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Economic effects of wild boar damage to crops in protected areas of Nepal

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ABSTRACT

Human wild-boar conflict is one of the prominent issues in Nepal, especially in areas adjacent to protected areas. Wild boars cause substantial damage to the agricultural crops and affect the lives of rural farmers through economic loss. However, the extent of this loss varies across protected areas. Thus, this study aims to compare the economic loss due to crop damage by wild boar between two protected areas with different management regimes; Shuklaphanta National Park (ShNP) and Dhorpatan Hunting Reserve (DHR). We used a questionnaire survey and descriptive statistics to characterize and compare the pattern of human wild boar conflicts between ShNP and DHR. Altogether, the two protected areas experienced a crop damage of 87,035.78 kg with an estimated economic loss of 26,389 USD within a year in our study. The most damaged crop in the ShNP was paddy whereas that in DHR was potato. We recorded a higher crop damage and economic loss in ShNP than in DHR. However, the severity of conflict is higher in DHR with around 8 % of the total production damaged by wild boar. Although the government declared wild boar an agricultural menace in 2023 and permitted killing on private lands, local communities should also apply other mitigation measures to prevent wild boars from entering crop fields. Additionally, the potential introduction of trophy hunting in ShNP (already permitted in DHR), following comprehensive studies, could help reduce economic losses associated with human-wild boar conflicts. Such combined efforts could create a more sustainable approach to managing wild boar populations while safeguarding local agriculture and livelihoods.

1. Introduction

The conflict between humans and wildlife has intensified significantly in recent years and is emerging as a major challenge to wildlife conservation (Ananad, Radhakrishna, 2017; König et al., 2020; Bharathy et al., 2022; Baral et al., 2023). The rapid expansion of human populations has led to the encroachment of wildlife habitats in and around protected areas, exerting considerable pressure on wildlife populations (Barua et al., 2013). This habitat encroachment has intensified competition for space between humans and

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wildlife as well as increased interactions, consequently leading to adverse impacts on humans and wildlife populations (Barua et al., 2013; Siljander et al., 2020; Bista and Song, 2022). Conflicts between humans and wildlife can be categorized as crop damage, livestock depredation, property damage, and human or wildlife casualties (Karanth et al., 2018; Lamichhane et al., 2018; Nyhus, 2016; Pant et al., 2023; Shahi et al., 2022). While crop damage may not always be equally prioritized as other categories, its occurrence can cause substantial economic losses and impact the livelihoods of individuals dependent on agriculture or forestry (Nyhus, 2016; Koirala et al., 2021; Wang et al., 2023). This, in turn, could exacerbate poverty and contribute to food shortages, underscoring the importance of addressing conflicts related to crop damage in the broader context of human-wildlife interactions (Wang et al., 2023).

In Nepal, species including Asiatic elephant (*Elephas maximus*), greater one-horned rhino (*Rhinoceros unicornis*), blue bull (*Boselaphus tragocamelus*), macaques (*Macaca sp.*), wild boar (*Sus scorfa*), porcupines (*Hystrix sp.*), and barking deer (*Muntiacus vaginalis*) are identified as species frequently causing crop damage (Awasthi and Singh, 2015; Baral et al., 2021; Bhatta and Joshi, 2021; Koirala et al., 2021; Dhami et al., 2023; Pandey et al., 2016; Pant et al., 2023). Among these species, wild boar induced crop damage is a prominent issue both inside and outside protected areas (Colomer et al., 2021; Pandey et al., 2016; Sapkota et al., 2014). While the population status of most wildlife species in Nepal remains uncertain, the wild boar populations appear to be increasing and have resulted in substantial crop damage (Pandey et al., 2016; Rothley et al., 2004). The increasing abundance of wild boar in combination with habitat fragmentation has increased their reliance on agricultural crops (Pandey et al., 2016).

Wild boars cause substantial damage to agricultural crops including paddy (*Oryza sativa)*, potato (*Solanum tuberosum*), wheat (*Triticum aestivum*), corn (*Zea mays*), oats (*Avena sativa*), and barley (*Hordeum vulgare*) (Lindblom, 2011; Pant et al., 2023). Crop damage is more severe in areas adjacent to protected areas (Colomer et al., 2021; Pant et al., 2023), where the ban on hunting in combination with increasing wild boar populations in adjoining forests exacerbates the problem (Amici et al., 2012; Fonseca, 2008). In fragmented landscapes with small farms, such as rural Nepal, wild boar poses a significant problem due to their large foraging groups, opportunistic diets, crop trampling behavior (Morelle and Lejeune, 2015; Schley and Roper, 2003) and preference for forest edge habitats (Pandey et al., 2016; Pant et al., 2023). These behaviors have caused significant economic loss to people within and adjacent to protected areas (Pandey et al., 2016; Pant et al., 2023).

