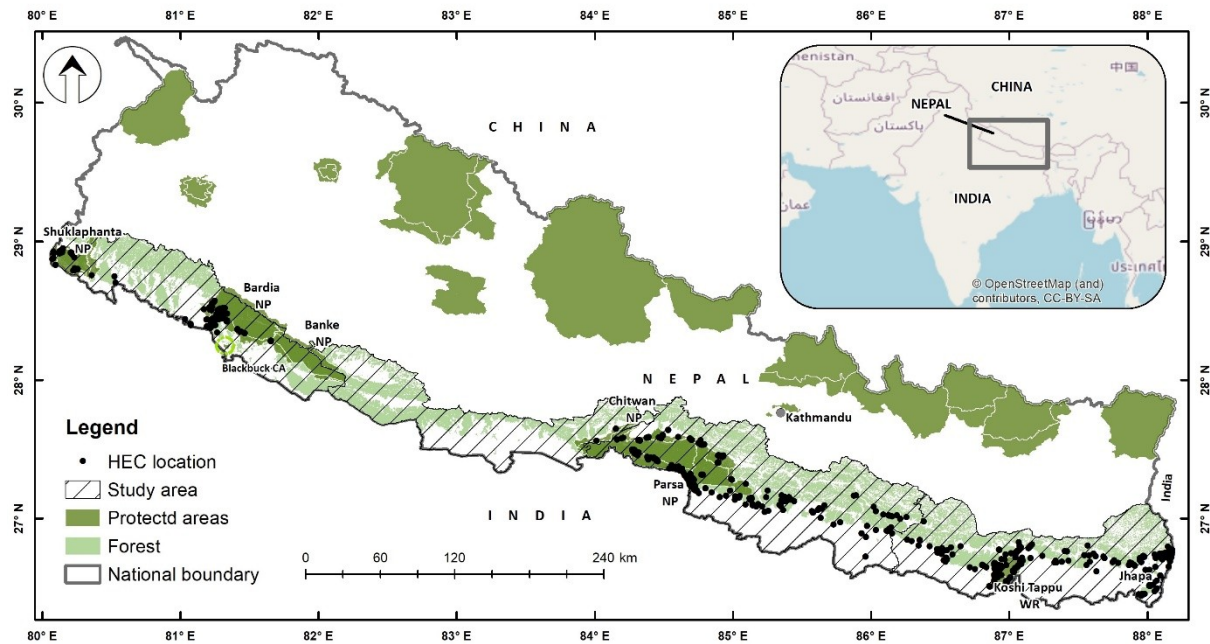


Figure 1. Study area location, forest cover, protected areas and locations of elephant attacks on humans in Nepal.

2.2. Elephant attacks data collection

We compiled all available data of elephant attacks on humans (death and injury) from the Divisional Forest Offices (DFO) and Protected Area (PA) offices across the study area for the period 2000 to 2020. We also conducted 30 stakeholder consultation meetings to gather information on human killings, livelihoods, elephant visiting patterns and people's perception towards the elephants. We also collected/verified the information on human killings by elephants from annual reports of parks, wildlife reserves, divisional forest offices, regional forest directorates, Department of National Parks & Wildlife conservation (DNPWC) and Department of Forests (DOF).

2.3. Victim household questionnaire survey

We conducted structured questionnaire surveys of all affected households (n=412) in the study area. On consent, either the head of the household or another adult member was interviewed. GPS location of each household was recorded. The questionnaire included demographic background of the interviewee and the victim, socio-economic status, victim behaviour and activity during attack, methods used for driving elephants off, characteristics of attacking elephant, and habitat characteristics (Table 1). We also collected information on relief to the victim or family (Annex I).

2.4. Data analysis

We entered all the questionnaire survey data in MS Excel and prepared descriptive summaries using pivot table function (Dan Clark, 2020). We then performed data analyses in the R statistical package

v. 4.0.2 (R Development Core Team 2020). We used chi-square test of independence for comparing the frequency of attacks (death and injury) between seasons, months, ethnicity, age group, sex and major occupation of people (Lamichhane, Persoon, et al., 2018). We categorized victims into five categories based on ethnicity, upper cast Hindus including Brahmin Chhetri Thakuri (BCT), Dalit or underprivileged group, Janajati (ethnic groups such as *Gurung, Magar, Newar, Tamang, Rai, Limbu, Tharu, Bote, Darai, Rajbansi* etc.), Madhesi, and Muslim. Similarly, we grouped the victims into five age categories i.e. <15, 15–24, 25–44, 45–64, 65+ years following (United Nations, 1982). Education level of the victims was categorized into illiterate (who cannot read and write), literate (who can read/write but have not attended formal school), Primary (completed primary school), and Secondary or above. Housing of the victim was categorized into cemented house, CGI roof house, tiled roof house, and thatched house.

