Research article

Temporal and spatial pattern of wildlife attacks on human in Chitwan National Park, Nepal

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Abstract

Wildlife attacks on humans pose a critical challenge to wildlife conservation. Comprehensive information about the conflict cases can be vital for effective wildlife management and conservation. In this study, we assessed the temporal and spatial patterns of wildlife attacks on humans in Chitwan National Park between January 2009 to December 2020 by using the annual reports published by the park. Our analysis revealed that out of the nine-wildlife species involved in conflicts, rhinos, elephants, tigers, sloth bears, and wild boars had significantly higher involvement in conflicts with humans. The findings showed that an average of 42 annual attacks and 10 human fatalities cases were reported annually. Of these species, rhinos exhibited the most frequent involvement in conflicts (38%), while elephants were found to be the most lethal species, causing an average of 3.75 human fatalities per year. The trend line indicated a marginal increase in wildlife attacks on humans by 3.97 per year (adjusted R^2=0.36). Our study further revealed that wildlife attacks were mostly concentrated in the winter season (χ^2=1.088, df=3, p<0.05), with elephant, rhino, and tiger attacks predominantly occurring in the proximity of human settlements. To evaluate the risk factors of human deaths due to wildlife attacks, we utilized logistic regression analysis and found elephant attacks were associated with the highest probability of causing human fatalities (odd ratio=15.2, p<0.05), followed by tiger attacks (odd ratio=8.41, p<0.05). The study revealed an increasing trend in attacks, predominantly occurring in winter and near human settlements. Elephants and tigers are identified as the highest risk factors for human fatalities. Understanding these patterns is crucial for effective wildlife management and conservation efforts.

Keywords: Chitwan; Conflict; Fatalities; Settlement area; Winter

1 | Introduction

Human-wildlife conflict (HWC) occurs when the needs and behaviors of humans and wildlife overlap. This interaction results in harm to both humans and wildlife (Inskip & Zimmermann 2009; Acharya et al. 2016; Ruda et al. 2018; Adhikari et al. 2022). As a result of HWC, rare and endangered wildlife species are at risk (Acharya et al. 2016; Bhandari et al. 2019). Local people are also restricted from accessing natural resources, which are a means of subsistence for them (Mohamed Ahmed 2012). Historical data shows that large mammals such as elephant (*Elephas maximus)*, leopards (*Panthera pardus),* tiger (*Panthera tigris*), rhinoceros ((*Rhinoceros unicornis)*, and snow leopard (*Panthera unica*) are particularly involved in conflict in Asia (Distefano 2005). These animals are involved in several types of conflicts, including crop raids, livestock predation, property damage, and human fatalities (White & Ward 2010). Such

incidents, may lead to negative attitudes toward the animals, resulting in lethal control or retaliatory killing of wildlife (Treves & Bruskotter 2014).

Although Nepal has achieved success in wildlife conservation with people's participation, HWC remains a significant challenge for managers (Baral et al. 2022). About 26 species of wildlife were associated with conflict cases in 69 districts of Nepal. Incidences were not recorded in Darchula, Humla, Manang, Khotang, Pyuthan, and Rolpa (DNPWC 2017). Among these species, 18 were mammals and 7 were reptiles (DNPWC 2017). Similarly, wildlife attacks in Nepal accounted for 63.4% of human injuries, 36.3% of casualties, and 0.4% of harassment (DNPWC 2017).

Chitwan National Park (CNP), the oldest national park of Nepal has been experiencing human and wildlife conflicts since its establishment (Sharma 1990). Consequently, the participatory approach to conservation was introduced in the 1990s (Heinen & Paudel 2015). This initiation

introduced a buffer zone area that benefits both park and the people through a revenue-sharing mechanism of 30-50%. It has also led to an increase in the population of mega species like rhinos and tigers in the park (DNPWC 2021; DNPWC & DFSC 2022). Similarly, the human population density has been also increasing annually in the district (CBS 2023). Tiger population, which was 91 in 2009, rose to 128 in 2020 (DNPWC & DFSC 2022). Similarly, the rhino population, which was 496 in 2008, rose to 694 in 2021 (DNPWC 2021). However, the resources and habitat of the park are limited, leading to increases in the competition for food and habitat not only between wildlife but also with humans. This shortage trigged the movement of animals outside the park, resulting in conflict with humans.