Crop damage by wild boar has caused severe economic losses to local farmers of Nepal. For example, the estimated crop damage by wild boars in the Rupendehi District during 2015 February – 2016 February was 23,962 USD (Khanal and Singh, 2019) whereas in Shivapuri Nagarjun National Park wild boar damage was 24,000 USD, with 36 % of these losses during March 2009 — April 2010 (Pandey et al., 2016). Similarly, in Shivapur VDC around Bardia National Park wild boar accounted for about 54 % of the total crop

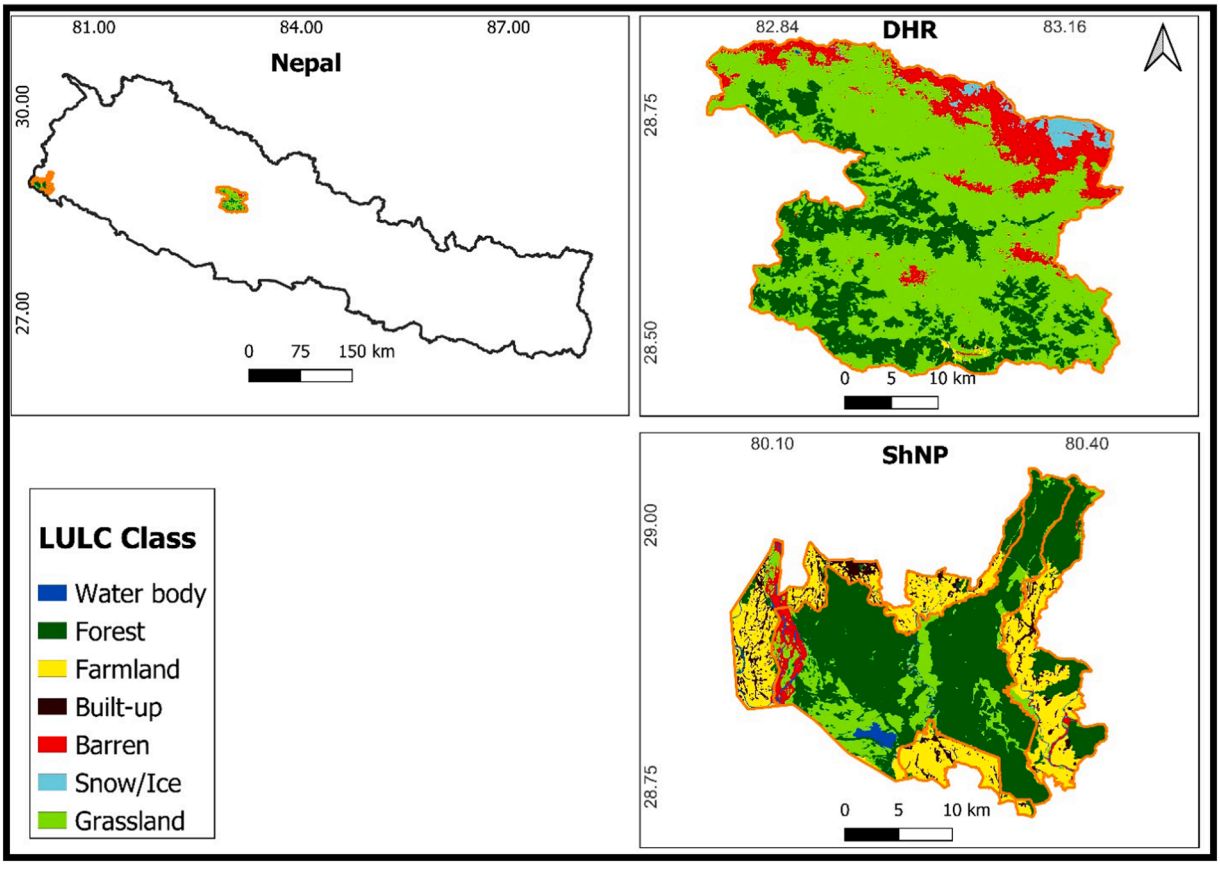

Fig. 1. Dhorpatan Hunting Reserve (DHR) and Shuklaphanta National Park (ShNP), Nepal.

damage (Dhakal, 2012) and in Shuklaphanta National Park, wild boar accounted for 21 % of total crop damage across five years period (Pant et al., 2023). Due to its wider distribution and higher adaptability, wild boar has become one of the major species causing crop damage in Nepal and globally (Barrios-Garcia and Ballari, 2012; Jhala et al., 2008).