We carried out binomial logistic regression by constructing a Generalized Linear Mixed Model (GLMM) (Zuur et al., 2010) to determine the factors associated with fatalities in elephant attacks. In the GLMM, fatalities on elephant attack were used as dependent variable by coding the human fatality–1 and injury–0. Fourteen explanatory variables representing elephant characteristics, human characteristics and site characteristics were defined (Table 1). Elephant behaviour included social characteristics (solitary bulls or herd elephant) and the elephant was in musth. The human characteristics included age and sex of the victim, education, activities of the victim during elephant attack, location of attack, type of house of victims. Human behaviour or response towards elephants (chasing with fire, explosives, or gun) was also included. Site characteristics included place of attack, migration route of elephants, and proximity to forest. We extracted the victim location’s habitat and environmental variables (Naha et al., 2019) (Table 1) using Google earth engine platform (Gorelick et al., 2017; Buchholtz et al., 2020) and Arc-GIS v 10.5 (ESRI, 2016; Wang et al., 2018).

We ranked models by the small-sampled corrected Akaike’s Information Criteria (AICc, lower AICc value indicates higher model ranking) using multi-model inference in ‘MuMIn’ package in R (Barton, 2020). The final model was obtained by averaging the top candidate models supporting the data equally well ($AICc \leq 2$, (Burnham & Anderson, 2001).

Table 1. Variables used in binomial logistic regression and their type/source. The human casualty in elephant attack was the dependent variable and the independent variables included elephant characteristics, human characteristics, and environmental and habitat characteristics.

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Variables	Type of variable	Categories/values	Data source
	Elephant characteristics		

Herd type/size	Categorical	Solitary adult bulls, Sub-adult male, Sub-adult male group, Herd without calves, Female with calves	Questionnaire survey
Musth	Binomial	1, 0, NA (1 – Yes, 0 – No, NA – Don't know)	Questionnaire survey
Human characteristics			
Response to elephant	Categorical	Shouting, Fire cracker, stones,	Questionnaire survey
Alcohol use	Binomial	1,0, NA (1 - Drunk, 0 - not drunk, NA – Don't know)	Questionnaire survey
Victim age and sex	Categorical	Sex (Male, Female) Age (<15, 15 – 24, 25 – 44, 45 – 64, 65+),	Questionnaire survey
Victim ethnicity	Categorical	1. BCT (Brahmin, Chhetri and Thakuri); 2. Janjati (Ethnic communities of hills & Terai like Gurung, Magar, Tamang, Newar etc.); 3. Indigenous Terai (Tharu, Bote, Darai, Mushahar); 4. Dalit (under-privileged casts of Kami, Damai, Sarki etc.); 5. Madhesi and 6. Mushlim	Questionnaire survey
Education	Categorical	Illiterate, literate, primary, Secondary or above	Questionnaire survey
Activity of the victim at the time of incident	Categorical	Chasing elephants, resting at home, guarding crops, travelling on foot,	Questionnaire survey
House type	Categorical	Concrete, GI sheet, tile house, thatch house	Questionnaire survey
Environmental and habitat characteristics			
Proximity to forest	Numeric		GIS & questionnaire survey
Season	Categorical	Winter, Summer, Monsoon	Questionnaire survey
Land use type	Categorical	Farmland, settlements, forests/grassland	GIS

3. Results

3.1. Victim characteristics

There were 412 records (274 fatalities and 138 injuries) of elephant attacks on humans. Males were attacked more frequently than females. Most of the victims (87.86%) had low level of education (illiterate or primary level). Ethnic people or *Janajati* were the most affected group followed by BCT, *Dalit*, *Madhesi* and Muslim. Age of the victims on elephant attacks range from infant (7 months) to 80 years old but most of them (71%) were adults of the age 24 - 64 years (Table 1). A quarter of elephant attacks occurred while people were chasing elephants and half took place around settlements or homes (Table 2). Most of the people attacked (88.8%) had low level of education (illiterate or primary education only) and the two third of the victims of elephant attacks were living in the thatched house.

Table 2. Characteristics of victims attacked by elephants in Nepal's Terai and Chure region of Nepal between 2000 and 2020.

Victim characteristics	Incident type		Total
	Death	Injury	
Sex			
Female	116	38	154
Male	158	100	258
Caste/ethnicity			
BCT	74	49	123
Dalit	46	20	66
Janajati	115	50	165
Madhesi	36	15	51
Muslim	3	4	7
Age			
<15	19	7	26
15-24	39	23	62
25-44	101	61	162
45-64	92	39	131
65+	23	8	31
Education			
Illiterate	141	63	204
Literate	44	36	80
Primary	55	27	82

Secondary or above	34	12	46
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Housing			
Cemented house	28	22	50
CGI roof house	31	27	58
Tiled roof house	28	9	37
Thatched house	187	80	267
Total	274	138	412

Table 3. Victim activity and location of elephant attacks in the Terai and Chure region of Nepal during 2000–2020.

