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Research article

Spatiotemporal variation in human-wildlife interactions: Evidence from forest edges of Khata Corridor, Bardia, western Nepal

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Abstract

Extensive modification of natural forest habitat for economic and social requirements can put humans and animals in a juxtaposition, encouraging them to vie for the common resources, resulting in conflicts. Very little is known about the wildlife response in different categories of forest edges. We analyzed the relation between the different types of forest edges, viz. agriculture, grassland, river, human trail, and the type of negative human-wildlife interaction (NHWI) inflicted at the Khata Corridor of Bardia District, western Nepal. We collected the GPS position of NHWI incidents, conflicting animals, and the time of incidents, NHWI type, and edge type from field records, secondary literatures and interview of witnesses. We analyzed the distribution of NHWI incidents concerning different land-use types across forest edges. We observed a significant relationship between conflict animals and the type of edges, and NHWI types and conflict animals. Our observation showed significant species-specific interaction with forest edge types, where the elephant was mainly associated with agricultural damage, the leopard (*Panthera pardus*) with livestock predation, while the tiger's pattern of conflict was less in count but the cause for human injuries and livestock predation, and often linked to human settlement proximity. The temporal dimensions of NHWI showed elephants active mainly in the late evening until early morning hours, tigers in the late afternoon and nighttime, and leopards mostly at dusk until early morning. Agricultural forest edge was most susceptible towards NHWI. The negative human-leopard interaction was also higher in agriculture land, but proportionately higher in diverse edge type compared to other species. The analysis showed the highest density of NHWI in the areas with small forest patches and fragmented forests. We suggest forest landscapes to be managed maintaining intactness at the larger spatial extent to reduce NHWI, and support co-existence of wildlife and adjacent local communities.

Keywords: Edge influence; fragmented landscape; Khata Corridor; negative human-wildlife interaction

1 | Introduction

Forest edges influence the behavior and demographics of animal populations across a wide range of species (Vanak et al. 2010). Forest fragmentation causes the forest biological systems to undergo a drastic change in terms of its structure and organization (Fahrig 2003). The discontinuities function as a transition zone between two distinct habitat features, each with its own set of biotic and abiotic properties; these zones are known as forest edges (Murcia 1995; Bolt et al. 2018). Forest edges are land-use categories that are directly adjacent to the forest specifically agriculture, human trail, grassland, and river, in this study. Hard and soft forest edges are the two types of forest edges. Hard edges have a higher degree of contrast and abrupt shift, whereas soft edges are associated with a low degree of contrast and gradual transition between the different habitats (Laurance et al. 2001; Cadenasso et al. 2003; López-Barrera et al. 2006). Natural and anthropogenic forest borders around wildlife habitat can influence animal migrations, foraging pathways, and use of their home range thus affecting the human-wildlife relationships (Peterson et al. 2010). Forest edges not only make difficult for animals to move across patches, but they can also alter daily or seasonal behavioral patterns by establishing more complicated migration routes (Johnson et al. 2002; McDonald and St Clair 2004; Vanak et al. 2010). Forest edges also cause abiotic environmental gradient changes in attributes like light, wind, and moisture, as well as increased access for organisms, biological materials pollen, seed, pollutants, and energy, all of which result in compositional and behavioral changes in both animal and plant species (Harper et al. 2005; Bolt et al. 2018; Li et al. 2018).

Creation of forest edges degrades and disturbs wildlife mobility while increasing their proximity to humans, increasing the number of negative human-wildlife interactions (NHWIs) which results in crop-raiding, property damage, injuries, and deaths of people, or the killing of wildlife in retaliation (Acharya et al. 2016). Herbivory, disease contamination, exotic species introduction, nest predation, and other character interactions have been shown to be influenced by their proximity to forest edges and their types (Benitez-Malvido and Arroyo-Rodríguez 2008). Understanding how an animal reacts to different types of forest edges that interrupt the natural flow of a habitat, based on geographical and temporal data, is crucial in reducing any undesirable human-animal interactions (Shi et al. 2018). The specific spatial and temporal dynamics of such interactions are poorly understood, especially in the context of habitat edge habitats, which could play a significant role in shaping the NHWI to establish conflict hotspots and tailor mitigation strategies (Ghosal and Kjosavik 2015).

Mega-faunas are considered keystone species in any forest ecosystem, yet they face serious ramifications and issues in terms of conservation and survival as a consequence of NHWI (Caro 2010). Bengal tiger (*Panthera tigris*), leopard (*P. pardus*), greater one-horned rhino (*Rhinoceros unicornis*) and Asian elephant (*Elephas maximus*) are the key conflict species of Nepal (Acharya et al. 2016). According to recent studies on global forest cover, approximately 20% of the world's remaining forest is within 100 m of an edge adjacent to agricultural, urban, or other modified habitat settings, while an astounding 70% of surviving forest is within 1 km of forest edge (Haddad et al. 2015). The anthropogenic mortality of large mammals has increased in recent years in Nepal, posing challenges in the conservation of the threatened wildlife species (Baral et al. 2022). The different dimensions of human-wildlife conflicts have been studied in different protected areas of Nepal (Dahal et al. 2021; Sharma et al. 2024), however, the impact of edges on human-wildlife situation is feebly understood. More than 2/3rd of the population lives in rural areas near forest boundaries or edges, with direct and indirect dependency on the forests (Ruda et al. 2018). However, we have limited understanding on how forest edge affects human-wildlife interactions. In this context, we aim to examine the spatiotemporal pattern of NHWI due to mega-fauna Bengal tiger, common leopard and Asian elephant in different edge categories at Khata Corridor of Bardia, Nepal.

