Journal of Animal Diversity

Online ISSN 2676-685X

Volume 5, Issue 4 (2023)

Research Article

http://dx.doi.org/10.22034/JAD.2023.5.4.1

Status, patterns, and trends of human-wildlife conflict in the buffer zone of Chitwan National Park, Nepal

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Citation: Parajuli, A., Basyal, C. R., Baral, M., Adhikari, H., Yadav, S. K., Basnet, J. B. and Timilsina, S. (2023). Status, patterns, and trends of human-wildlife conflict in the buffer zone of Chitwan National Park, Nepal. *Journal of Animal Diversity*, 5 (4): 1–14. http://dx.doi.org/10.22034/JAD.2023.5.4.1

Received: 30 September 2023
Accepted: 25 December 2023
Published online: 31 December 2023

Abstract

Human-wildlife conflicts (HWC) are common in locations where human settlements and wildlife ecosystems intersect. Conflict between people and wildlife is a significant conservation issue that is challenging to resolve. Therefore, this research aims to reveal the trends, status, and patterns of HWC in the Buffer Zone (BZ) of Chitwan National Park (CNP) from July 2012 to July 2021. Primary data were collected through household surveys, key informant interviews (KIIs), direct observation, and secondary data from park offices, the Buffer Zone User Committee (BZUC), and institutions through reports, documents, and booklets. Our study shows crop raiding was the most common and notable problem, followed by livestock depredation, with 4416 documented cases. According to the report, elephants are the biggest conflict-causing species, accounting for 37.86% of overall losses. HWC occurrences peaked in 2018, accounting for 23.41% of total incidents from July 2012 to July 2021. During the research period, victims of HWC received compensation totaling ~0.805 million US dollars (106641196.00 Nepalese rupees). Autumn is identified as the greatest season for HWC, owing to paddy harvesting, which draws animals. Most people believe that the population density of wildlife increases in the park due to positive human participation. By adopting a participatory management approach to conservation, the park has the potential to increase the number of locals who benefit from it significantly.

Key words: Adaptation, buffer zone, compensation, crop raiding, Human-wildlife conflicts (HWC), perception

Introduction

Conflicts between humans and wildlife have emerged as one of the most significant challenges for wildlife conservation on a global scale (Acharya et al., 2016; Pant et al., 2023; Pratap et al., 2023). The expansion of rapid human settlement and increased encroachment on natural habitats has increased human-wildlife interactions, and increasing conflict situations (Pathak, 2023). These conflicts often result in property damage, livestock depredation, economic losses, and danger to human lives and even wildlife populations (Acharya et al., 2016; Angelici, 2016; Hudu et al., 2017). Additionally, the continuous expansion of human population results in conflicts between people and wildlife over limited resources, such as crop raids, livestock predation, property damage, human injury, and retaliatory killing (Peterson et al., 2010; White and Ward, 2010). Human-wildlife conflicts (HWC) are often more severe among farmers who reside in rural communities (Treves and Bruskotter, 2014; Akampulira et al., 2015; Baral et al., 2021) who may lose 10-15% of

their entire crop yield due to wildlife damage (Lamarque et al., 2009; Madhusudan and Sankaran, 2010). For example, in Bardia National Park (BNP), Nepal, 70% of respondents interviewed experienced crop damage by Asian elephants *Elephas maximus* Linnaeus (Shahi et al., 2022). In Chitwan National Park (CNP), Nepal, crop damage represented 70% of all HWC reported during 2013–2017 (Dangol et al., 2020). Addressing HWC has become a global priority for conservationists and policymakers (Lamichhane et al., 2019; Chaudhary et al., 2021). Reducing human-wildlife impacts requires a combination of strategies based on the location and species involved that can be broadly categorized into preventive measures (or direct interventions), and indirect interventions (Treves et al., 2009; Goodrich, 2010). Direct interventions aim to reduce the severity of the impacts by lowering the frequency and extent of damage from wildlife, whereas indirect interventions aim to raise the tolerance of residents to impacts (Treves et al., 2009).

The HWC consequences are more severe in the sub-optimal tropics and developing countries (Lamarque et al., 2009; Acharya et al., 2016). In Asia, HWC has been particularly pronounced due to the region's high population density and rich biodiversity (Braczkowski et al., 2023). Among the countries in Asia, Nepal stands out as a crucial example, given its diverse ecosystems and the coexistence of a large human populace alongside a wide range of wild species (Bista and Song, 2022). Research about HWC in Nepal can provide essential guidance and motivate local communities towards biodiversity conservation, management, and research priorities (Primack et al., 2013). In Nepal, most protected areas (PAs) are designed to conserve large mammals. Large mammals, such as the Asian elephant *Elephas maximus*, the greater one-horned rhinoceros *Rhinoceros unicornis* Linnaeus and the Bengal tiger *Panthera tigris tigris* (Linnaeus) are causing more HWC since PAs were established and implemented (Silwal et al., 2013; Pandey et al., 2016). The CNP in Nepal, a renowned PA known for its rich wildlife diversity, experienced a significant increase in HWC over recent years (Pathak, 2023). We selected CNP for this study because it typifies a national park in the tropics where wildlife density inside the park is increasing, and communities around the park have experienced frequent economic losses and safety threats from wildlife since its establishment in 1973 (Sharma, 1990; Lamichhane et al., 2019). CNP is also a flagship park in Nepal whose success or failure largely determines the overall direction of wildlife conservation in the country (Carter et al., 2012). Participatory conservation and habitat restoration around the park periphery was initiated in the 1990s, and a buffer zone (BZ) was legally declared in 1998 (Budhathoki, 2004). Despite their existence for over 20 years, only a few studies focus on BZ programs in Nepal, and whether they have helped reduce HWC is poorly understood (Lamichhane et al., 2019).

The escalation of HWC in CNP has raised concern among local communities and conservationists (Ghimire et al., 2022). These conflicts threaten conservation efforts and impact the safety and livelihoods of the people dwelling nearby (Kandel et al., 2023). Understanding the conditions, patterns, and dynamics of HWC in this region is critical to developing effective mitigation measures and sustainable coexistence between people and wild species. Numerous studies have been conducted to understand the HWC in Nepal; however, CNP lacks sufficient research on the identification of attacking species, factors that influence attacks, or the effects of attacks on victims (Hudu et al., 2017; Lamichhane et al., 2019). Previous studies about human-wildlife interaction in CNP and BZ focused on either a single species (Gurung et al., 2008; Pant et al., 2016; Dhungana et al., 2018) or only human casualties (Acharya et al., 2016; Silwal et al., 2017), but a comprehensive analysis of HWC over a longer timespan remains unreported (Lamichhane et al., 2018).