Activity of the victim	Location of attack			Total
	Crop field	Forest	Home/ settlement	
Chasing elephants	11	22	70	103
Travelling	1	30	50	81
Sleeping or working at home	-	-	66	66
Fetching forest products	-	65	-	65
Guarding crops	36	1	2	39
Livestock grazing	2	23	1	26
Open defecation	-	-	21	21
Other	1	7	3	11
Total	51	148	213	412

3.2. Elephant characteristics

Most of the elephant attacks on humans (85.2%, n=412) were caused by solitary adult bulls or group of sub-adult males. Attacking elephants were mostly tusked in musth (Table 34). Only 6.8% and 4.6% of the attacks were caused by the elephants in herd and females separated from the herd respectively.

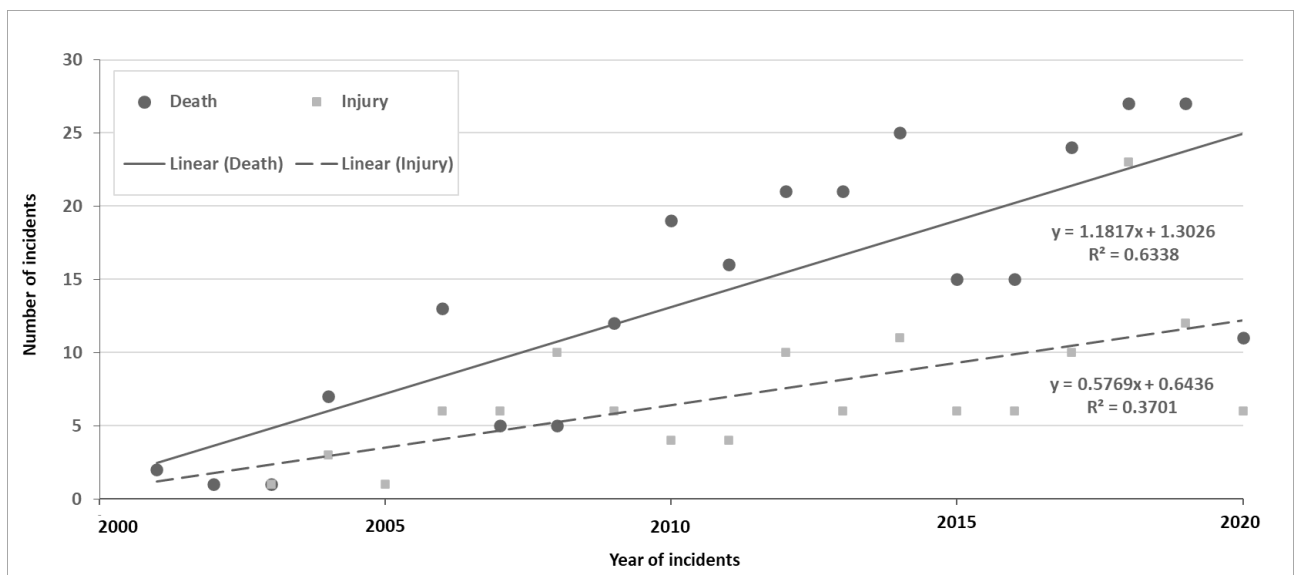
Table 4. Characteristics of the elephants involved in attacks on humans in Nepal's Terai and Chure region between 2000 and 2020.

Elephant characteristics	Attacks on humans		
	Death	Injury	Total
Group type			
Adult males	213	103	316

Adult females	6	13	19
Mixed group herd	17	11	28
Sub-adult male group	27	8	35
Unknown	11	3	14
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Adult/sub-adult bull elephant			
Yes	240	111	351
No	24	24	48
Don't know	10	3	13
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Elephant in musth			
Yes	131	76	207
No	71	36	107
Don't know	72	26	98
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Total	274	138	412
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3.3. Temporal and spatial distribution of elephant attacks on humans

Elephant attacks on humans varied significantly across months ($\chi^2 = 76.272$, $df = 11$, $p < 0.001$) with peak in post-monsoon season (September to December). Number of attacks were higher outside protected areas (Table 4) but the difference was not significant ($t = -1.0751$, $df = 19.296$, $p = 0.2956$). Linear regression showed a gradual increase of attacks between 2000 and 2020 (Figure).