2 | Materials and methods

2.1 | Study area

Khata Corridor, a biological corridor in Nepal's western lowlands, is located in the Bardia District (Fig. 1). Between Katarniaghat Wildlife Sanctuary in India and Bardia National Park (BNP) in Nepal, nearly 12 km long and 8 km wide corridor serves as a connecting bridge, allowing key mega faunas such as the Asian elephant, greater one-horned rhino, Bengal tiger, and common leopard to move across the landscape.

Within the corridor, the elevation ranges from 361 m in the north to 121 m in the south (Adhikari and Khadka 2009). Khata Corridor was recognized as an area crucial for restoration in 2000 AD, followed by its restitution that started in 2001 AD. The corridor consists of areas of intact forest, degraded forest, grasslands, human settlements, agricultural fields and rivers, and is adjoined by 74 community forests. The corridor enacts as an immensely effective continuation between two high-density conservation areas between India and Nepal. The area is inhabited majorly by the indigenous Tharu Community with other migrated people from different hilly areas of Nepal like Pyuthan, Jumla, Mugu, Kalikot. Agriculture and livestock husbandry are basic components of livelihood in the area. Fuelwood collection, timber harvesting, grass cutting, grazing, fishing, hunting and snaring of wildlife, sand and stone quarrying are the major human activities in the study area (Adhikari and

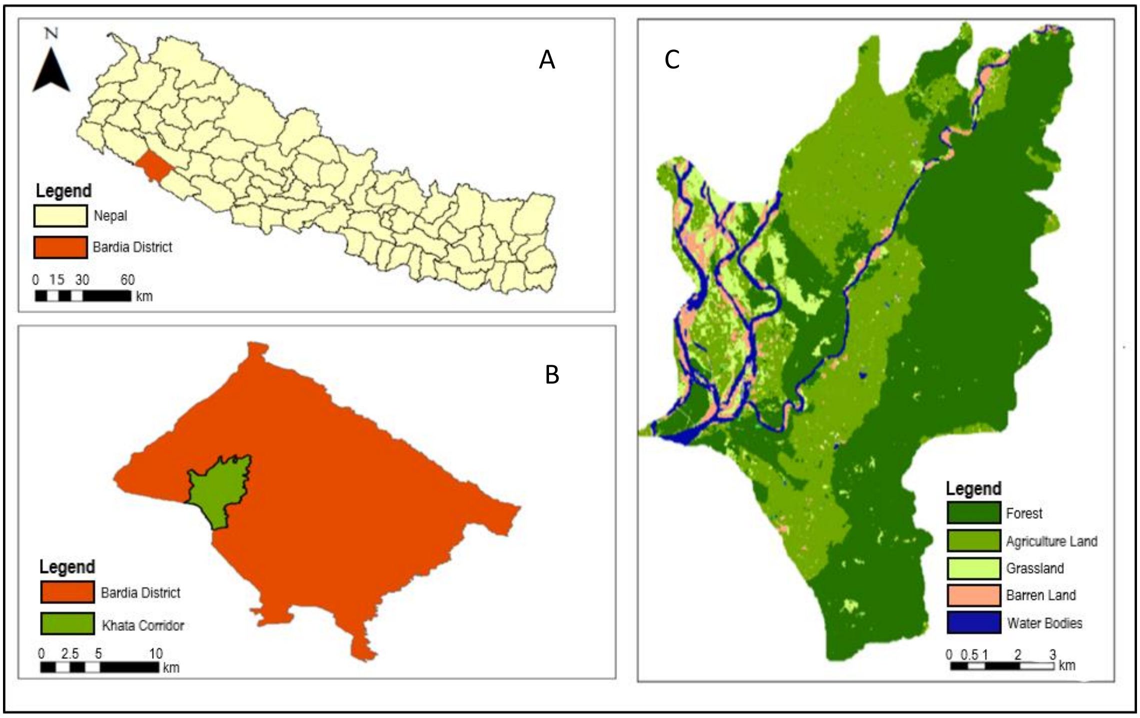

Figure 1. Study area map showing Bardia District and Khata Corridor. (A) Location of Bardia District in Nepal (B) Location of Khata Corridor in Bardia District, and (C) Land use type of Khata Corridor

Khadka 2009). A major part of the Khata Corridor is under the management of the Department of Forests and Soil Conservation while a smaller portion of the corridor is also managed under buffer zones of BNP. Human-wildlife conflict and compensation schemes are monitored by Khata Corridor Coordination Committee (Wegge et al. 2018).

2.2 | Data collection

We collected data on NHWI incidents observed from 2015 to 2019 from multiple sources, such as the Khata Corridor Coordination Committee, Bardia National Park Office, Divisional Forest Office in Bardia, and Regional Forest Directorate Office in Butwal. These offices have been consistently maintaining and updating the NHWI incident records. They are responsible for providing compensation to local communities that have suffered losses due to NHWI, following the protocols specified in Nepal's Government Wildlife Damage Relief Guideline of 2013 which was subsequently amended in 2019. The maintenance and update of such data follows the protocols as described in Inskip and Zimmermann (2009). To further ensure the accuracy and reliability of the HWC incidents data, we cross-checked the data with the International Union for Conservation of Nature IUCN Nepal Monitoring of Illegal Killing of Elephants MIKE Project database. In cases where NHWI incident location coordinates were missing, we conducted interviews with eyewitnesses in February to March 2020 and used the GARMIN ETREX 64s GPS to collect GPS coordinates of the sites.