Several studies suggested wild boar as one of the major drivers of human-wildlife conflicts in Nepal (Pandey et al., 2016; Pant et al., 2023). Given this, it is necessary to examine recent conservation practices to evaluate what management practices benefits in mitigation of human-wild boar conflicts in Nepal. We characterized human-wild boar conflicts in two protected areas with different management regimes, Shuklaphanta National Park and Dhorpatan Hunting Reserve, Nepal. In Shuklaphanta National Park, settlements are restricted to the buffer zone area, whereas in Dhorpatan Hunting Reserve, settlements are permitted within the core area. We evaluated and compared the intensity of crop damage between these protected areas and because of the pervasiveness of wild boar crop damage and their generalist habitat and foraging, we hypothesized that crop damage would be similar between these protected areas.

2. Methods

2.1. Study area

We investigated the human-wild boar conflicts across two protected areas Dhorpantan Hunting Reserve and Suklaphanta National Park. Dhorpatan Hunting Reserve (DHR; 23°3′-28°50'N, 82°50'E-83°15'E) is located in the mid-hills and mountain region, while Suklaphanta National Park (ShNP; 28°45'47"−29°02'52"N and 80°05'45"−80°21'43"E) is situated in the Tarai Region of Nepal (Fig. 1).

The DHR is the only hunting reserve in Nepal, established in 1983 and officially declared in 1987. Encompassing 1325 km^2 with elevations of 2700 — 7000 m above sea level, the reserve comprises seven blocks: Surtibang, Fagune, Barse, Ghustung, Dogari, Seng, and Sundaha. Dhorpatan Hunting Reserve provides opportunities for seasonal hunting of blue sheep (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*) which in 2022 was updated to include hunting of wild boar (Khadka, 2022). Annual precipitation of the area is less than 1000 mm and the temperature fluctuates from an average low of 1.4°C in winter to an average high of 24.8°C in summer. Large mammal fauna in DHR include blue sheep, Himalayan ghoral (*Naemorhedus goral*), barking deer (*Muntticus vaginalis*), Himalayan tahr, wild boar, snow leopard (*Panthera uncia*), leopard (*P. pardus*), Himalayan black bears (*Ursus thibetanus*) and red panda (*Ailurus fulgens*) (Kandel, 2000; Regmi et al., 2023; Sharma et al., 2023).

Shuklaphanta National Park in southwestern Nepal comprises 305 km^2 and was initially a wildlife reserve since 1979, later becoming a national park in 2017. It is bordered by settlement, forests, the Syali River, Indian (Pilibhit Tiger Reserve and Lagga Bagga Forests), and the Mahakali River. The park is mainly in the Gangetic floodplain with elevations of 175 — 1300 m. It has a tropical monsoon climate with annual temperatures ranging from 7 to 37°C. The park hosts 53 mammal species including Bengal tiger (*Panthera tigris tigris*), sloth bear (*Melursus ursinus*), honey badger (*Mellivora capensis*), leopard, Asiatic elephant, greater one-horned rhino, blackbuck (*Antilope cervicapra*), wild boar, and chital (*Axis axis*) (Nyaupane et al., 2020, 2022).

2.2. Data collection

We collected secondary and primary data on wildlife attacks in ShNP and DHR. Secondary data included the number of households to determine the sample sizes needed for surveys and were collected from respected protected areas office. Primary data were collected during field visits and questionnaire surveys including the key informant interviews (Supplementary file 1). In ShNP we conducted a questionnaire survey among 300 out of 900 affected households, exceeding the minimum required sample size of 270 households which provides a 95 % confidence interval with a 5 % error margin (Krebs 2014). In DHR, we conducted the questionnaire survey with respondents of 270 households. An oral consent with all respondents was taken before the survey. We conducted the questionnaire survey from September 2021 to January 2022 in ShNP and August to September 2022 in DHR. The survey was conducted with one person from each household >18 years old. We selected the respondents without regard to formal education, gender, ethnicity or religion. We collected demographic data including age, gender, education, number of family members and religion, and socio-economic information. We asked the people if they experienced wild boar conflicts and to characterize the conflicts. We also asked them the type of crops they cultivate and amount of crop production. We noted the amount of crop loss during the survey year due to wild boar from each household in both the protected areas.