Most studies in CNP have focused on specific species such as tigers and their prey species (Dhungana et al. 2017), elephants (Pant et al. 2015), and rhinos. There have been 88 recorded human death due to tiger attacks since 1979-2006 (Gurung 2008). A study conducted in CNP showed an increasing trend in human-wildlife conflict from 2003 to 2013 (Silwal & Kolejka 2016). According to the study by Silwal and Kolejka (2016), a total of 329 attacks on people were carried out by rhinos (38%), tigers (21%), sloth bears (18%), elephants (9%), and wild boars (8%). In Nepal, the government has implemented various HWC conflict management strategies and compensation schemes. However, the number of conflict cases has been increasing in recent years (Bhandari et al. 2019). To develop effective and sustainable conservation strategies, it is crucial to understand the patterns of HWC. The objective of our study is to identify the trend of wildlife attacks on humans from 2009 to 2020 and to determine the spatial and temporal patterns of the conflict cases.

2 | Materials and methods

2.1 | Study area

The study was conducted in Chitwan National Park (27° 16.56'–27°42.14'N and 83°50.23'–84°46.25') and its buffer zone area (Fig. 1). CNP is Nepal's first national park, designated in 1973. The park is located in the southern part of Nepal, covering an area of 953 km². It is home to rare and threatened flora and fauna, such as the greater one-horned rhino, Bengal tiger, Asian elephant, and clouded leopard. There are 70 species of mammals, 600 species of birds, 50 species of reptiles, 156 species of butterflies, and 120 species of fish reported in the park (CNP 2017). The park is predominantly covered by forest (80%), including Sal (*Shorea robusta*) forest, riverine forest, and hardwood forest. Approximately 12% of park consists of grassland, 5% is exposed surface, and 3% is occupied by water bodies (Thapa 2011). The buffer zone spans 750 km² and comprises forest patches, farmland, and human settlement. There are 54,155 households residing in the buffer zone of the park (CNP 2022). The
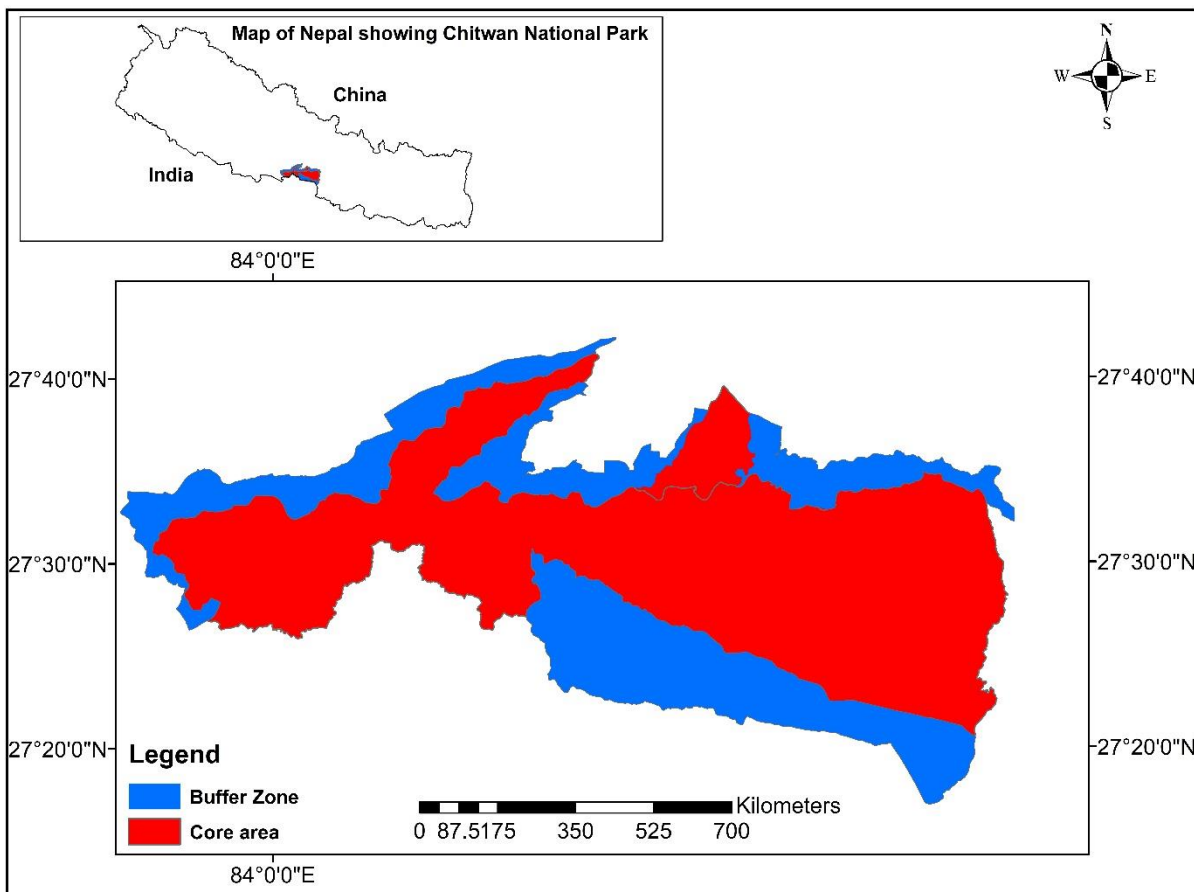
Figure 1. Chitwan National Park and its buffer zone area