Moreover, no research has been conducted on the spatial and temporal distributions of attacks by individual species or combinations of influencing factors. Thus, in our study, we present a comprehensive analysis of HWC around CNP over 10 years (2012 to 2021) using the largest available dataset for a park in Nepal. Hence, this research aims to assess HWC in CNP buffer zones, explore temporal patterns of damage, crop raiding, livestock depredation, and property loss, and understand local people's perception of wildlife conservation response to these conflicts.

Material and Methods

Study Area

CNP (27°34' to 27°68' N; 83°87' to 84°74' E) is a natural treasure situated in the Chitwan district, that extends its boundaries to Parsa, Makwanpur, and Nawalpur districts of Nepal. It was established in 1973 as Nepal's first National Park, covering an area of 952.63 km^2 and with a buffer zone of 729.37 km^2, and it lies within the Inner Terai Lowlands of south-central Nepal, ranging from 150 to 815 meters above mean sea level (msl) (DNPWC, 2020). The Park is divided into 22 Buffer Zone User Committees (BZUCs), 1700 user groups, and a human population of about 54,155 (CNP, 2022). Of the 22 BZUCs, this study was carried out in the Meghauli Buffer Zone User Committee. CNP's rich biodiversity comprises 600 species of plants, 68 mammal species, 544 bird species, 56 reptile and amphibian species, 150 butterfly species, and 126 fish species (UNESCO, 2003; Shova and Hubacek, 2011). The area is inhabited by various ethnic groups, including the Tharu, Botey, Darai, Brahmin, Chhetri, Gurung, Magar, and Rai communities. The livelihoods of many in these communities are intricately connected to the park's BZ forest, relying on it for fodder, fuelwood, thatch grass, and livestock grazing (CNP, 2013). Agriculture remains a crucial part of life in the BZ, with significant crops such as maize, mustard, and paddy (rice) being cultivated.

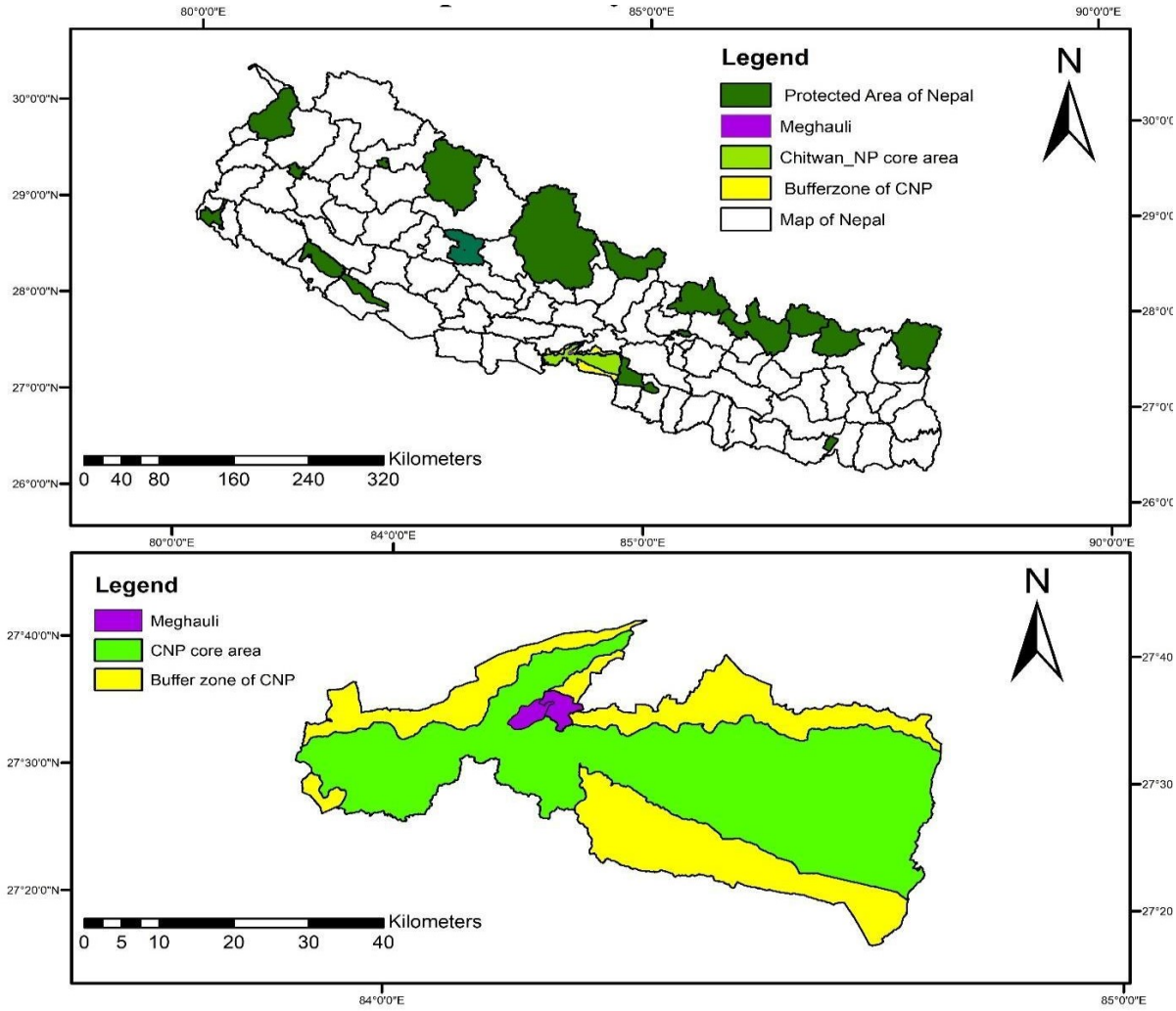

Figure 1: Study area map showing Meghauli Buffer Zone, Chitwan National Park, Nepal.

Data collection

Households (n= 132) of Meghauli BZUC were chosen randomly to analyze people's perceptions regarding conservation, management of wildlife, and their attitudes towards wildlife animals. Meghauli BZ was chosen as a study area for primary data collection according to the preliminary survey, the distance from the park, problems related to crop damage, and livestock loss. Semi-structured questionnaires (n= 23) were used, focusing on (1) demographic data, (2) human injury, (3) livestock depredation, (4) property loss, (5) crop raids, (6) compensation distribution, and (7) management procedures. Key Informant Interview (KII) (n= 10) was carried out in interaction with the park staff, authorities of the National Trust for Nature Conservation (NTNC), user's committee members and community forest user group to visualize the status of wildlife conservation and management procedures. To obtain secondary data, we relied on CNP annual reports and other related documents aggregating all the wildlife conflict incidents recorded in CNP for ten years (2012 to 2021). The data were arranged according to the Nepalese fiscal year, which runs from mid-July to mid-July, based on the Nepalese Calendar Bikram Sambat (B.S). For the uniformity of the data for time series analysis, we converted them to A.D. The data were categorized into four types of losses: human casualties (including human deaths and injuries), livestock depredation, crop damage (including crop raids and stored grain damage), and property damage. This classification enabled the visualization of yearly trends, seasonal patterns, and overall conflict trends in the BZ.