2.3 | Classification of land use and identification of edges

Landsat 8 image of 2019 AD with a resolution of 30 m, classified using supervised classification in ArcGIS 10.1, was used to develop land use and land cover map (Campbell and Wynne 2011). Forest, agricultural land, grassland, barren land, and water bodies were classified as distinct dominant landmasses. The principal land-use type around the forest matrix was used to identify the distinct forest edge types around the corridor. We chose two natural forest edges, a grassland forest edge and a river forest edge, as well as two artificial forest edges, a human trail forest edge and agricultural forest edge (Ghosal and Kjosavik 2015). Since the human settlements in the area are mostly amidst the agriculture land, we considered them as a single entity.

2.4 | Categorization of NHWI events

The data on NHWI was divided into five categories: i. human deaths, ii. human injuries, iii. crop depredations, iv. livestock predation, and, v. property damage (Dickman 2010; Nyhus 2016). Within five years, we discovered 178 separate NHWIs incidents. Based on the significant episodes that happened in the Khata Corridor, we selected three essential animals for analysis: two are apex predators in the food chain i) Bengal tiger and ii) leopard, and another topmost herbivore iii) Asian elephant.

2.5 | Spatial and temporal analysis

A NHWI distribution map (Ruda et al. 2018) was prepared to investigate the magnitude and intensity of NHWI incidence around the Khata Corridor. Further, distance from each conflict point to the nearest forest patch was assessed. We further categorised the data according to the four main forest edge namely, human trail mostly used by the locals to commute around villages, farmlands as agricultural forest edge, grassland edge and finally river edge. The association of NHWI between the species and different forest edges was analyzed using the Fisher's exact test, and goodness of fit of NHWI incidents among groups by Chi-square test in R (R Core Team 2019).

For understanding species-specific behaviours in human-altered landscapes we classified the temporal date of NHWI events were into four temporal classes: night-time 20:00–3:59, morning 4:00–11:59, afternoon 12:00–15:59, and evening 16:00–19:59 (Graham et al. 2005). Mode of the times of NHWI were calculated to identify peak activity period. The variability in timing was assessed to reflect the degree of flexibility or predictability in species' behavioral patterns (Karanth and Sunquist 2000). We calculated the mean and standard deviation of each animal species proximity relative to the four major land use classes: human trails, river, forest, and human settlements. Similarly, for identifying the patterns between species and NHWI type, we applied cross-tabulation (Treves and Karanth 2003).

3 | Results

3.1 | Distribution of NHWI incidents by Species

A total of 178 documented cases during 2015 to 2019 AD of NHWIs were analysed (Table 1; Fig. 2). The interactions, grouped by conflict species revealed that elephants dominated 132 the negative interactions, 75% of the total incidents reported. Similarly, common leopards had 36 of the interactions (20%), while tigers were responsible for 10 incidents (5%).

The analysis of data across different forest edge types showed that agricultural edge was the most frequent site (χ^2= 311.21, df = 3, $p < 0.0001$) for the NHWIs, accounting for 146 interactions, or 82% of the total. Similarly, river edges recorded 18 interactions (10%), grassland edges recorded 11 interactions (6%), and human trail edges had the least number of incidents, with only 3 interactions (2%). This shows that agricultural areas

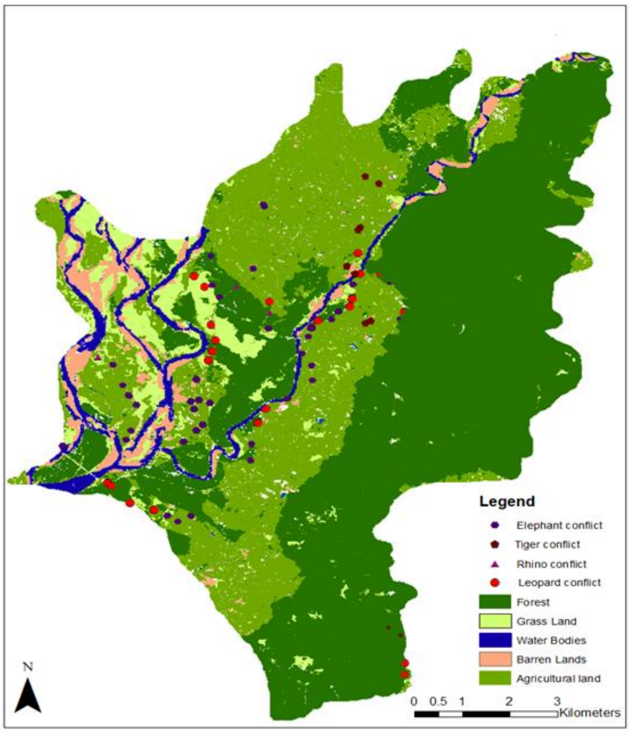

Figure 2. NHWI incident points concerning major different land use and land cover of Khata Corridor

Table 1. NHWI incidents (from 2015 to 2019) caused by mega animals at Khata Corridor