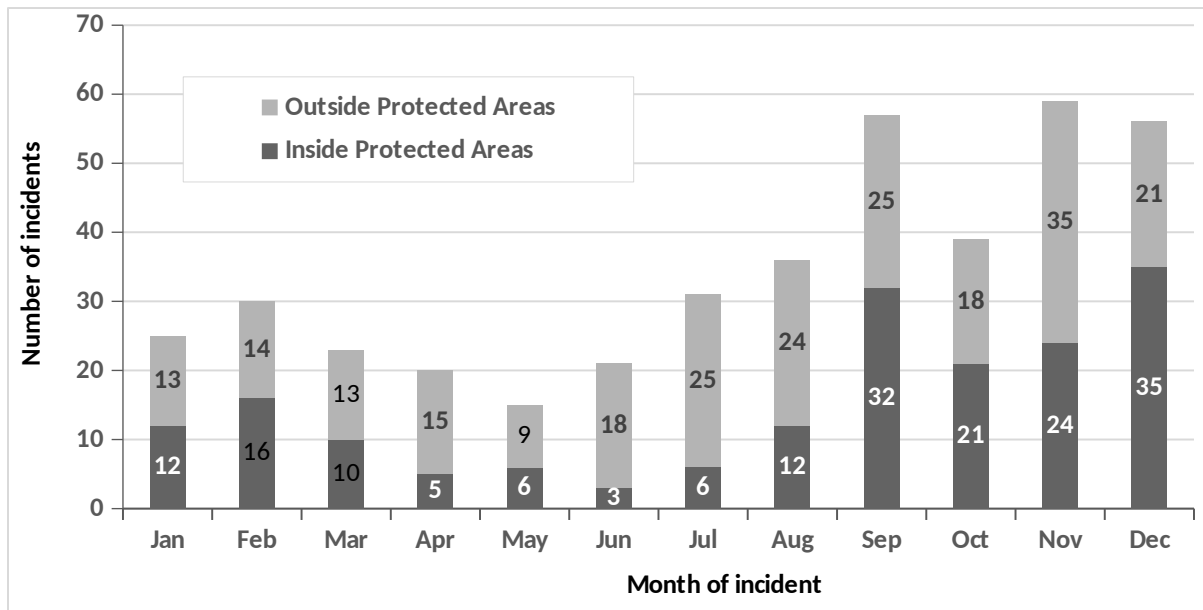


Figure 2. Temporal distribution of elephant attacks on humans (death and injuries) in Nepal during 2000 and 2020 a) over the years, b) over the different month.

Two peaks of the attacks on humans by elephants was observed, 1) afternoon (4–5 pm), and 2) evening (7–9 pm). In the forested areas, elephant attacks on humans are at peak in the afternoon, whereas, in settlement areas, elephant attacks peaked in the evening (Fig. 3).

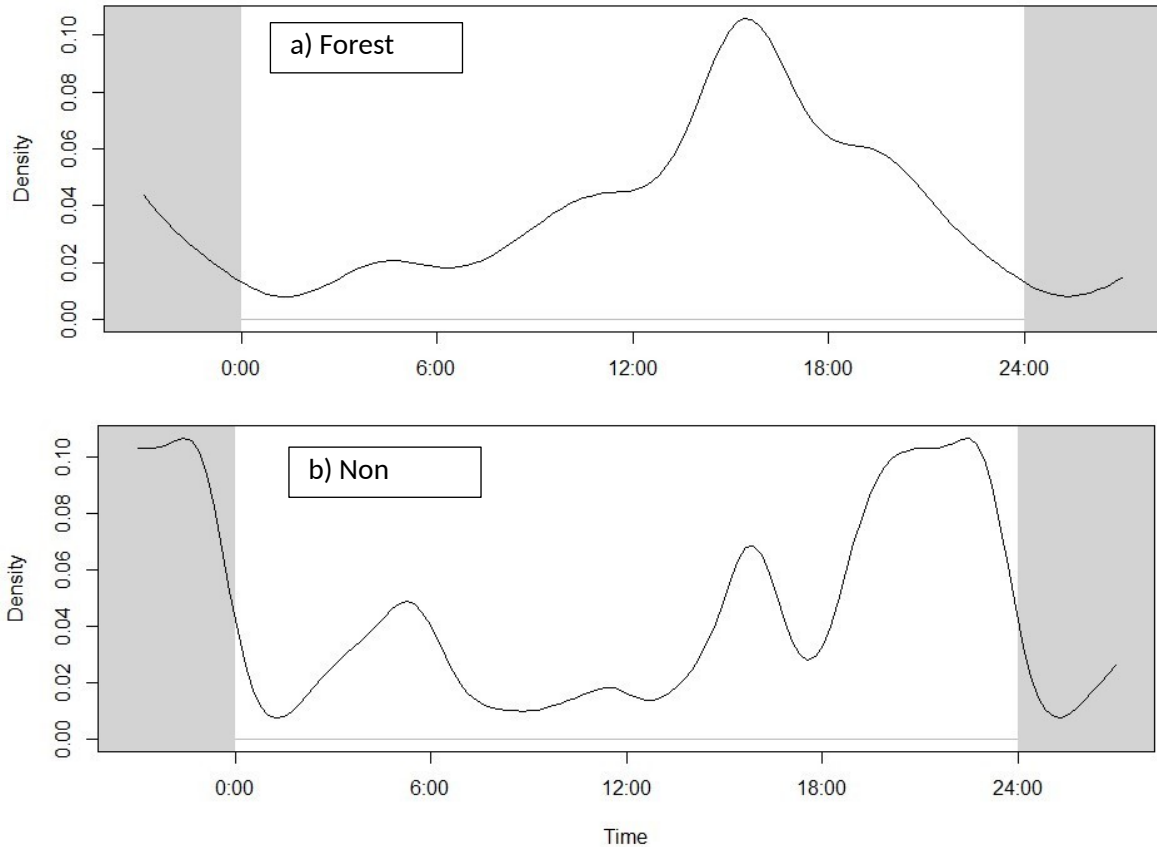


Figure 3. Elephant attacks on humans at the different time of day in a) forested areas and b) settlement and agriculture areas outside forests.