Data analysis

Data analysis was performed using two software programs: Microsoft Excel 2016 and the Statistical Package for the Social Sciences (SPSS v27). The sample size was determined using a confidence level of 95% (Kothari 2004). Q-Q plot was used to examine the normality of the total number of incidents data over the last ten years. Chi-square test of independence was used to analyze the perception. Two-way ANOVA (Analysis of Variance) was utilized to examine whether the number of incidents varied significantly with respect to fiscal year and seasons at 5% significance level, whereas an independent sample t-test was conducted to compare the number of incidents caused by herbivores and carnivores.

Results

Incidents and relief payment

A total of 4416 incidents involving human and economic damage was recorded in the BZs of CNP between 2012 and 2021. These incidents were attributed to nine different wild animals, with elephants being responsible for many cases (37.86%). Other contributing animals include the Rhinoceros *Rhinoceros unicornis* (30.16%), wild boar *Sus scrofa* Linnaeus (13.65%), leopard *Panthera pardus* (Linnaeus) (10.26%), *Panthera tigris tigris* (6.41%), sloth bear *Melursus ursinus* (Shaw) (1.22%), mugger crocodile *Crocodylus palustris* (Lesson) (0.32%), gaur *Bos gaurus* (Smith) (0.09%), and the Burmese python *Python bivittatus* (Kuhl) (0.02%) (Fig. 2A). The number of incidents caused by herbivores was significantly higher than those caused by carnivores (t= 2.101, df= 18, p= 0.05).

Between 2012 and 2021, the park authority disbursed USD ~$0.805 million (106641196 Nepalese rupees) to the families affected by the above incidents. The distribution of these funds was primarily allocated to the victim's families based on the types of damages they experienced. Most of the funds (71%) were provided as relief to the families who suffered from human casualties. Additionally, relief was provided for livestock depredation (6.75%), crop damage (20.1%), and property damage (2.15%) (Table 1). It is evident from the data that a substantial portion of the funds was allocated to families who lost their family members due to these incidents. Moreover, relief was also provided to those who suffered losses to their livestock, crops, and property (Table 1).

Wildlife damage

Human death and injury

A total of 413 human casualties were documented in CNP BZs in ten years. On average, there were 31.5 human injuries per year, comprising 14.4 general injuries and 17.1 severe injuries. Additionally, an average of 9.8 human deaths occurred annually. The year with the highest number of injuries was in 2016, while the maximum human deaths were recorded in 2017 (Table 4). Figure 4A illustrates the peak of wildlife attacks on humans during 2016. The year 2021 witnessed the highest number of human casualties caused by carnivores, reaching 44. Figure 4B demonstrates that the frequency of attacks by carnivores surpassed those by herbivores. Major conflict-causing animals involved in human casualties included *Elephas maximus, Rhinocerus unicornis, Sus scrofa, Panthera pardus Panthera tigris tigris*, *Melursus ursinus*, *Crocodylus palustris*, *Bos gaurus* and *Python bivittatus*.

Among these, *Panthera tigris tigris* were the primary cause of human deaths, followed by *Rhinocerus unicornis* and *Elephas maximus*. *Rhinocerus unicornis* was responsible for most severe injuries, with *Melursus ursinus* and *Sus scrofa* also contributing. Furthermore, *Rhinocerus unicornis* caused the highest number of general injuries, followed by *Sus scrofa* and *Melursus ursinus* (Fig. 2B).

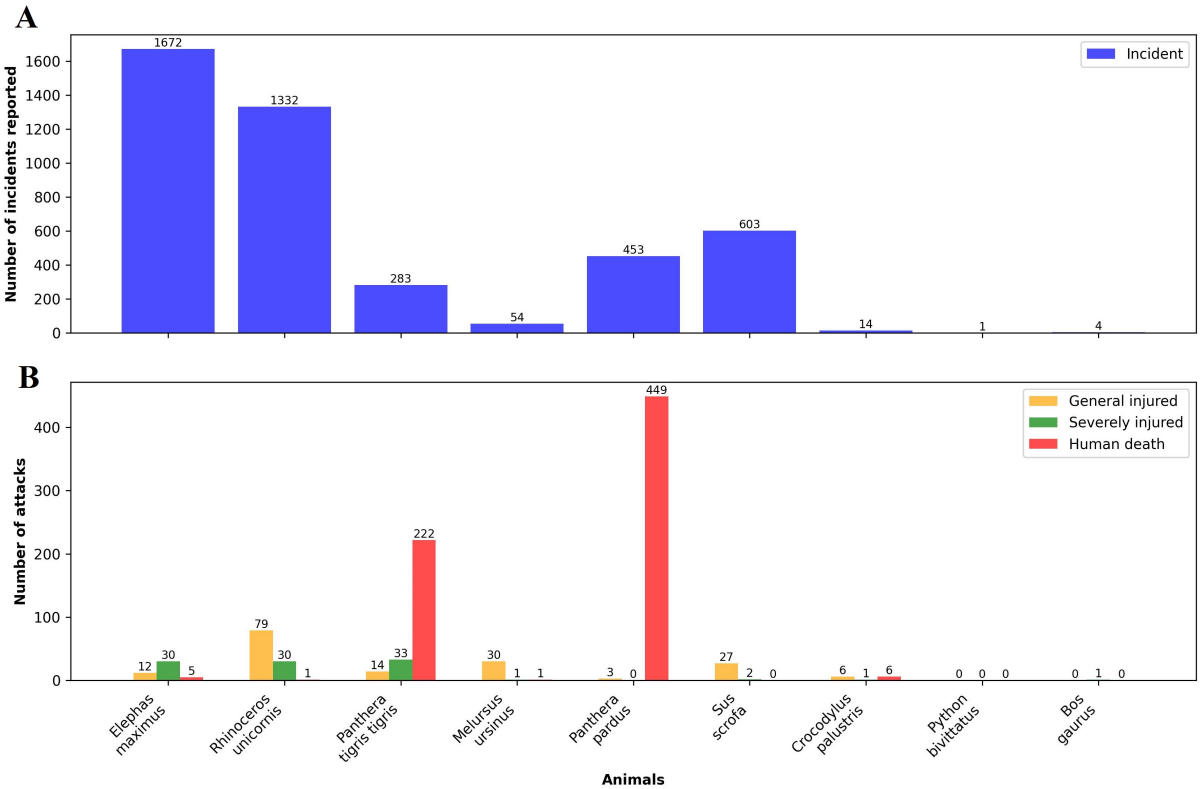

Figure 2: (A) Total number of reported incidents caused by wild animals in CNP from 2012 to 2021, (B) Total number of human casualties caused by wild animals in CNP from 2012 to 2021.