S.N.	**Conflicting animal (mega)**	**NHWI count***	**Percentage**	**Types of forest edge**			
				Agriculture	Grassland	River	Human trail
1.	Elephant	132 (26)	75	115	5	12	0
2.	Leopard	36 (7)	20	24	6	3	3
3.	Tiger	10 (2)	5	7	0	3	0
Total		178	Total	146 (29)	11 (2)	18 (4)	3 (1)
			Percentage	**82**	**6**	**10**	**2**

*Data in parenthesis are NHWI per year rounded to significant whole number

Table 2. Distance between NHWI points and the nearest land use type

Conflicting animal (mega)	**Distance to different land use classes (m)**							
	Human trail		**River**		**Forest**		**Human settlements**	
	Mean	**St. dev**	**Mean**	**St. dev**	**Mean**	**St. dev**	**Mean**	**St. dev**
Elephant	51	86	599	487	338	404	79	121
Tiger	179	177	533	317	507	157	189	153
Leopard	41	72	898	1372	39	62	235	229

adjacent to forests are important areas of human-wildlife interactions, mainly with elephants and common leopards. The analysis showed significant association between conflict animal species and different kinds of forests edges ($p = 0.001$) confirming that the distribution of human-wildlife interactions is not random across landscapes but influenced by the nature of the forest edge. Elephants had 115 interactions at agricultural edges. The common leopards had 24 interactions in the agricultural edges, and tigers also had 7 interactions in the agricultural lands, over the study period.

3.2 | Distance from NHWI locations to different land use type

Elephants tends have a relatively higher number of NHWI incidences at and around human trails and human settlement areas, while the incidences were comparatively farther from rivers and forests (Table 2). Tigers also followed the similar trend with more NHWIs near human trails and human settlements, and the NHWI occurred at farther distances from forests and rivers. Similarly, common leopard showed interesting pattern with NHWI occurring very close to human trails and forests.

3.3 | NHWI frequency by time of day

Considering the NHWI frequency by time of the day, night time was observed with having significantly higher NHWI compared to other time slots ($\chi2= 54.00$, $df = 3$, $p < 0.0001$). Considering the species-specific NHWIs, elephant conflicts were also strongly concentrated during the night, with 99 incidents of crop depredation and 19 of property damage. This suggests that mitigation efforts should focus on interventions at night to protect livestock and crops during which the probability of conflict is highest. Common leopard conflicts were mostly at evening (18 cases) and night (15 cases), establishing their nocturnal activity pattern (Table 3). Similar results were observed for the tiger-related human injuries mostly occurred during night. The record shows fatal encounters during afternoon and evening hours.

3.4 | Cross-tabulation of species by type of NHWI

The cross-tabulation illustrates species-specificity of the NHWI patterns for the period of 2015 to 2019 AD. Elephants were mostly related in crop depredation (105 events) and the property damage (24 events) was the second-most frequent negative incidence. This highlights the association of elephants with agricultural environment and suggests that NHWIs with elephants are largely driven by their needs for food rather than competition with humans or livestock. Common leopards were associated with livestock predation (36 events). Tigers, however, showed a variety, including livestock depredation (5 events), human injuries (3 events), and 2 lethal human encounters (Table 4).

4 | Discussion

The NHWI in Nepal has been increasing in recent years (Neupane et al. 2017). BNP has been reported as one of the largest mega fauna accommodator of Nepal which can be attributed to have interaction with humans (Ram & Acharya 2020). A study conducted by Bajimaya (2012) suggests

Table 3. NHWI frequency (from 2015 to 2019) by time of day

Mega animals and their prime conflict events	**Night**	**Morning**	**Afternoon**	**Evening**	**Conflict time (Mode)**
Leopard - livestock predation	15	1	2	18	23:00
Tiger - human injuries	1	1	0	1	0:00
Tiger - livestock predation	4	0	0	1	0:00
Tiger - death	0	0	1	1	15:00
Elephant - crop depredation	99	6	0	0	23:00
Elephant - human injuries	0	3	0	0	7.45
Elephant - property damage	19	3	1	1	23:00
Total	138	14	4	22	-
NHWI frequency (per year) *	28	3	1	4	-

*Data rounded to significant whole number

Table 4. Cross-tabulation of mega animals and NHWI incidences record from 2015 to 2019

Conflicting animal (mega)	Crop Depredation*	Human injuries	Livestock predation	Property damage	Death
Leopard	0 (0)	0 (0)	36 (7)	0 (0)	0 (0)
Tiger	0 (0)	3 (1)	5 (1)	0 (0)	2 (1)
Elephant	105 (21)	3 (1)	0 (0)	24 (5)	0 (0)

*Data in parenthesis are NHWI per year rounded to significant whole number

approximately 40% of the total NHWI incident and 70% of NHWI inflicted casualties have been caused by Asian elephants. The endangered species was observed as equally interacting at the Khata Corridor, accounting for the highest NHWI portion of 70%. The NHWI has been reported to be the cause of around 12 human and 3 retaliation casualties annually in Nepal (Neupane et al., 2014). Our study suggests higher agricultural depredation followed by property damage and human injuries. It has been observed from various studies that immigrant elephant herds are reportedly more troublesome than resident herds (Pradhan et al. 2011; Neupane et al. 2014; Neupane et al. 2017). In our study, negative human-elephant interaction occurred mostly in forest edge with agricultural land followed by river forest edge and grassland forest edge, however it was observed that NHWI had occurred in closer proximity to human trails frequented by humans. The average distance observed between human trails and human settlement from the NHWI point was less than 100 m in both the sites. From research conducted in various protected areas in Nepal by Acharya et al. (2017), amongst the main conflicting animals in Nepal, elephant attacks were observed in highly fragmented landscapes with higher agricultural fields, a consistent result from our study. Crop damage was found to be more prevalent than property damage, with few human casualties which was similar to the results found in studies conducted by Neupane et al. (2017), Shrestha et al. (2007) and Yadav (2007) on low-lands of Nepal. Our study suggests higher agricultural depredation followed by property damage and human injuries. From research conducted in various protected areas in Nepal by Acharya et al. (2017), amongst the main conflict animals in Nepal, elephant attacks were observed in highly fragmented landscapes with higher agricultural fields, a similar result from our study.