The number of attacks on humans varied significantly among the districts ($\chi^2=338.49$, $df = 19$, p -value < 0.01) with the highest number of incidents ($n=66$) from Jhapa and Bardia districts in the eastern and the western Nepal respectively (Figure). The majority of elephant attacks (67%) occurred within 500 m from the forest edge (Figure5).

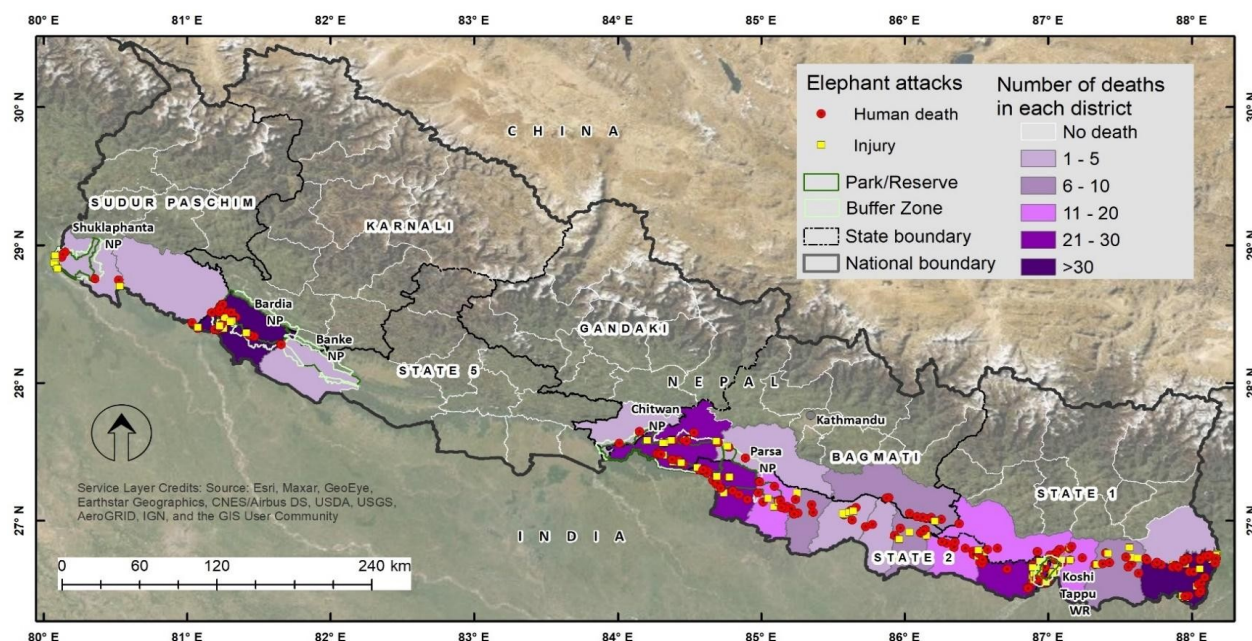


Figure 4. Spatial distribution of elephant attacks on humans in Nepal.

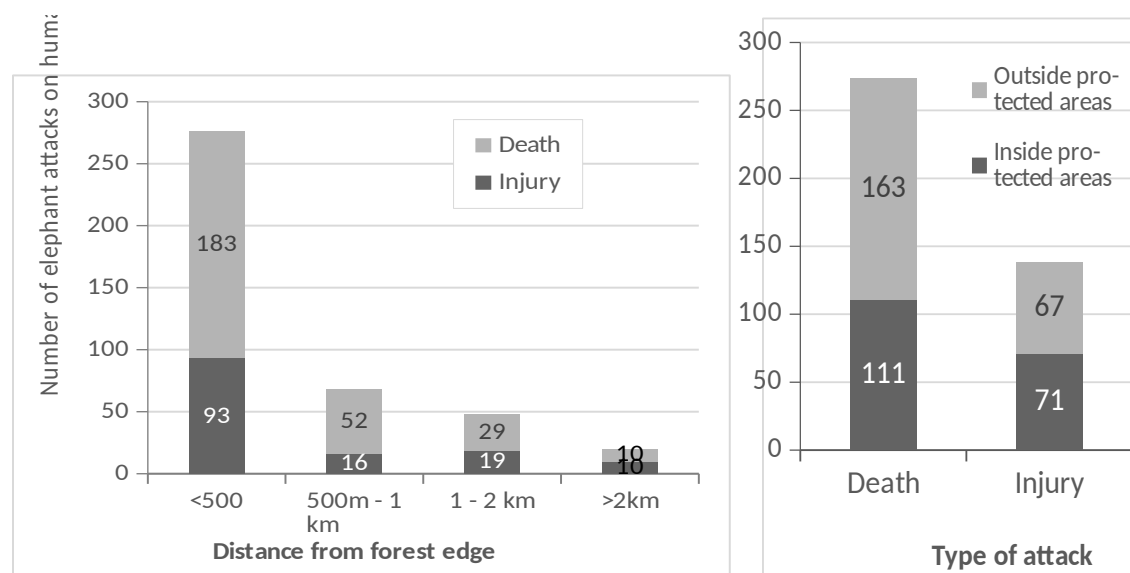


Figure 5. Spatial distribution of elephant attacks on humans in Nepal with respect to distance from forest edge (left) and inside/outside of the protected areas (right).