Table 1: The total amount of compensation (in NRs.) provided to the victims of human-wildlife conflict in the CNP from 2012 to 2021.

Species	Human Injury	Human Death	Livestock Depredation	Property Damage	Crop Raiding	Total Compensation
Elephant	1063271	20200000	33500	2290059	9735676	33322506
Rhino	9075256.9	19600000	5500	0	7760356	36441112.9
Tiger	943859	15500000	3113200	0	10000	19567059
Bear	2275241	150000	7500	0	0	2432741
Leopard	159413	0	3993860	0	0	4153273
Wild Boar	2633962	1150000	0	0	3924405	7708367
Mugger Crocodile	927204	1000000	46700	0	0	1973904
Burmese Python	9720	0	0	0	0	9720
Gaur	32513	1000000	0	0	0	1032513
Total	17120440	**58600000**	**7200260**	**2290059**	**21430437**	**106641196**

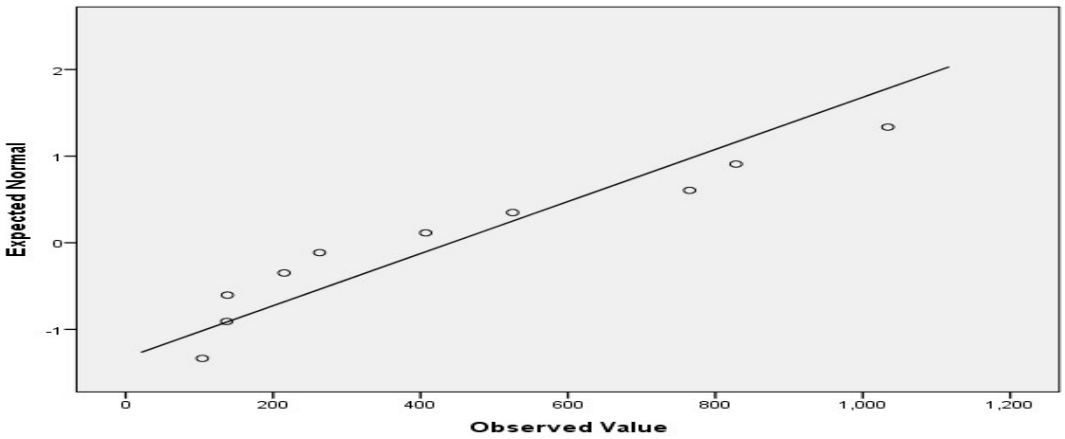

Figure 3: Q-Q plot showing the normality of total incidents of HWC in CNP from 2012 to 2021.

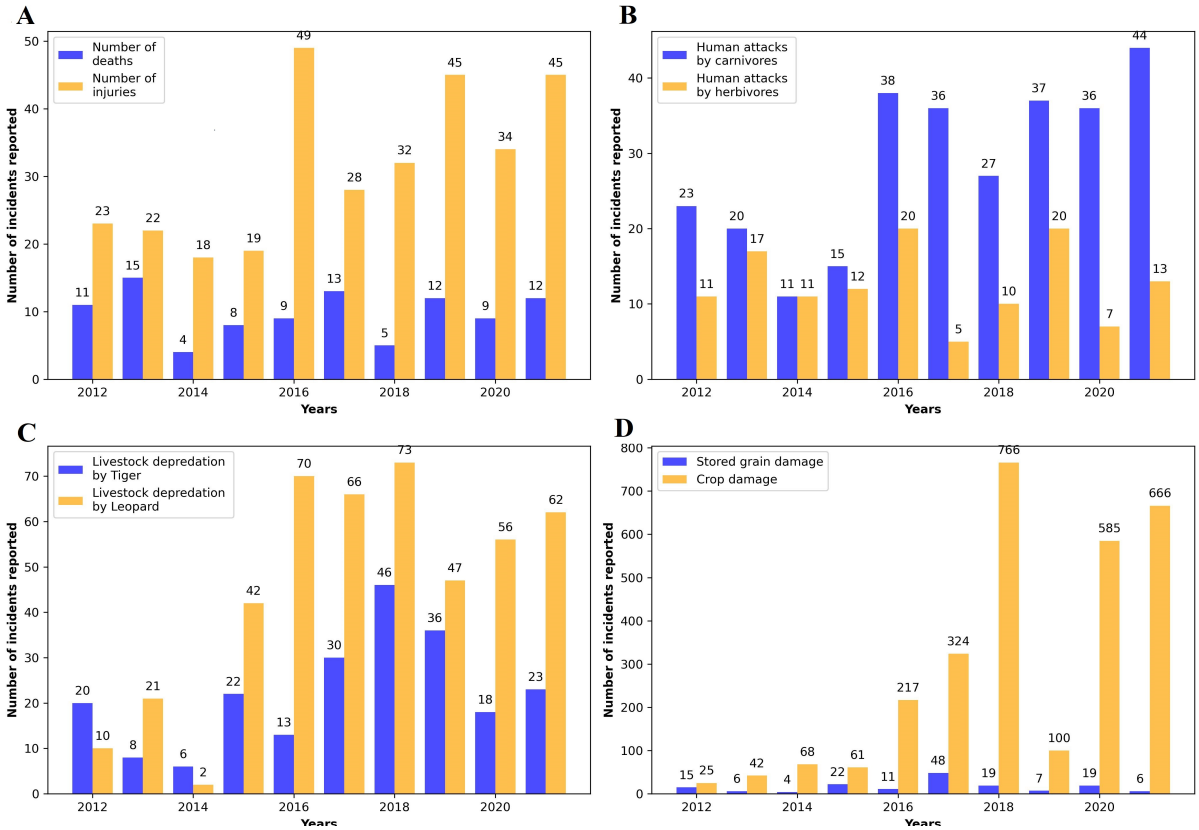

Figure 4: (A) Wildlife attacks on humans by wild animals in buffer zones of CNP from 2012 to 2021. (B) Total number of human casualties caused by carnivores and herbivores in buffer zones of CNP from 2012 to 2021. (C) Total number of livestock depredations by leopard and tiger in buffer zones of CNP from 2012 to 2021. (D) Total number of crop and stored grain damage by wildlife in buffer zones of CNP from 2012 to 2021.