Common leopards attack was observed in all the landscape sites. The NHWI occurrence was found in all types of edges, unlike the NHWI pattern noted from tigers and elephants. A significant positive relationship between the heterogeneity of landscape and frequency of common leopard attack has been suggested in other studies (Brodie et al. 2015; Acharya et al. 2017). Common leopards are reported to be adaptable survivor in human modified landscapes this might reflect towards the reason why the negative human-leopard interaction incident was mostly observed near a human-dominated landscape at the agricultural edged forest (Odden et al. 2014; Constant et al. 2015). Our study showed negative human-leopard interaction occurring mostly at a closer proximity to the forest with higher human intervention activities such as livestock grazing. The average distance between the NHWI incident areas and the forests was measured to be less than 40 m. Common leopards were observed increasing their interaction near the forest edge region. The rise in availability of prey at the forest edges is suspected to be the primary reason for the edge utilization by the predator species, which increases the human-wildlife interaction incidents (Šálek et al. 2010; Brodie et al. 2015). Acharya et al. (2016) reflected that common leopards are most commonly involved in attacks on people in terms of attack frequency and fatalities. Contrary to this, our study suggests common leopards to be dominantly responsible for livestock predation in the area. Countries like Bhutan and Pakistan also have similar livestock depredation results caused by common leopard (Sangay and Vernes 2008; Dar et al. 2009).

Acharya et al. (2017) from the study of protected areas of Nepal revealed that amongst the main conflict animals in Nepal, the tiger's attack was mostly recorded in fragmented landscapes with dense human settlements, a similar to our study. Tigers were observed to have been more active in recent years (DNPWC and DFSC 2018), which could be explained by an increase in tiger population in the area and decrease in their natural prey density over the years (Kolowski and Holekamp 2006; Bhattarai and Fischer 2014; Sharma and Neupane 2023). However, the availability of easy livestock prey is also an attraction for livestock depredation. It was also observed from data that human injuries and deaths have been on the rise due to tigers consistent with the findings of Nyhus and Tilson (2004) and Sharma et al. (2024). It has been suggested from previous studies that tigers with physical impairments or deformities making them unable to hunt, decrease in prey density at their habitat or habitat depletion as a whole may cause them to opt outside the forest area (Gurung et al. 2008). As depicted by Balme et al. (2010) increasing utilization of the forest edge region by predator species due to higher and easier prey availability could result in a phenomenon called the "Vacuum effect" where predator species not native to the habitat matrix are attracted to the forest edges zones with the purpose of mating. This phenomenon can be suspected to increase further NHWI. As per our findings, the tiger NHWI occurred on average of about 500 m from the forest, which corresponds to Gurung et al. (2008) study, which determined that the distance between the NHWI site and the closest forest occurs within 1 km of the forest.

The major negative human-elephant interaction occurrence existed at agricultural field. According to NCD (2019) human injuries and deaths mostly occurs during attempts made to chase the herd back from their fields Daniel (1995) and Santiapillai et al. (2010) found that factors such as village proximity, the phenophase of agricultural crops, the area of crop cover, the density of certain preferred browse species, the availability of shade, the incidence of wood cutting, the availability of water, rainfall, cattle grazing, the abundance of weed, and the occurrence of forest fire influence crop raiding incident. Elephants tends to relax during the afternoon heat inside the forest and are more active during the evening till dawn when the temperature drops, thus causing more impacts after sunset and before sunrise (Thapa et al. 2019; Ram et al. 2021). According to Ram et al. (2021) the NHWI location for elephants lies within nearly 500 meters away from the forest. Our analysis indicates comparable results, with the NHWI location being at an average distance of 338 m from the closest forest. Tiger's activities were also observed to be bimodal with one peak occurring after midnight and the other occurring just after sunset at the Mudumalai Tiger Reserve of Western Ghats (Ramesh et al. 2012). Similarly, in the case of common leopards it was observed that NHWI density for common leopards were between 20:00

PM to 4:00 AM, respectively. The peculiar dynamics of NHWI for each species underlines the need for mitigation strategies tailored for each species but customized to the prevalent forms of NHWI to which they are associated. Our results indicated that the type of NHWI largely depends on the species under consideration. This reflects that each species has unique ways of interacting with the human-dominated landscapes driven by their ecological and behavioral adaptations.