3.4. Factors associated with human fatality

Based on the averaged value of the top candidate models, people who were drunk and chasing elephants using fire crackers were more vulnerable to fatalities. In contrast, chasing elephants using fire was negatively associated to fatalities (Table 5).

Table 5. Factors associated with human fatality.

Parameters	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)	Significance
(Intercept)	0.652	0.795	0.798	0.81	0.413	
Crackers_Drums	1.095	0.508	0.511	2.14	0.032	*
Drunk	1.124	0.380	0.382	2.93	0.003	**
Fire_chasing	-1.715	0.576	0.579	2.96	0.003	**
House_typeCGI	0.063	0.588	0.592	0.10	0.915	
House_typethatched	0.795	0.504	0.508	1.56	0.117	
House_typedtiled	1.585	0.828	0.833	1.90	0.057	.
Place_attackForest	-0.914	0.530	0.533	1.71	0.086	.
Place_attackHome/settlement	-0.272	0.522	0.526	0.51	0.605	
prox_forest	-0.001	0.000	0.000	1.91	0.055	.
Age	0.013	0.010	0.010	1.21	0.223	
Ele_Musth	-0.294	0.358	0.360	0.81	0.414	

Significance codes: <0.001 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4. Discussion

Our study presents the most comprehensive analysis of the elephant attacks on humans in Nepal. Elephants attacked an average of 20 humans per year with two thirds resulting into fatalities in the Terai and Chure region. We documented the increasing trend of Elephant attacks on humans over the years. All three of our hypotheses were found true. Human response towards elephants was a major factor resulting in elephant attacks, supporting our first hypothesis. Higher number of attacks by elephants on humans was recorded outside the protected areas, mostly in proximity of the forest (66.99 % attacks in <500m from forest edge) supporting our second hypothesis. Over 76% of the attacks on humans were caused by the solitary bulls (third hypothesis).

4.1. Characteristics of the victims of elephant attack

Elephants attacked males more frequently than females which can be associated with the high mobility of males and their involvement in chasing the elephants (Sarker et al., 2015). For instance, majority of the males were attacked while chasing elephants or travelling whereas females were attacked more frequently while fetching forest products or working at home. Most of the attacks on humans occurred close to forests where socio-economically marginalized people reside (Pant et al., 2015; Neupane, Johnson, et al., 2017). Most of the attacked persons were illiterate, living in thatched house, an indicator of poor social and economic condition (Neupane et al., 2013). People living in thatched house often keep their grain storage close to where they sleep due to limited space in the house. It increases the chances of elephant damage in their house and risks of elephant attack (Naha et al. 2019). Neupane et al. (2013) documented low level of education and awareness about elephants as an important determinant of the elephant attacks on humans. High proportion of attacks on *Janajati* (ethnic) people can be associated with their involvement in local liquor production, consumption and selling for their livelihood (Parajuli, 2015; Lamichhane et al., 2018b). Such liquor also attracts elephants (Naha et al., 2019), primarily the solitary bulls, increases the chances of encounter with humans. Thus, marginalized people living in the settlements near to the forest edge, especially on the elephant migration routes are vulnerable to elephant attacks (ten Velde, 1997; Jadhav & Barua, 2012).

4.2. Characteristics of elephants attacking humans

Mixed herd elephants rarely attacked humans (<5% of the incidents) although they are involved in crop raiding during migration through agriculture areas or settlements (Naha et al., 2020). Solitary adult bull elephants were responsible for majority (76.7%) of attacks on humans in Nepal (Acharya et al., 2016). Attacks on humans were highly varied among elephant individuals. In our observation, a few individual bulls, who repeatedly visited human settlements and agriculture areas, were involved

in the majority of the attacks. Similar findings of attacks on humans by solitary bulls is reported from some parts of Bangladesh(Sarker et al., 2015) . With frequent interaction with humans, these bulls become familiar with the human behaviour and lose the natural fear. However, they are also harassed by people most of the time while raiding crops or grain stores. These irritating actions of humans make them more aggressive resulting in violent attacks. We identified 37 such bulls causing three quarters of all attacks on humans in the last twenty years. Out of 37 identified bulls, 19 were involved in more than five incidences and some caused a disproportionately higher number of attacks (up to 36). Such individuals can be termed “problem individuals” (Lamichhane et al., 2017; Swan et al. 2018). Thus, human-elephant conflict management should prioritise managing such problem elephants.