Crop raiding and stored grain damage

Between 2012 and 2021, 157 stored grain losses and 2,854 incidents of crop damage were recorded (Fig. 4D). Most stored grain losses were attributed to *Elephas maximus*. On the other hand, *Rhinoceros unicornis* was the primary cause of crop damage, followed by *Elephas maximus* and *Sus scrofa* (Table 1).

Livestock depredation

A total of 684 livestock depredation incidents were recorded, peaking during 2018, while the lowest occurred in 2014 (Fig. 5A). *Panthera pardus* was the primary species responsible for livestock depredation, closely followed by *Panthera tigris tigris*. Though the trend of livestock depredation decreased to eight in 2014, it surged to a maximum of 120 in 2018 before gradually declining (Fig. 5A).

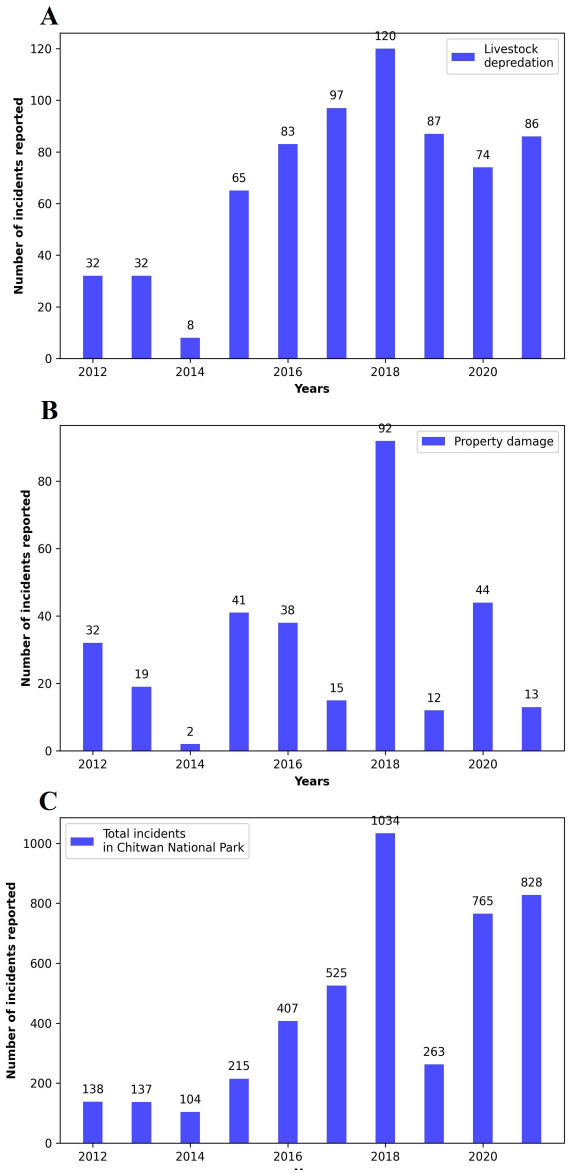

Figure 5: (A) Total number of livestock depredation incidents, (B) Total number of incidents of property damage, and (C) Trend in total wildlife incidents in CNP from 2012 to 2021.

Property damage

Property damage incidents reached 308 from 2012 to 2021, with *Elephas maximus* being the sole wildlife species responsible. The highest number of property damage events took place in 2018 (29.87%), followed by 2020 (14.28%) (Fig. 5B).

The trend of Human-Wildlife Conflict in the Buffer Zones of the CNP

The trend of HWC incidents in CNP displayed fluctuations over ten years. From 2012 up to 2014, the number of incidents decreased. However, from 2015 to 2018, there was an increase in incidents, reaching a peak of 1,034, accounting for 23.41% of the total incidents. Subsequently, there was a decline in incidents to 263 in 2019, but the number of incidents again rose to 828 by 2021 (Fig. 5C).

Seasonal pattern of human-wildlife conflict

The analysis revealed interesting patterns regarding human injuries, human deaths, livestock depredation, and property damage based on seasonal variations over the 10 years from 2012 to 2021. In terms of human injuries, the winter season had the highest number of incidents, accounting for 37.66% of all injuries. On the other hand, the autumn season has witnessed the highest number of human deaths, making up 31.37% of all fatalities. Most attacks on humans occurred while people were in the jungle collecting fodder and fuelwood. Regarding livestock depredation, the autumn season had the highest number of incidents, with 180 reported cases, followed by summer and then winter, with 179 incidents. The spring season had the lowest number of livestock depredation incidents, totaling 146. Notably, the number of livestock attacks in both summer and winter were similar, totaling 179 incidents. Turning to property damage, the winter season accounted for the highest number of incidents, with 165 out of 307 recorded cases.

Conversely, the spring season had the fewest property damage incidents, totaling 42 out of 307. Regarding crop raids, they constituted the highest proportion (68.18%) between the four types of wildlife damage recorded in the last ten years. The autumn season stood out with the maximum number of crops raiding incidents, totaling 1,349. In contrast, the spring season had the fewest, with only 308 incidents (Fig. 6A). The findings indicate seasonal variations in HWC, with specific patterns observed for human injuries, human deaths, livestock depredation, property damage, and crop raids over the ten years.

HWC incidents in CNP followed a seasonal pattern, with fluctuations observed throughout the year. The incidents increased notably during the autumn season and then decreased afterward. The maximum number of incidents occurred during the autumn season, accounting for 37.89% of all recorded incidents (Fig. 6B). Conversely, the lowest number of incidents was observed during the summer.