5 | Conclusions

This research focused on the importance of forest edges in driving human-wildlife associations. Elephants, tigers, and leopards showed distinct NHWI patterns, which were driven by both habitat preference and temporal activity. Agricultural edges formed high-risk areas for elephants and leopards, while tigers showed a preference for avoiding human-modified landscapes. Analysis of the rate of NHWIs by time of day shows that the number of NHWI events peaks during the night hours. This time has a similar alignment with the behavior of the studied species: leopards and tigers are crepuscular and nocturnal, showing peaks of conflicts at night when predator activity increases and human presence decreases. Moreover, crop raiding and property damage by the elephants were mostly done during the night and early morning hours, further indicating these animals might actively avoid people while foraging. These results thus show that temporal patterns of NHWI are likely driven by animals' adaptations to human avoidance. The wildlife management and conservation effective in the field need to focus on species-specific strategies: implementing physical barriers for elephants, strengthening forest corridors for tigers, and managing livestock in agricultural areas to decrease conflicts with common leopards. This will help in understanding the spatial dynamics and behavioral patterns of the species to assist in establishing mitigation strategies that minimize human-wildlife conflicts and promote sustainable coexistence between humans and wildlife in shared environments.

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Authors' contributions

S.R. and K.D.H. collected and analyzed the data. S.R. wrote the manuscript. R.P.S. and N.M.B.P. contributed in the research design, data analysis and edited the manuscript. All authors have given final approval for publication after critically contributing to the drafts.

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Conflicts of interest

The authors declare no conflict of interest.

References

Acharya K.P., Paudel P.K., Neupane P.R. and Köhl M. 2016. Human-wildlife conflicts in Nepal: Patterns of human fatalities and injuries caused by large mammals. PLoS ONE, 11(9): e0161717. https://doi.org/10.1371/journal.pone.0161717

Acharya K.P., Paudel P.K. Jnawali S.R. Neupane P.R. and Koehl M. 2017. Can forest fragmentation and configuration work as indicators of human–wildlife conflict? Evidences from human death and injury by wildlife attacks in Nepal. Ecological Indicators, 80:74–83. https://doi.org/10.1016/j.ecolind.2017.04.037

Adhikari, S. and Khadka, A. 2009. Study on relative abundance and distribution of tiger prey base ungulates in Khata Corridor, Bardia National Park. Kathmandu University Journal of Science, Engineering and Technology, 51:121–135. https://doi.org/10.3126/kuset.v5i1.2852

Bajimaya, S. 2012. Managing human-wildlife conflict in Nepal. In: Acharya K. and Dhakal M. (Eds.) Biodiversity conservation in Nepal: a success story. Department of National Parks and Wildlife Conservation, Kathmandu, Nepal, pp 31–44.

Balme G.A., Slotow R.O.B. and Hunter L.T. 2010. Edge effects and the impact of non-protected areas in carnivore conservation: leopards in the Phinda–Mkhuze Complex, South Africa. Animal Conservation, 133: 315–323. https://doi.org/10.1111/j.1469-1795.2009.00342.x

Baral K., Bhandari S., Adhikari B., Kunwar R.M., Sharma H. P., Aryal A., and Ji W. 2022. Anthropogenic mortality of large mammals and trends of conflict over two decades in Nepal. Ecology and Evolution, 12(10), e9381. https://doi.org/10.1002/ece3.9381

Benítez-Malvido J. and Arroyo-Rodríguez, V. 2008. Habitat fragmentation, edge effects and biological corridors in tropical ecosystems. In: Del Claro K. et al. (Eds.) Encyclopedia of Life Support Systems (EOLSS), International Commission on Tropical Biology and Natural Resources, UNESCO, Eolss Publishers, Oxford, UK.

Benitez-Malvido J. and Martínez-Ramos, M. 2003. Influence of Edge Exposure on Tree Seedling Species Recruitment in Tropical Rain Forest Fragments. Biotropica, 35(4):530–541. https://doi.org/10.1111/j.1744-7429.2003.tb00609.x

Bennett A.F. and Saunders D. 2010. Habitat fragmentation and landscape change. In: Sodhi N.S. and Ehrlich P.R. (Eds.) Conservation Biology for All, (Oxford, 2010; online edn, Oxford Academic, 1 Feb. 2010). https://doi.org/10.1093/acprof:oso/9780199554232.003.0006

Bhattarai B.R. and Fischer K. 2014. Human–tiger *Panthera tigris* conflict and its perception in Bardia National Park, Nepal. Oryx, 48(4):522–528. https://doi.org/10.1017/S0030605313000483

Bolt L.M., Schreier A.L., Voss K.A., Sheehan E.A., Barrickman N.L., Pryor N.P. and Barton M. C. 2018. The influence of anthropogenic edge effects on primate populations and their habitat in a fragmented rainforest in Costa Rica. Primates, 59(3):301–311. https://doi.org/10.1007/s10329-018-0652-0

Brodie J.F., Giordano A.J. and Ambu L. 2015. Differential responses of large mammals to logging and edge effects. Mammalian Biology, 80(1):7–13. https://doi.org/10.1016/j.mambio.2014.06.001

Cadenasso M.L., Pickett S.T., Weathers K.C. and Jones, C.G. 2003. A framework for a theory of ecological boundaries. BioScience, 53(8):750–758. https://doi.org/10.1641/0006-3568(2003)053[0750:AFFATO]2.0.CO;2

Campbell J.B. and Wynne R.H. 2011. *Introduction to remote sensing*. Guilford Press, New York, NY, USA.

Caro T. 2010. *Conservation by proxy: indicator, umbrella, keystone, flagship, and other surrogate species*. Island Press, Washington, USA.