2.3. Data analysis

We summarized data as percentage or frequency for analysis. The monetary value of crop loss was estimated based on the annual sale price of each crop, and then converted to USD using the Nepal Rastra Bank's Exchange rate (1 USD = 132.12 NPR on 12 December 2022). We used chi-square tests to estimate the differences between gender, age, occupation, age group and education of ShNP and DHR. We performed Wilcox-tests (W) to compare family size, and land owned of both the protected area. We considered statistical significance using $p < 0.05$; all analyses were performed in the R program (R Core Team 2023). To understand the intensity of crop damage by wild boar, we also calculated damage per production ratio for both the PAs dividing total damage amount by total production amount.

3. Results

Altogether, we interviewed 570 people in two protected areas (ShNP = 300, DHR = 270). The median age of respondents in ShNP was 40 years and in DHR it was 45 years (Table 1). We interviewed a greater percentage of males in DHR (81 %) than in ShNP (51 %). More respondents were educated in DHR than ShNP. Family size, total land owned and employment percentage were greater in ShNP than in DHR (Table 1).

The respondents living around the ShNP cultivated four major crops: paddy (n= 264), wheat (n= 263), mustard (n=234) and maize (n=223) whereas respondents of the DHR area mainly cultivated potato (n= 260) and oats (n=118). The annual income from these crops was 2363,751 USD in ShNP and 108,593 USD in DHR. Wild boar damaged an estimated 87,035.78 kg of crops across both protected areas with a total estimated economic loss of 26,389 USD within a year. The damage was greater in ShNP (64,100 kg, 18,052 USD) than in DHR (22,935 kg, 8337 USD; Fig. 2a). The average damage of crops in ShNP was 214 kg; 60 USD (range: 0–2400 kg; 0–658 USD) while that in DHR was 86 kg; 31 USD (range: 0–927 kg; 0–334 USD). Crops receiving greatest damage in ShNP was paddy (10,514 USD) followed by wheat (6798 USD; Fig. 2b) whereas in DHR it was potato (7995 USD; Fig. 2c). However, damage to production ratio was higher in DHR (0.079) than ShNP (0.031; Fig. 2d).

4. Discussion

Our study provides insights into the patterns of human wild boar conflicts in two different management-based protected areas of Nepal. The most frequently damaged crops were paddy in ShNP and potato in DHR, with overall higher amount of damage and economic loss in the lowlands ShNP. However, the severity of damage was more pronounced in DHR with higher damage to production ratio.

We observed a relatively higher number of male respondents than female respondents. In societies where men predominantly hold leadership roles, there is a recurring pattern of imposing restrictions that hinder women from actively participating in conservation efforts (Lendelvo et al., 2012). This observation highlights a tendency to limit or discourage the engagement of women in various aspects of environmental preservation and wildlife conservation initiatives (Lendelvo et al., 2012). This pattern is consistent with a study on human leopard conflict in Bardia National Park, which highlighted that male respondents greater than female respondents (Sijapati et al., 2021). However, Sijapati et al. (2021) revealed that female respondents were more likely to report losses than were male respondents.

A high percentage of respondents lacked formal education in both study areas. The fact that the literacy rate in these study areas was lower than the national average of 76.2 % (CBS, 2021) suggests that communities near DHR and ShNP could have reduced educational opportunities. This might be related to lower income and greater need for family members to work at earlier ages to aid in livelihood. Further, in communities with lower economic means, males are more prioritized for education (Hatlebakk and Gurung, 2016) which supports the higher overall literacy rate in DHR compared to the ShNP. Additionally, the Tarai region, where ShNP is located inhabited by the ethnic Tharu community, and their literacy rates are notably low, potentially influencing the overall literacy rate in Shuklapanta (Bista, 1987). Higher land ownership in the lowlands can be correlated to lack of fertile lands in the highlands of Nepal, a result of the traditional practice of mixed cereal grain based farming (Kharal et al., 2018). Further, the prevalence of lowland deforestation for agriculture and plain lands that are more amenable to crop farming in Tarai Region (Regmi, 1987) may in part explain the higher rate landownership among people of ShNP.