majority of people are farmers who depend on the buffer zone forest for fodder, fuelwood, thatch grass, and livestock grazing (CNP 2013). In recent years, people have started to stall feeding for livestock due to restrictions on grazing and a shortage of labor (Gurung 2008).

2.2 | Data collection and analysis

Data on human fatalities and injuries were obtained from annual reports of CNP and DNPWC, covering the period from January 2009 to December 2020. In addition to CNP and the buffer zone, data from the district forest offices of Chitwan and Nawalparasi, as mentioned in the annual reports, were also incorporated. The data were recorded based on the Nepalese fiscal year, which runs from mid-July to mid-July according to the Nepalese Calendar (Bikram Sambat). To ensure consistency in data analysis, the fiscal year's data were converted into AD.

Wildlife attacks on humans were categorized as either "death" or "injury". The timing of each conflict event (year, month, and season) was determined. The 12 months were grouped into four seasons: winter (January, February, December), spring (March, April, May), summer (June, July, August), and autumn (September, October, November). Regarding spatial location, data from 2015 to 2020 were presented. The location of conflicts was classified as "Farmland", "Forest", "Home", and "River". The category of "Home" includes houses, livestock sheds, other structures, gardens, and nearby vegetable plots. Similarly, "Farmland" includes agriculture production areas (Acharya et al. 2016).

The wildlife attacks were classified as "fatalities" and "injuries", coded as 1 and 0, respectively. Temporal and spatial patterns were analyzed through data visualization using bar plots and tables. Our first hypothesis postulates that the frequency of attacks by each wildlife species is independent of time (year, season, month) and location (home, farmland, forest, and river). The alternative

hypothesis stated that the frequency of attack by each wildlife species is dependent on time and location. To test our hypothesis, we employed a chi-square test of independence, which determines if there is an association between two categorical variables. Additionally, our next hypothesis stated that there is no association between the wildlife species and their likelihood of causing human fatalities during attacks. The alternative hypothesis was there is an association between wildlife species and the likelihood of causing human fatalities. To test this hypothesis, logistic regression was used. All data analyses were conducted using R 4.2.1 (R Core Team 2022).

3 | Results

3.1 | Overall conflict pattern

A total of 504 incidents were registered during the period from 2009 to 2020. Our data reveal that the wildlife species involved in these incidents were rhinos (38%), wild boars (15%), sloth bears (15%), tigers (14%), elephants (13%), and others (5%) (Table 1). The highest number of injuries were caused by rhinos, while elephants were responsible for the highest number of fatalities (Fig. 2). In total, there were 120 cases of fatalities and 384 cases of injuries on average, 10 fatalities, and 32 injuries were reported annually. Elephants exhibited the highest average fatalities at 3.75 per year, followed by tigers and rhinos with 3 per year and 2.91 per year, respectively.