4.3. Temporal patterns of elephant attacks

Documented records of elephant attacks on humans in Nepal goes back to the 1970s (Upreti 2020, Pers. Comm.) with sporadic records until the late 1990s. In our study, we only included data between 2000 and 2020 (June). Elephant attacks on humans increased over the years from an average annual 11 (± 8.5 SD) attacks during 2000–2010 to 29 attacks (± 11.2 SD) during 2011–2020. The wild elephant population has gradually increased in Nepal from 52–53 individuals during the 1990s to 107–145 individuals in 2007 and 227 individuals in 2020 (Smith & Ishra, 1992; ten Velde, 1997; DNPWC, 2009; Ram & Acharya, 2020). Elephant movement is also increasing with escalating elephant population. Human population growth rate in the Terai and Siwalik region (1.72%) is also higher compared to the national average (1.35%; CBS, 2014). Consequently, the deforestation rate is also higher in this region especially in the Siwaliks (0.18% annually) (DFRS, 2015). The remaining forests are also becoming increasingly fragmented with planned and ongoing large-scale infrastructure development such as roads, railways, canals, industries, airports and urban areas forming barriers to elephant migration (MOFSC, 2015). Overlap in forest use by elephants and humans is increasing, resulting a high human–elephant interaction (Acharya et al. 2017; Lamichhane et al., 2018a; Mariki et al., 2015; Mukeka et al., 2019).

Elephant attacks on humans occurred throughout the year but peaked during September–December coinciding with the rice harvesting season. Lamichhane et al. (2018a) also shows that elephants use both forested and human-dominated areas but use of human-dominated areas varies seasonally with peak in the autumn. Pre-monsoon (March–June) had the lowest level of attacks as agriculture areas are devoid of crops and elephants are concentrated primarily in the forests feeding on climbers, tree barks and new grass (Koirala et al., 2016; Lamichhane et al., 2018a).

Most of elephant attacks occurred between 15:00 – 22:00 hours with two peaks at ~16:00 and ~20:00. Elephant attacks in forested areas peaked during the afternoon (~16:00) when human activity, mainly cattle grazing, and fodder and forest resource collection, is high inside the forests. The elephants generally rest during the mid-day hot period and start become active with decreasing temperature in the afternoon (after 15:00). This increases the chance of interaction between elephants and humans. Close to the time of sunset (~18:00), most of the people are returning home from the forest while elephants remain inside forest so decreasing the chances of interaction between them. Elephant attacks again increase in the evening (19:00–21:00) when elephants enter the settlements or agricultural fields and people come in direct confrontation while chasing elephants away.

4.4. Spatial pattern of elephant attacks

Two-thirds of elephant attacks on humans occurred within 500 -meters from the forest edge. Similar finding was also documented in previous studies (Neupane et al., 2018; Ruda et al., 2018; Pant et al. 2016). People living in proximity of forests are vulnerable to elephant attacks because 1) chances of encountering elephants is high at close distance to forest, 2) generally marginalized communities live in these areas with lack of proper housing (thatched houses), and 3) low level of education and awareness. Similar finding of a higher number of attacks by wildlife close to forest or park boundary (<1 km) and an inverse relationship between the distance from the forest edge and wildlife attacks is reported in other studies (Gurung et al., 2008; Lamichhane et al., 2018b; Pant et al., 2016).

A higher number of elephant attacks outside protected areas (59.5%) in our study is consistent to Acharya et al. (2016). Similar results with higher conflict incidents outside protected areas has been reported from north-east India (Choudhury, 2004a). Elephants require large areas to fulfil their needs of large quantity of forage, water, and also finding mates. Their home ranges surpass the protected area. People living close to protected areas are more aware about elephant behaviour and respond accordingly (Lamichhane et al., 2019). Beyond protected areas, human response towards elephants is more aggressive resulting in a high number of human casualties as well as retaliatory killing of elephants (25 out of 33 retaliatory killing in past 20 years, unpublished data compiled by the first author).

The elephant attacks on humans were concentrated in four pockets, Jhapa, Koshi, Chitwan Parsa, and Bardiya. Despite the smaller population of elephants (~35) in eastern Nepal, the number of attacks on humans is proportionately higher (43% of total attacks in Nepal). The reason for such a high casualty in eastern Nepal especially in Jhapa district of south-eastern border of Nepal is because of 1) the highly fragmented habitats outside of the protected areas, 2) historical migration route of

elephants from West Bengal, India straddling the national boundary, 3) low level of awareness on elephant behaviour, and 4) provoking human actions towards elephants. Historically, ~100 elephants used to migrate annually from West Bengal (India) entering Nepal from the eastern border during September–October and May–June (Mallick, 2012). While migrating, they often come in confrontation with people as they are forced to travel through settlements and agricultural land, with a large part of their historic migration route encroached by people (Choudhury, 2004b). A fence installed in Bahundangi area (Jhapa district) at the Eastern border of Nepal have contributed in reducing human-elephant conflict in the fenced areas. However, the elephant continue their movement in Nepal from south of the fenced area (Jyamiregadhi and Jalthal) (Naha et al., 2019; NTNC, 2019). Some elephants, especially males, break the fence and continue their movement up to Koshi Tappu WR and westwards.