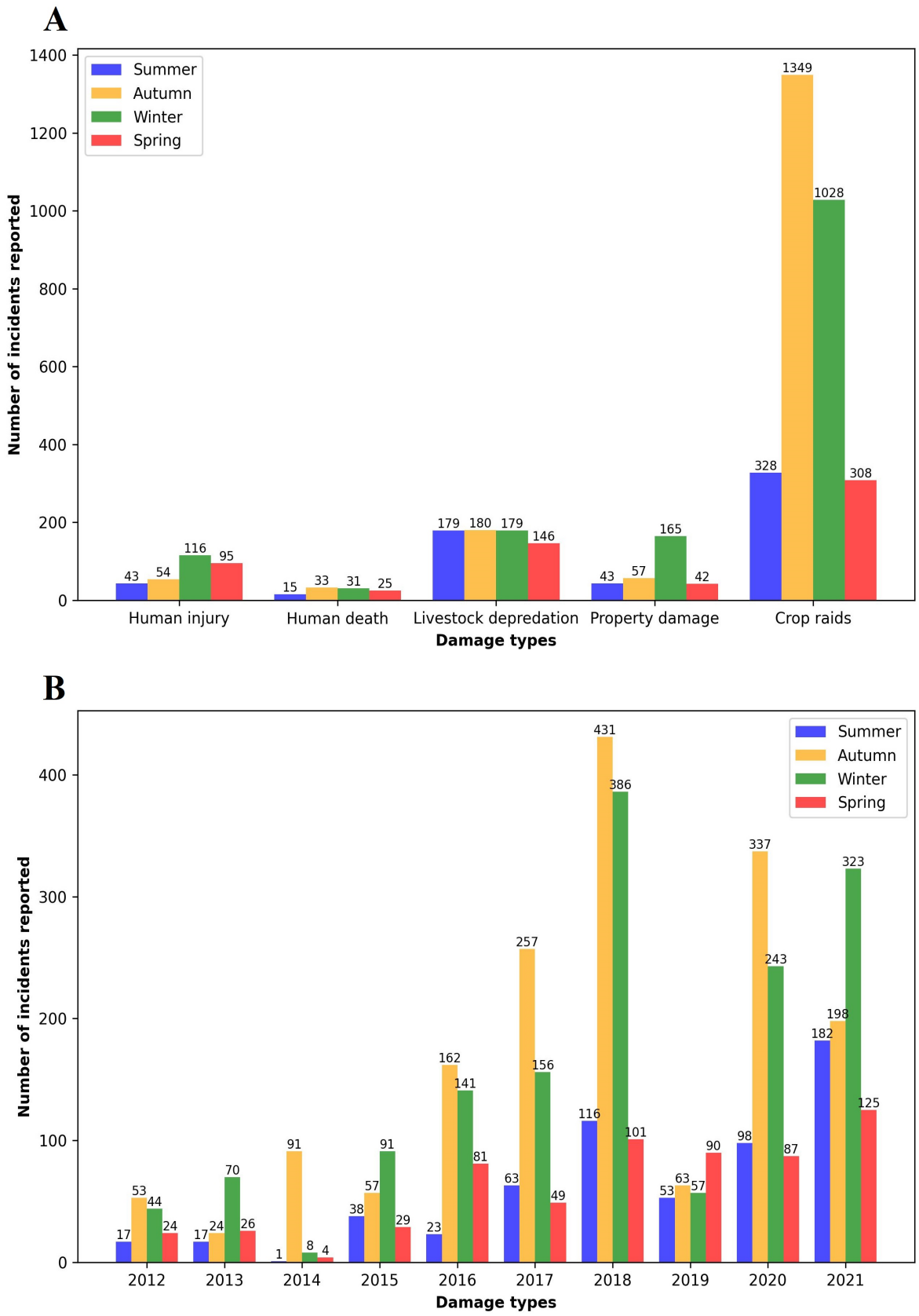

Figure 6: (A) Total number of HWC incidents by season from 2012 to 2021 at the buffer zones of CNP. (B) Total number of HWC incidents by season in different years at the buffer zones of CNP.

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of incidents occurred during the autumn season, accounting for 37.89% of all recorded incidents (Fig. 6B). Conversely, the lowest number of incidents was observed during the summer.

The analysis of HWC incidents revealed significant differences based on fiscal year (F9, 39= 6.88, P= 0.05) and seasons (F3, 39= 8.13, P= 0.05). These results indicate that incidents varied significantly across different fiscal years and seasons. Furthermore, the data revealed a strong disassociation between fiscal year and season. This suggests that the distribution of HWC incidents was not uniform across fiscal years and seasons, and specific factors might influence the patterns of incidents during different periods.

People's perceptions of conservation

The study revealed that 70% of the respondents' experienced problems caused by wild animals, including human casualties, livestock depredation, crop raids, and property damage. On the other hand, the remaining 30% of respondents did not encounter any damage attributed to wildlife. Interestingly, 78% of the people held positive perceptions and acknowledged the importance of wildlife conservation despite the damage caused to them. They recognized the value of conserving wildlife and its ecological significance. Conversely, 21.97% of the respondents displayed a negative attitude towards conservation, possibly reflecting their concerns about the negative impacts of wildlife on their lives and livelihoods. Similarly, Pearson's Chi square test with respect to gender (Male/Female) for perception towards conservation ($\chi2$= 4.045, p= 2, df≤0.05, n= 132) and with respect to age (($\chi2$= 1.657, p= 2, df≤0.01, n= 132) showed the diverse attitudes and experiences of people living in the proximity of CNP towards wildlife and conservation efforts.

Adaptation measures to control damage

In the BZ area, various techniques were adopted to chase wild animals when encounters occurred (Fig. 7). The most used technique, accounting for 49% of cases, involved following the animals while carrying fire and shouting to scare them away. Additionally, 15% of incidents involved chasing the animals using fire alone. Other techniques used to scare away wild animals included scaring them by hitting tins, which constituted 15% of cases. In 11% of instances, people resorted to throwing stones and shouting to deter the animals. Lastly, a combination of shouting and following was employed in 10% of cases to chase away the wild animals.

To address HWC, park authorities adopted several mitigation techniques. The most frequently applied technique, comprising 38% of the efforts, was boundary wall fencing. Another approach taken by park authorities, accounting for 21% of the efforts, was providing alternative options to farmers. Park authorities also invested in raising awareness and education about HWC, making up 15% of the applied techniques. Another 15% of the mitigation techniques involved stall feeding. Lastly, 11% of the efforts focused on constructing concrete buildings to protect against wildlife damage.