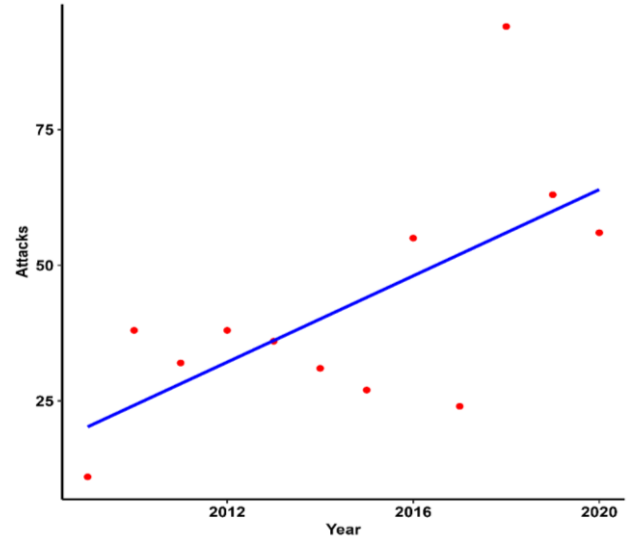## 3.2 | Temporal pattern of human injuries and fatalities

The study reveals an increasing trend in the frequency of wildlife attacks on humans. The trend line analysis indicates a significant annual increase of approximately 3.97 attacks (adjusted $R^2=0.36$, $p<0.05$) (Fig. 3). The highest number of attacks was recorded in 2018, followed

Table 1. Overall conflict pattern from 2009 to 2020

Year/Species	Rhino	Sloth Bear	Tiger	Wild Boar	Elephant	Others	Total
2009	4	4	2	0	0	1	11
2010	14	7	4	3	8	2	38
2011	12	7	5	2	6	0	32
2012	12	6	11	3	5	1	38
2013	10	7	10	7	2	0	36
2014	12	6	8	3	2	0	31
2015	13	8	2	1	3	0	27
2016	24	1	11	12	7	0	55
2017	11	5	1	2	5	0	24
2018	28	14	7	11	17	17	94
2019	26	4	4	14	9	6	63
2020	22	6	5	19	3	0	55
Total	188	75	70	77	67	27	504
%	38	15	14	15	13	5	
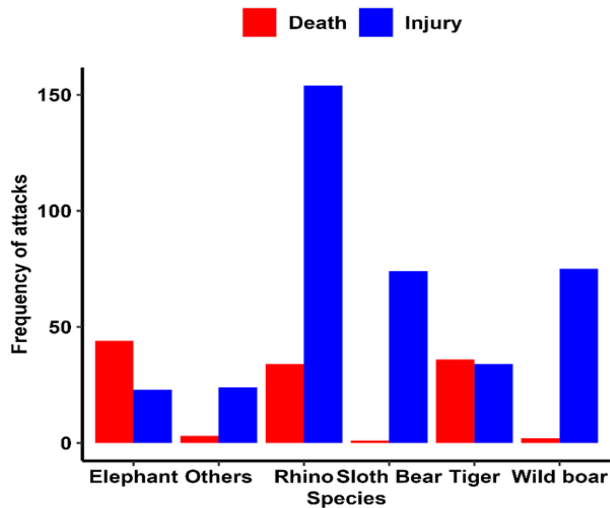
**Figure 2.** Frequency of attacks (death and injury) by different wildlife species from 2009 to 2020.

by 2019 and 2016. Furthermore, the majority of conflict incidents occurred during winter (n=157), followed by spring (n=138), autumn (n=121), and the fewest incidents during summer (n=88) (Fig. 4). In terms of monthly distribution, December has the highest number of incidents, followed by January and May (χ^2=44.24, df=11, p<0.05). The total number of incidents varied significantly throughout the year (χ^2=125.76, df=11, p<0.01). Regarding wildlife species, most attacks occurred during the winter season. However, tiger attacks were most prevalent in the spring, while elephant attacks predominantly took place during autumn. The interaction between different species and seasons exhibited significant variation (χ^2= 41.088, df=15, p<0.05)