Constant N.L., Bell S. and Hill R.A. 2015. The impacts, characterisation and management of human–leopard conflict in a multi-use land system in South Africa. Biodiversity and Conservation, 24:2967–2989. https://doi.org/10.1007/s10531-015-0989-2

Dahal N.K., Harada K., Adhikari S., Sapkota R.P. and Kandel S. 2021. Impact of wildlife on food crops and approaches to reducing human wildlife conflict in the protected landscapes of Eastern Nepal. Human Dimensions of Wildlife, 1926601. https://doi.org/10.1080/10871209.2021.1926601

Daniel J.C., Desai A.A., Sivaganesan N., Datye H.S., Rameshkumar S., Baskaran N., Balasubramanian, M. and Swaminathan, S. 1995. Ecology of the Asian elephant. Final Report, 1987–1994. Bombay Natural History Society, Bombay. India.

Dar N.I., Minhas R.A., Zaman, Q. and Linkie, M. 2009. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. Biological Conservation, 142(10):2076–2082. https://doi.org/10.1016/j.biocon.2009.04.003

Dickman A.J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. Animal Conservation, 13(5):458-466. https://doi.org/10.1111/j.1469-1795.2010.00368.x

DNPWC and DFSC. 2018. *Status of Tigers and Prey in Nepal*. Department of National Parks and Wildlife Conservation and Department of Forests and Soil Conservation. Ministry of Forests and Environment, Kathmandu, Nepal

Fahrig L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics, 34:487–515. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419

Ghosal S. and Kjosavik D.J. 2015. Living with leopards: Negotiating morality and modernity in human-wildlife interactions in India. Society and Natural Resources, 28(10):1092–1107. https://doi.org/10.1080/08941920.2015.1014597

Graham K., Beckerman A.P. and Thirgood, S. 2005. Human–predator–prey conflicts: ecological correlates, prey losses and patterns of management. Biological Conservation, 122(2):159–171. https://doi.org/10.1016/j.biocon.2004.06.006

Gurung B., Smith J.L.D., McDougal C., Karki J.B. and Barlow A. 2008. Factors associated with human-killing tigers in Chitwan National Park, Nepal. Biological Conservation, 141(12):3069–3078. https://doi.org/10.1016/j.biocon.2008.09.013

Haddad N.M., Brudvig L.A., Clobert J., Davies K.F., Gonzalez, A., Holt, R.D., et al. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances, 1(2), e1500052. https://www.science.org/doi/10.1126/sciadv.1500052

Harper K.A., Macdonald S.E., Burton P.J., Chen, J., Brosofske K.D., Saunders S.C., et al. 2005. Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology, 19(3):768–782. https://doi.org/10.1111/j.1523-1739.2005.00045.x

Hemson G.A. 2004. The ecology of conservation of lions: Human wildlife conflict in semi-arid Botswana. Doctoral Dissertation, University of Oxford.

Inskip C. and Zimmermann, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. Oryx, 43(01):18–34. https://doi.org/10.1017/S003060530899030X

Johnson C.J., Parker K.L., Heard D.C. and Gillingham M.P. 2002. Movement parameters of ungulates and scale-specific responses to the environment. Journal of Animal Ecology, 71(2):225–235. https://doi.org/10.1046/j.1365-2656.2002.00595.x

Karanth K.U. and Sunquist M.E. 2000. Behavioural correlates of predation by tigers *Panthera tigris*, leopards *Panthera pardus* and dholes *Cuon alpinus* in Nagarahole, India. Journal of Zoology, 250(2):255–265. https://doi.org/10.1111/j.1469-7998.2000.tb01076.x

Kolowski J.M. and Holekamp K.E. 2006. Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan Reserve Border. Biological Conservation, 128(4):529–541. https://doi.org/10.1016/j.biocon.2005.10.021

Laurance W.F., Didham R.K. and Power, M.E. 2001. Ecological boundaries: a search for synthesis. Trends in Ecology and Evolution, 16(2):70–71. https://doi.org/10.1016/S0169-5347(00)02070-X

Lele S.R., Moreno M. and Bayne E. 2008. Dealing with detection error in site occupancy surveys: what can we do with a single survey? Journal of Plant Ecology, 5(1):22–31. https://doi.org/10.1093/jpe/rtr042

Li J., Zhao C., Peng Y., Hu Y. and Yuan X. 2018. Edge effects on tree growth and species diversity in forests of different types and ages. Polish Journal of Ecology, 66(3):239–249. https://doi.org/10.3161/15052249PJE2018.66.3.004

López-Barrera F., Manson R.H., González-Espinosa M. and Newton, A.C. 2006. Effects of the type of montane forest edge on oak seedling establishment along forest–edge–exterior gradients. Forest Ecology and Management, 225(1-3), 234–244. https://doi.org/10.1016/j.foreco.2005.12.055

McDonald R.W. and St Clair C. 2004. The effects of artificial and natural barriers on the movement of small mammals in Banff National Park, Canada. Oikos, 105(2):397–407 https://doi.org/10.1111/j.0030-1299.2004.12640.x

Murcia C. 1995. Edge effects in fragmented forests: implications for conservation. Trends in Ecology and Evolution, 10(2): 58–62. https://doi.org/10.1016/S0169-5347(00)88977-6

NCD. 2019. *Elephant Action Plan for Bhutan 2018-2028*. Nature Conservation Division, Department of Forests and Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan.

Neupane D., Johnson R.L. and Risch T.S. 2014. Temporal and spatial patterns of human-elephant conflict in Nepal. In: 2013 International Elephant and Rhino Conservation and Research Symposium, Proceedings pp. 856-888. USA: Pittsburgh Zoo and PPG Aquarium.