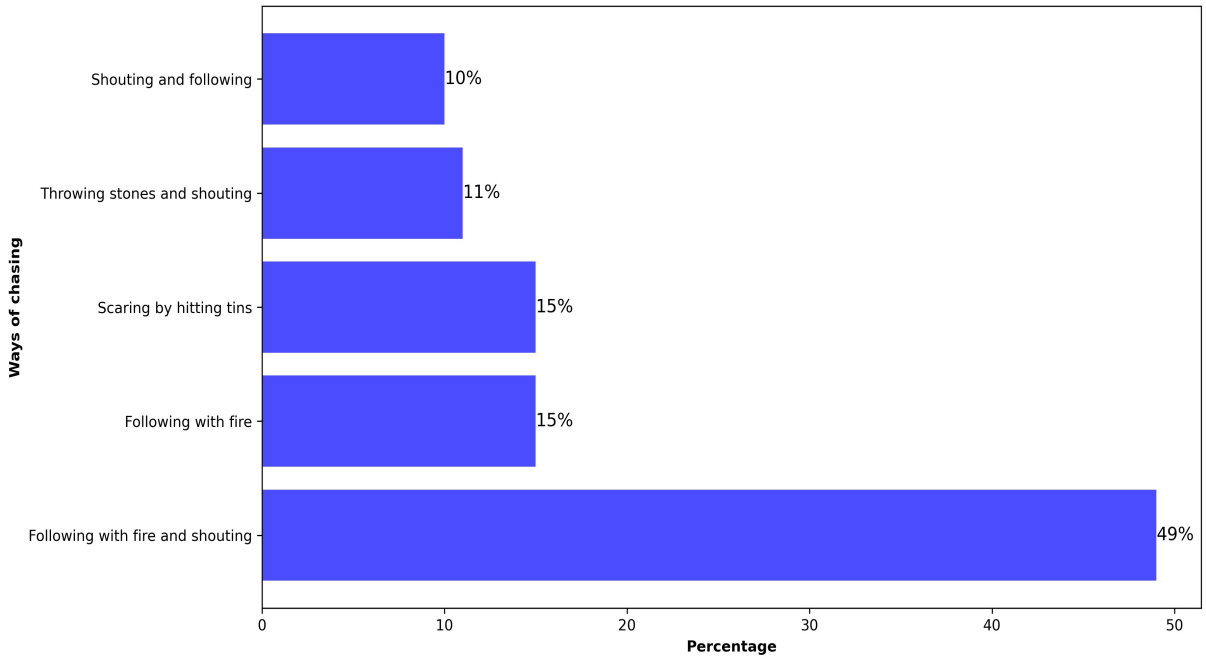

Figure 7: Local techniques applied to chase away wild animals during HWC in CNP from 2012-2021.

Discussion

Incidents and relief payment

For the period of 10 years (2012 - 2021), the total number of incidents, including human and economic damages from nine different species recorded were 4,416 (Fig. 2A), which, despite the shorter time interval, is consistent to the study of Lamichhane et al. (2018) in CNP. This implies that the HWC is increasing in CNP despite various efforts from the park and various agencies. According to our study, most of the incidences occurred while people were collecting park resources like firewood, fodder, grass etc. Thus, increasing awareness programs about wildlife behavior, forming an effective emergency rescue team to deal with the problematic animals in high-risk areas, and decreasing local people's dependency on park resources can be effective measures to control the situation. This trend is the same in the study of Madden (2004) and Konig et al. (2020), supporting the evidence that HWC incidences are increasing worldwide and will likely continue to escalate in the agricultural landscapes and transboundary wildlife management. Considering the damage, the park authority disbursed a total sum of USD ~0.805 million (Table 1) to the families affected by the incidents compared to USD 403,648.51 for the 18 years from 1998 to 2016. Hence, the support to HWC victims is increasing, parallel to the study of Lamichhane et al. (2018) in CNP. The relief funds were dominated by the families who suffered from human casualties, which is also the same in the study of Lamichhane et al. (2018) and Gulati et al. (2021) in CNP and India, respectively. This implies that priority still needs to be given to the control of human casualties. Moreover, elephants emerged as the primary instigators for HWC, while tigers maintained their dominance (Fig. 2B), aligning with the finding of Lamichhane et al. (2018), covering the period from 1998 to 2016. The number of incidents caused by herbivores was significantly higher than those caused by carnivores (Fig. 4B), which is also supported by the study of Sharma (2021) in Hindu Kush Himalaya, but it was found to be insignificant in the study of Lamichhane et al. (2018) in CNP.

Human death and injury

A total of 41.3 human casualties, with 9.8 human deaths and 31.5 human injuries was recorded annually between 2012 and 2021 in CNP BZs, which is higher than previously recorded by Lamichhane et al. (2018) and Silwal et al. (2017) in CNP. Lamichhane et al. (2018) reported an annual average of 40.6 wildlife attacks on humans from 1998 to 2016, but Silwal et al. (2017) recorded 30 attacks on an annual average between 2003 and 2013. Compared to the other PAs in Nepal, CNP observed the highest rate of human casualties (Baral, 2022). However, the total number of wildlife attacks per year could be even higher since our data only covers the BZ and does not include the incidents when people illegally entered the park's core area. Among these, *Panthera tigris tigris* were the primary cause of human death, followed by *Rhinocerus unicornis* and *Elephas maximus* which might be due to the human disturbances in forests. Parallel to our results, Treves et al. (2006) and Gurung et al. (2008) also reported that humans invading forests (e.g., fodder/firewood collectors) were often killed by tigers. Moreover, the frequency of attacks by carnivores surpassed those by herbivores (Fig. 4B). Similar study on livestock predation by large carnivores has been previously reported for the Maasai Mara (Karani et al., 1995) and the Tsavo (Patterson et al., 2004) in Kenya and Maasai steppe in Tanzania (Kissui, 2008). Conversely, the number of attacks by herbivores was not significantly different from the number of attacks by carnivores (*Panthera tigris tigris*, *Panthera pardus*, and *Melursus ursinus*) in the CNP, Nepal (Lamichhane et al., 2018). The year 2021 witnessed the highest number of human casualties caused by carnivores, reaching a total of 44 (Fig. 4B). The reason behind it, according to the CNP staff, is due to the COVID 19 outbreak, which led to more dependency on people toward forest resources due to increasing economic crises.

Livestock depredation and property damage

An annual average of 68.4 livestock depredation was recorded in the last 10 years in CNP (Fig. 5A), which was less in comparison to BNP (118/year, NTNC unpublished data) (Gurung, 2009) and some of the other Indian National Parks (462/year, Kanha National Park) (Miller et al., 2016). *Panthera pardus* was the primary species responsible for livestock depredation, closely followed by *Panthera tigris tigris* (Fig. 4C). A similar trend was found in a study by Lamichhane et al. (2018), from 2014 to 2021 in CNP. However, before 2014, *Panthera tigris tigris* caused more losses than *Panthera pardus* in our study. The increasing *Panthera tigris tigris* population of Chitwan may have pushed *Panthera pardus* into the edges of park or in the BZs, where they kill livestock frequently, which could be the main reason for higher livestock kill by *Panthera pardus* (Lamichhane et al., 2018). A similar observation was reported in BNP, the other park in Nepal's Terai (Gurung, 2009).