3.3 | Spatial pattern of wildlife attacks on human

A total of 227 incidents of wildlife attacks were recorded between the years 2015 and 2020 in different locations,

Figure 3. Trend line showing the wildlife attacks on human from 2009 to 2020.

including farmland, forest, home, and river (Acharya et al. 2016). The majority of the attacks occurred in settlement areas or homes (40%), which encompass houses, livestock sheds, other structures, gardens, and nearby vegetable plots (Fig. 5).

Elephants, rhinos and tigers were frequently involved in conflict around the people's settlement areas and buffer-zone forest, respectively. Conversely, sloth bears and wild boars were primarily involved in incidents that took place in farmlands. In general, our findings suggest that elephant attacks have the highest probability of causing human fatalities, with an odd ratio of 15.2, followed by tiger attacks with an odd ratio of 8.41. However, our study did not find any significant association between rhino, sloth bear, and wild boar attacks and human fatalities (Table 2).
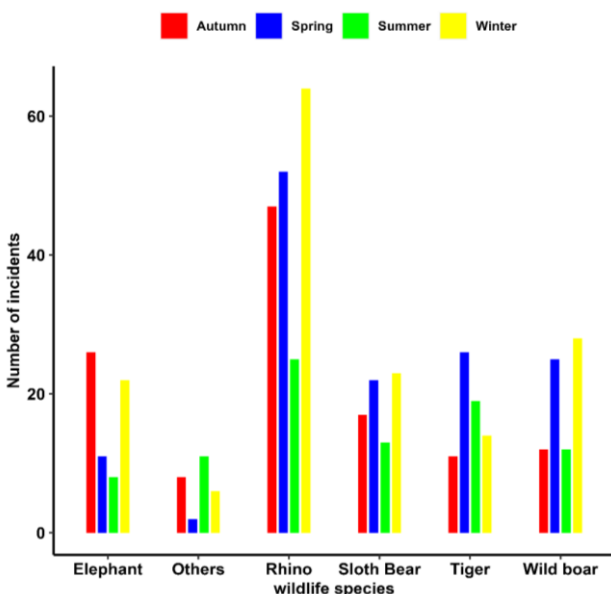
Figure 4. Specific seasonal occurrence of wildlife attacks.
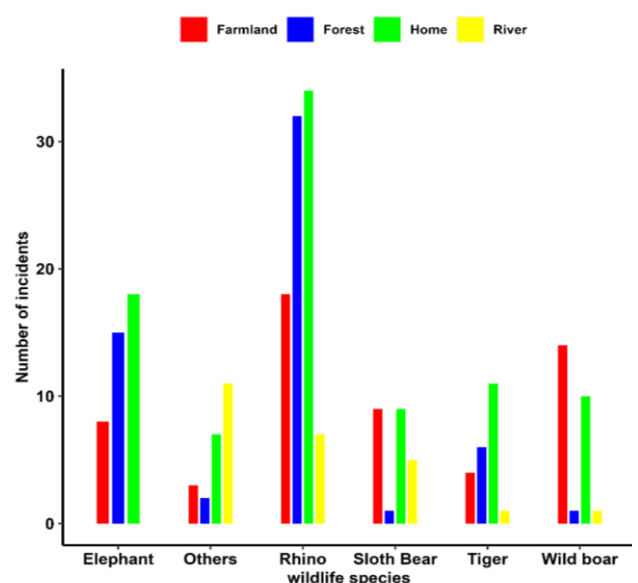
Figure 5. Wildlife attacks on different location.

4 | Discussion

Our paper presents a comprehensive analysis of wildlife attacks on humans registered in Chitwan National Park. The study period revealed an increasing trend in wildlife attacks on humans. Rhino, wild boar, and sloth bear were the top three conflict-causing species followed by tiger and elephant. However, elephants caused the highest number of fatalities, followed by tiger and then rhino. The movement patterns of these megaherbivores, such as using farms, roads and human trails, may contribute to increased conflicts with humans (Adhikari et al. 2022; Baral et al. 2022). Our findings suggest that the likelihood of human fatalities increases when drunk people chase the elephant during interaction, as the human response plays a crucial role in provoking attacks (Ram et al. 2021). Therefore, our results highlight human-elephant conflicts as the most serious challenge human wildlife conflict within the park.