Our findings suggest greater crop damage by wild boar in ShNP than in DHR. This might be associated with limited agricultural practices in the highlands of DHR due to steep terrain and low soil fertility (Bharathy et al., 2022), as well as the impact of trophy and illegal hunting, exacerbated by insufficient patrolling. In contrast, the extensive year-round farming on larger agricultural lands in ShNP and lack of trophy hunting could be another factors influencing the differing patterns of wild boar crop damage between these regions. In conflict-prone areas, higher crop production is often associated with higher damage as areas with higher production provide more opportunity for wild boars to forage (Branco et al., 2019). Major crops damaged by wild boar were paddy in the lowlands and potatoes in the highlands. These crops are rich in carbohydrates which could result in greater use and subsequent damage by wild boars (Kanter and Elkin, 2019; Ramanathan and Krishnamoorthy, 1973). Further, the dominant crops in the highlands are potatoes (Hijmans, 2001) and paddy in the lowlands (Basyal et al., 2019), so comparative damage of these crops could be a consequence of higher availability between protected areas (Branco et al., 2019).

The agricultural crop damage ratio was higher in DHR than in ShNP, likely due to the limited implementation of effective wildlife management practices such as electric or barbed wire fencing or other preventive measures in DHR. The only preventive measures we

Table 1
Demographic variation in Shuklaphanta National Park (ShNP) and Dhorpatan Hunting Reserve (DHR), Nepal.

Parameters	ShNP	DHR	Statistics	p
Median age (years)	40 (18−90)	45(21−80)	W = 46758	p= 0.004
Gender (male %)	51	81	$\chi^2 = 61.734$	p < 0.001
Educated (%)	43	57	$\chi^2 = 11.209$	p < 0.001
Median family size (number)	6(1−34)	5(2−18)	$\chi^2 = 5.066$	p < 0.001
Median land owned (ropani)	7(0.1–88.7)	2(0.5–25)	W = 15310	P < 0.001
Employed (%)	13	8	$\chi^2 = 3.049$	p = 0.081