The total annual average of incidents of property damage was 30.8 from 2012 to 2021 (Fig. 5B), which is higher than in the study of Lamichhane et al. (2018). *Elephas maximus* being the sole wildlife species responsible for the damage, the finding is supported by different studies of Lamichhane et al. (2018) and Gross (2020) in CNP and South Luangwa/ Zambia: Zambia, National Parks, respectively. The major reason for the damage by *Elephas maximus* was for access to food (Gross, 2020).

Crop raiding and stored grain damage

A total of 157 incidents of stored grain loss and 2,854 incidents of crop damage were recorded (Fig. 4D)

which is much higher than the study of Lamichhane et al. (2018), where they found 83 incidents of storage grain damage and 639 incidents of crop raiding in CNP, Nepal. The vast difference may be due to the limitation mentioned by Lamichhane et al. (2018) for lack of sufficient data. The study shows that the elephants were responsible for most stored grain losses (Table 1), which is consistent with the study of Gross (2021) in Asia and Africa and Joshi et al. (2020) in Kailali, Nepal, but in the study of Uprety (1995) found *Rhinocerus unicornis* was the most destructive raider in CNP. This study identified *Rhinocerus unicornis*, *Elephas maximus*, and *Sus scrofa* were the main reasons behind crop damage during the specified period, while Dangol et al. (2020) identified *Elephas maximus* for most of the crop damage.

Seasonal pattern of human-wildlife conflict

This study demonstrated the severity of HWC in the autumn (Fig. 6B) since it is the best time to harvest rice and the wild animals leave parks to access more appetizing food (Lamichhane, 2018). Because herbivores go to the edges, predators follow in pursuit of their prey, which results in the most significant amount of harm to humans and their property (Bhandari et al., 2020). Additionally, this study revealed that human casualties surged during the winter, which is consistent with the findings of Acharya et al. (2016) in Nepal and Silwal et al. (2017) and Bhandari et al. (2020) in CNP. The season with the fewest attacks was summer because there are abundant supplies of edible grasses inside the park, preventing animals from frequently leaving the area and reducing the likelihood of human-animal interactions (Kurland et al., 2017). Due to the decreased palatability of forage in the winter (Laurie, 1982; Acharya et al., 2016), both the herbivores and the carnivore species move out from the center of the core region. Many assaults that took place in the early morning hours were initiated by animals that had either left the croplands after feeding on paddy, wheat, or lentils or became lost inside the croplands and were unable to find their way back to the forest (Silwal et al., 2017).

Trend of Human-Wildlife Conflict in Buffer Zones of CNP

This study displayed the fluctuations in the trend of HWC over ten years (Fig. 5C). The outbreak of the COVID-19 pandemic led people to become more dependent on the forest, potentially leading to an increase in HWC (Lendelvo, 2020). Our study addressed the detrimental effects of animals on people. This demonstrates the anthropocentric nature of our approach to solving this problem, while HWC is a phenomenon that, by definition, has an equal influence on people and animals (Conover, 2001). This study provides more detailed findings than Conover (2001) as it provides information on the trends of all four types of wildlife losses in a clarified way from 2012 to 2021 (Fig. 5C).

People's perceptions towards conservation

This study also reveals community perceptions regarding conservation near CNP, which presents a nuanced picture of the interactions between humans and wildlife. The presence of a 21.97% minority with negative attitudes highlights the intricate balance between acknowledging conservation's value and grappling with its tangible repercussions. The study's breakdown by gender and age further underscores the diverse viewpoints within the community, shaped by distinct sociocultural contexts. Local governments should manage HWC in a way that protects biodiversity. However, conflicts frequently occur along the borders of PAs or involving endangered species, coming under the purview of wildlife management (Bangs et al., 1998). It also supports the theory that it requires the attention of national and international communities to further conduct extensive research activities (Kafle et al., 2020) and the collaboration between communities, managers, and conservationists is essential.

Adaptation measures to control damage

Local communities used several methods to deal with wild animals. The most common technique, which accounted for 49% of incidents, involves approaching animals and scaring them away with vocalizations and fire (Fig. 7). In contrast, Distefano (2005) supported these techniques as well as he added other techniques such as improved policy, limitation of persecution and poaching, and insurance programs. Furthermore, better livestock management strategies like fencing, corralling livestock, less foraging time, mixed herds, and awareness about wildlife ecology can notably decrease the depredation rate and increase tolerance in people who are most vulnerable to the negative impacts of conflict (Suryan et al., 2023).

Conclusion

We studied the trends and patterns of HWC in the CNP BZs from the long-term data of almost a decade (2012–2021). During this period, crop raiding (68.18%) emerged as the most pervasive and noticeable issue, closely followed by livestock depredation. Regarding conflict-causing animals, nine wildlife species harmed people and their possessions. *Elephas maximus* were the most conflict-causing animal, accounting for 37.86% of the damage, followed by *Rhinocerus unicornis* (30.16%). The most damage occurred during the autumn season (37.89%) in 2018, accounting for 23.41% of all incidents over the preceding ten years. Out of the total compensation disbursed, the largest was awarded in 2019. Most of the disbursed compensation was for human casualties (71%),

followed by crop damage (20.1%). Most individuals had a good attitude toward wildlife protection despite the numerous harms and difficulties. This study can help minimize the conflict and bring appropriate intervention strategies in the National Parks since it analyzed by season and yearly patterns of four types of conflicts from a wide range of species. It also discusses how residents of the CNP BZ respond to wildlife conservation and how to put essential measures in place to lessen conflicts between people and animals. These findings mirror the larger discourse on conservation psychology, emphasizing the necessity of inclusive strategies that address both positive and negative perceptions. Ultimately, the study reinforces the importance of community engagement in shaping effective and sustainable conservation approaches.

Acknowledgments

We are grateful to Mr. Ganesh Prasad Tiwari, Assistant Conservation Officer, Chitwan National Park (CNP), who guided and encouraged us throughout this research. We also greatly acknowledge Mr. Ajit Yadav (Ranger), Ms. Sabita Thapa (Ranger), and Mr. Sitaram Phuyal (Ranger) for their continuous encouragement, coordination, and support throughout this study. We thank Dr. Baburam Lamichhane from NTNC for his valuable help and encouragement. We thank all the CNP, Kasara headquarters staff for their support, hospitality, and encouragement. Finally, we would like to express our deep respect and sincere thanks to all the helping hands including the anonymous reviewers and editors for their valuable suggestions and comments to improve our manuscript.

Author contributions

A. P. conceptualized the idea, conducted all the field studies, and carried out data collection, C. R. B., M. B., J. B. B., S. K. Y., and S. T. prepared the draft manuscript. A. P., H. A., and S. T. performed data analysis, visualization, results interpretation, and prepared the final manuscript.

Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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