Throughout the study period, an average of 42 wildlife attacks on humans were recorded annually. This aligns with similar findings reported in CNP (Lamichhane et al. 2018), which documented an average of 40.6 wildlife attacks on humans annually from 1988 to 2016. The consistency in these results emphasizes the significant occurrence of human-wildlife conflicts in the park. These

Table 2. Logistic regression showing the different wildlife species attacks resulting death of human

	Estimate	Std. Error	Z value	P value	Odd ratio
Intercept	-2.04	0.61	-3.34	0.001	
Rhino	0.56	0.64	0.88	0.37	1.75
Sloth bear	-2.22	0.17	-1.88	0.058	0.11
Tiger	2.13	0.65	3.25	0.001	8.41
Wild boar	-1.54	0.94	-1.63	0.101	0.22
Elephant	2.72	0.66	4.10	0.0005	15.2

conflicts can be attributed to various factors, including habitat fragmentation (Acharya et al. 2017), high human population density (CBS 2023), people's dependence on forest for livelihood, forest encroachment, habitat destruction inside the park due to invasive plant species, and habitat improvement in buffer zone through forest restoration (Pant et al. 2015; Silwal et al. 2016). Additionally, the rise in the population of major wildlife species like rhinoceros (DNPWC 2021) and tigers (Baral et al. 2022; DNPWC & DFSC 2022) also plays a great role in human-wildlife conflict. Tigers attacks have been observed within a 2 Km range from the park's boundary (Gurung 2008; Dhungana et al. 2017). However, the conflict-causing tigers is typically different from the source population. Tigers without fixed territories and those physically impaired in hunting prey are more likely to engage in conflicts with humans (Lamichhane et al. 2018).

Similar to the findings of Silwal et al. (2016), our study also reveals that the winter season has the highest number of attacks. The foggy weather during winter reduces visibility, increasing the chances of sudden interactions between humans and wildlife nearby (Silwal et al. 2016). Most incidents occurred in the vicinity of human settlements, where wildlife attacked people while they were moving around their homes. Our study found that most of the incidents occurred around the settlement area of people. Elephants, tigers and rhinos predominantly attacked people around residential and farmland areas, which aligns with the result of (Bhandari et al. 2020). The reason for wildlife attacks in the settlement areas may be related to the search for crops and livestock. Additionally, loud noises and bright lights used by humans to deter wildlife may trigger violent behavior and lead to attacks. Sloth bear primarily attacks a human in farmland areas, as they are commonly found in areas with an abundance of termites and fruits (Paudel et al. 2022). Similarly, wild boars are considered the drivers of human and wildlife conflict in the protected area of Nepal (Pandey et al. 2015). Electric fences and wire nets have proven ineffective against wild boars, as they adapt easily to changing environments (Pandey et al. 2015). Our study relies solely on registered cases in CNP, which underestimate the actual incidents due to underreporting. Therefore, we recommend combining registered data with field data to gain a better understanding of the patterns of wildlife attacks on humans.

5 | Conclusions

In conclusion, this study summarizes the spatial and temporal patterns of wildlife attacks on humans in CNP. The analysis revealed an increasing trend in wildlife attacks; mostly near the human settlement areas over the study period. The involvement of diverse wildlife species in conflict indicates the diversity of potential conflict scenarios. Understanding of spatial and temporal patterns as well as the ecological and behavioral characteristics of wildlife species is crucial for developing mitigation strategies and for the conservation of wildlife.

Acknowledgements

Authors' contributions

Kandel, S. conceptualized the study, collected and analyzed the data, and prepared the first draft of manuscript. Silwal, T., Yadav, S. K., and Dhakal, S. revised and finalized the manuscript.

Conflicts of interest

Authors declare no conflict of interest.

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