Neupane D., Kunwar S., Bohara A.K., Risch T.S. and Johnson, R.L. 2017. Willingness to pay for mitigating human-elephant conflict by residents of Nepal. Journal for Nature Conservation, 36:65-76. https://doi.org/10.1016/j.jnc.2017.02.004

Neupane D., Johnson R.L. and Risch T.S. 2017. How do land-use practices affect human-elephant conflict in Nepal? Wildlife Biology, 2017(1):1-9. https://doi.org/10.2981/wlb.00313

Nyhus P.J. and Tilson, R. 2004. Characterizing human-tiger conflict in Sumatra, Indonesia: implications for conservation. Oryx, 38(1):68-74. https://doi.org/10.1017/S0030605304000110

Nyhus P.J. 2016. Human-wildlife conflict and coexistence. Annual Review of Environment and Resources, 41:143-171. https://doi.org/10.1146/annurev-environ-110615-085634

Odden M., Athreya V., Rattan S. and Linnell J.D. 2014. Adaptable neighbours: movement patterns of GPS-collared leopards in human dominated landscapes in India. PLoS ONE, 9(11), e112044. https://doi.org/10.1371/journal.pone.0112044

Peterson M.N., Birckhead J.L., Leong K., Peterson M.J. and Peterson, T.R. 2010. Rearticulating the myth of human–wildlife conflict. Conservation Letters, 3(2), 74-82. https://doi.org/10.1111/j.1755-263X.2010.00099.x

Pradhan N.M., Williams A.C. and Dhakal M. 2011. Current status of Asian elephants in Nepal. Gajah, 35:87-92.

R Core Team 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Ram A.K. and Acharya, H. 2020. Status distribution and habitat use by Asian elephants in Nepal. In: A Compendium of Conservation News Bulletin, published by Department of National Parks and Wildlife Conservation, Governmetn of Nepal.146-153.

Ram A.K., Mondol S., Subedi N., Lamichhane B.R., Baral H.S., Natarajan L. et al. 2021. Patterns and determinants of elephant attacks on humans in Nepal. Ecology and Evolution, 11(17), 11639-11650. https://doi.org/10.1002/ece3.7796

Ramesh T., Kalle R., Sankar K. and Qureshi Q. 2012. Spatio-temporal partitioning among large carnivores in relation to major prey species in Western Ghats. Journal of Zoology, 287(4): 269-275. https://doi.org/10.1111/j.1469-7998.2012.00908.x

Ruda A., Kolejka J. and Silwal T. 2018. GIS-assisted prediction and risk zonation of wildlife attacks in the Chitwan National Park in Nepal. ISPRS International Journal of Geo-Information, 7(9), 369. https://doi.org/10.3390/ijgi7090369

Šálek, M., Kreisinger, J., Sedláček, F. and Albrecht, T. 2010. Do prey densities determine preferences of mammalian predators for habitat edges in an agricultural landscape? Landscape and Urban Planning, 98(2):86-91. https://doi.org/10.1016/j.landurbplan.2010.07.013

Sangay T. and Vernes K. 2008. Human–wildlife conflict in the Kingdom of Bhutan: patterns of livestock predation by large mammalian carnivores. Biological Conservation, 141(5):1272-1282. https://doi.org/10.1016/j.biocon.2008.02.027

Sharma B. and Neupane D. 2023. Enhancing human-tiger coexistence in forest corridors of Nepal through a socio-ecological approach to conservation. Trees, Forests and People, 13, 100402. https://doi.org/10.1016/j.tfp.2023.100402

Sharma B., Hope A.G., Neupane D. 2024. Dimensions of human–tiger conflict and solutions for coexistence in the forests of the Khata Corridor, Bardiya, Nepal. Oryx. Published online:1-9. https://doi.org/10.1017/S0030605323001849

Shi H., Shi T., Yang Z., Wang Z., Han F. and Wang C. 2018. Effect of roads on ecological corridors used for wildlife movement in a natural heritage site. Sustainability, 10(8), 2725. https://doi.org/10.3390/su10082725

Shrestha R., Bajracharya S. and Pradhan N.M.B. 2007. A case study on human-wildlife conflict in Nepal. A Report Submitted to the WWF Nepal Program. Nepal.

Thapa K., Kelly M.J. and Pradhan N.M.B. 2019. Elephant Elephas maximus temporal activity, distribution, and habitat use patterns on the tiger's forgotten trails across the seasonally dry, subtropical, hilly Churia forests of Nepal. PLoS ONE, 14(5), e0216504. https://doi.org/10.1371/journal.pone.0216504

Treves A. and Karanth K.U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology, 17(6), 1491-1499. https://doi.org/10.1111/j.1523-1739.2003.00059.x

Vanak A.T., Thaker M. and Slotow R. 2010. Do fences create an edge-effect on the movement patterns of a highly mobile mega-herbivore? Biological Conservation, 143(11): 2631-2637. https://doi.org/10.1016/j.biocon.2010.07.005

Wegge P., Yadav S.K. and Lamichhane B.R. 2018. Are corridors good for tigers Panthera tigris but bad for people? An assessment of the Khata Corridor in lowland Nepal. Oryx, 52(1): 35-45. https://doi.org/10.1017/S0030605316000661

Yadav B.R. 2007. Human-elephant relationships and conflicts in eastern Nepal. The Initiation, 1:93-99. https://doi.org/10.3126/init.v1i0.2689