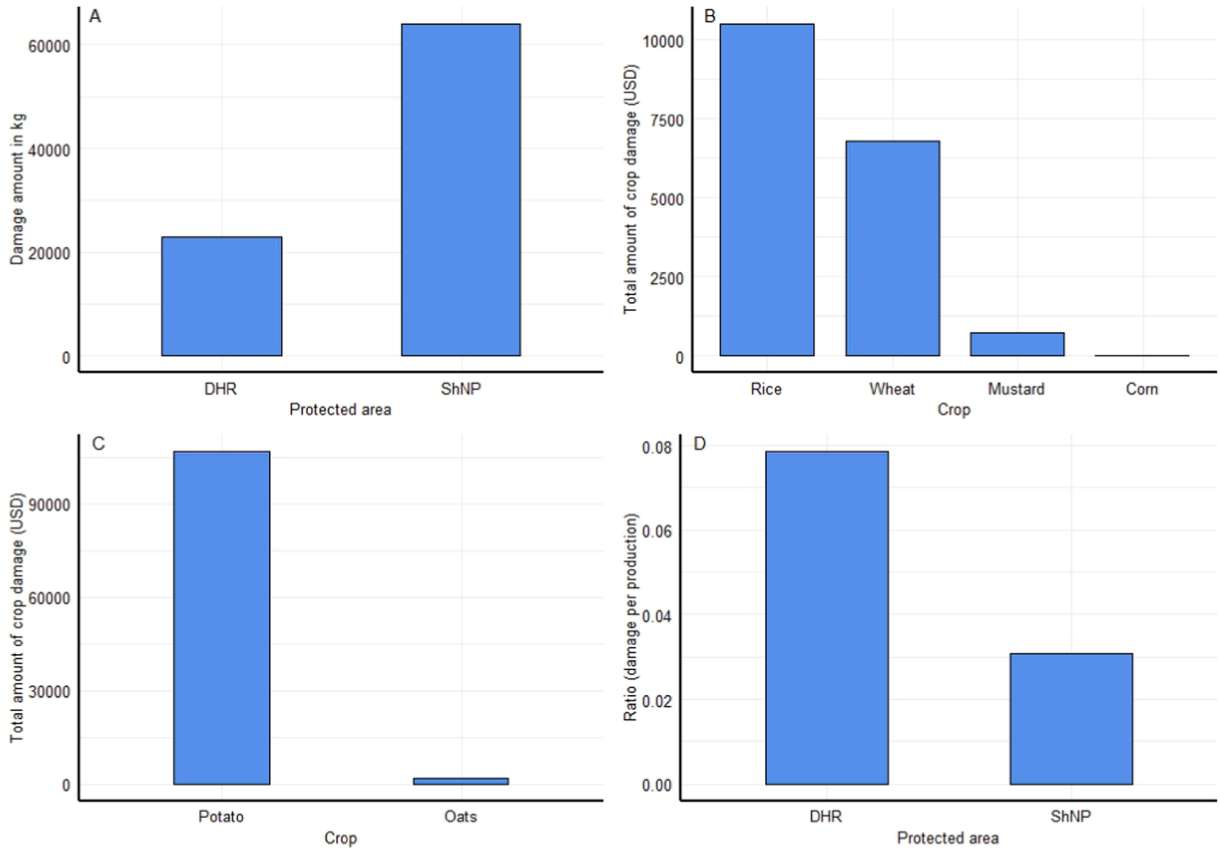

Fig. 2. Crop damage by wild boar in Shuklaphanta National Park (ShNP) and Dhorpatan Hunting Reserve (DHR), Nepal. A. Total crop damage (kg) and damage across two protected areas B. Major crop damage and economic loss (USD) in Shuklaphanta National Park C. Major crop damage and economic loss (USD) in Dhorpatan Hunting Reserve D. Damage to production ratio of crops across two protected areas.

noted in DHR was stone fences which were also built too low to prevent wild boar from entering crop fields (authors, personal observation). In ShNP, methods like barbed wire and electric fencing has been implemented in most of the areas (Pant et al., 2023) which may have reduced the severity. However, this method also is not able to mitigate the conflict completely in the area (Pant et al., 2023). The greater severity of wild boar damage in DHR adversely impacts local livelihoods, and environmental factors, such as weather and available refugia for wild boar, may also influence the frequency of these interactions (Murray et al., 2015). Nonetheless, following the Nepal government's declaration in November 2023, which classified wild boar as an agricultural menace and permitted hunting on private lands—with the stipulation that captured boars must be handed over to local government offices—there is an expectation of reduced crop raiding incidents in both of these areas. This new policy is anticipated to mitigate economic losses from wild boars, and future studies should assess its effectiveness by comparing crop loss data before and after its implementation.

5. Conclusions

Our study provides insights into the scenario and differences in crop types and amount of crop damage by wild boar across two protected areas based on different management practices. We observed a substantial economic loss of locals due to wild boar across both the PAs and there occurs a difference in the pattern of crop damage by wild boar between the PAs. The implementation of mitigation measures—such as installing physical barriers, employing deterrents, and enhancing community awareness—combined with the government-sanctioned killing of wild boars in agricultural fields can significantly reduce human-wild boar conflicts in both areas. Furthermore, we recommend government-managed trophy hunting of wild boar as a potential solution to reduce human-wildlife conflicts and provide economic benefits to local communities in ShNP, where such practices are already permitted in DHR. However, it is essential to consider the population status and conservation needs of the species to ensure that this approach is sustainable and does not adversely affect wild boar populations. Such a balanced strategy can help achieve both wildlife conservation goals and local economic development.

Ethics approval

No approval of research ethics committees was required to accomplish the goals of this study because the work did not involve capture, handling or experimentation on any animal. However, oral consent was taken with participants before questionnaire survey. The participants were provided with clear information regarding the purpose, nature, and use of the data collected through the survey. In addition, we did not survey to the people below 18 years old.

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CRediT authorship contribution statement

Conceptualization: Y.G.M, B.P., S.R., H.B.K., H.P.S.; Data collection: Y.G.M. B.P.; Supervised: H.P.S.; Data analyzed: Y.G.M, B.P, S. R.; writing-original draft preparation: Y.G.M, B.P., S.R., H.B.K., H.P.S.; Writing- review and editing: Y.G.M., B.P., S.R., H.B.K., J.L.B., H. P.S.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Research Permission

Department of National Parks and Wildlife Conservation, Nepal, for providing permission [2077/78/Eco/115/1619 (ShNP) and 2079/80/Eco/10/137 (DHR)].

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2024.e03301.

Data Availability

Data will be made available on request.

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