About one quarter (24%) of all elephant attacks on humans in Nepal occurred in Koshi Tappu WR and its periphery. Koshi Tappu WR acts as a stepping stone for the elephant population in eastern Nepal. Koshi Tappu WR (173 km²) is much smaller than the home range of elephants (188 – 400 km², Williams et al., 2008; Alfred et al., 2012; Williams, Krausman and Asir, 2015). With the high dependency of communities on the reserve for grazing, fodder, firewood and fishing, elephants and people come in frequent confrontation. The situation is further aggravated in the densely populated agrarian areas in the periphery of the reserve.

Human casualty was recorded throughout Central (upto Nawalparasi East) and Eastern Terai. In the Chitwan-Parsa Complex in central Nepal, 27.4% of the elephant attacks were recorded, mostly from Chitwan, Parsa and Bara districts. There is a gap in elephant distribution between the central population (Nawalparasi East) and the western population (Bardia) with only a sporadic presence in Banke, Dang and Kapilvastu districts (Lamichhane et al. 2018a). The largest elephant population (>100) in Nepal exists primarily in Bardia NP in western Nepal where 16.7% of total elephant attacks on humans occurred. Elephants in the western population also migrate through the Chure-Siwalik foothills West of Bardia reaching up to Shuklaphanta NP causing some incidents of attacks on humans (ten Velde, 1997).

4.5. Factors associated with the human fatality

Our results of two third of elephant attacks resulting in the fatality is consistent with Acharya et al. (2016). Human behaviour and responses towards elephants were the major factors to cause elephant attacks on humans. Aggressive human behaviour towards elephant with intolerance was the major determinant of human fatality in elephant attack (Nelson et al., 2003). People were killed mostly while chasing wild elephants using fire crackers and other high sound and light objects. Drunk

people were more vulnerable to deaths if elephant attacked (Neupane, Kunwar, et al., 2017). Negative association of fatalities while chasing elephants using fire torch indicates it as a safe and effective method for pushing elephants outside of the village.

5. Conclusions

Human casualties from elephants have been increasing with its multifaced impact on human-elephant coexistence in Nepal. Elephant attacks were concentrated in proximity of forests primarily affecting the socio-economically marginalized communities. Most of the attacks on humans were caused by solitary bull elephants. Human response towards elephant was a major factor associated with the elephant attacks on humans. Chances of elephant attacks and human fatalities increases when drunk people are chasing elephant. This urgently requires a human elephant conflict (HEC) mitigation strategy to combat this issue. Local people as well as the Government of Nepal (GON) have adopted various preventive and curative measures such as fences in hotspots, problem animal management, and relief support for victims/families to reduce both human casualties and elephant retaliation. These measures should be continued and additional activities such as integrated settlement, safe housing for marginalized community and community grain house in the settlement should be promoted to reduce the confrontation between elephants and humans. Conservation of elephant should be carried out in entire landscape, extending beyond the boundary of protected areas to reduce threats of elephant extinction. Conservation awareness campaign should be carried out throughout the landscape and involve community for elephant conservation.

Acknowledgements

We thank Wildlife Institute of India, Ministry of Forests and Environment (Nepal), Department of National Parks and Wildlife Conservation (DNPWC), National Trust for Nature Conservation (NTNC), ZSL Nepal, WWF Nepal for supporting at different stages of the study. Ms. Carol Inskipp and Dr. Narendra Man Babu Pradhan reviewed and provided crucial feedback on earlier version of the manuscript. We acknowledge the contribution of field assistants Mr. Suman Acharya, Mr. Dinesh Ghimire, Mr. Badri Chaudhary, Mr. Buddhi Binod Acharya and Shankar Luitel. We are indebted to the support of Director General of DNPWC, National Park/Wildlife Reserve wardens and Divisional Forest Officers of the Terai region during this study. The study would not be possible without the funding support of Rufford Small Grants Foundation, International Elephant Foundation, USAID – Hariyo Ban Program through WWF Nepal and ZSL Nepal.

Author contributions

AKR, NS, SM & BP designed the study; AKR conducted the fieldwork; AKR, BR & RA analysed the data; AKR & BR wrote the first draft of the manuscript; HSB, NLN and all authors revised the manuscript.

Data Accessibility

Data and outputs including the Rcodes will be available after article is published. These files are deposited in Dryad (<https://doi.org/10.5061/dryad.f7m0cfxvp>).

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505 Supplementary Information S1. Sex of victim and their activity while attacked by elephant.

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Activity of the victim	Death		Injury		Total
	female	male	female	male	
Chasing elephants	14	51	13	25	103
Fetching forest products	23	20	14	8	65
Guarding crops	7	23	3	6	39
Livestock grazing	5	12	4	5	26
Open defecation	6	5	4	6	21
Other	1	7	1	2	11
Sleeping/working at home	27	22	5	12	66
Travelling	16	35	10	20	81
Grand Total	99	175	54	84	412

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