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Research article

Factors influencing Chinese pangolin (*Manis pentadactyla*) burrow selection in the Chandragiri-Champadevi hills of Kathmandu Valley, Nepal

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ABSTRACT

The Chinese pangolin (*Manis pentadactyla*) confronts challenges from illegal hunting, trading, and habitat degradation. Therefore, it is imperative to establish and implement effective conservation strategies at both local and regional levels. However, there is limited information, particularly within the Kathmandu Valley of Nepal, underscoring the significance of local-level habitat characterization for burrowing animals like pangolins. In this context, our study aimed to assess how anthropogenic and environmental factors influence the presence of Chinese pangolins along the elevational gradients of Chandragiri-Champadevi Hills, renowned for the scenic beauty and popular hiking trails within the valley. We conducted surveys of foraging and resting burrows at 72 plots distributed along 12 elevational line transects from 1500 to 2100 m elevational gradients of Chandragiri-Champadevi Hills. Notably, we observed pangolin burrows spanning from 1550 m to 2095 m. With increasing elevation, we recorded a decline in both foraging and resting burrow numbers. Furthermore, our findings indicated an increase in burrow numbers with increasing the distances from roads, whereas burrow numbers decreased with increasing proximity to human settlements. Interestingly, foraging burrows exhibited an increase with noise but a decrease with slope, while resting burrows showed an increase association with higher canopy and ground cover percentages. Our study shows the substantial anthropogenic disturbances in the habitats of Chinese pangolins in the Chandragiri-Champadevi Hills. We recommend managing the human-associated threats to ensure the species conservation at this site-specific area.

1. Introduction

Insights into pangolin burrow selection contribute valuable knowledge regarding the ecological and anthropogenic elements influencing their populations and habitat preferences [1–3]. A range of ecological factors, including vegetation cover, water bodies, and soil type, alongside anthropogenic influences like land use changes and habitat fragmentation, impact the availability, suitability, and choice of burrows [4,5]. Comprehending these factors that shape burrow selection holds the key to formulating effective

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conservation strategies for pangolins, which are critically imperiled globally due to rampant illegal hunting and trading [1,3,6]. Notably, pangolins are considered as rare delicacies in various Asian and African regions and are subjected to widespread trafficking for use in traditional medicinal practices [7].

The Chinese pangolin (*Manis pentadactyla*) has an extensive distribution encompassing Nepal, Bhutan, India, Bangladesh, Myanmar, Vietnam, Thailand, and Taiwan [8]. This species is critically endangered as per the International Union for Conservation of Nature Red List [8] and holds a position on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora [9]. In Nepal, it is protected under the National Parks and Wildlife Conservation Act of 1973, and the National Red List of Nepal categories the species as endangered [10]. The Chinese pangolin is distributed across 25 districts of Nepal [11,12], with an elevation range usually below 2500 m above sea level [8]. The species thrives in diverse landscapes, including riverine forests, sal (*Shorea robusta*) forests, grasslands, and agricultural areas [5], where they either excavate their own burrows or enlarge termite-constructed passages [3,13]. Their burrowing activities serve dual purposes: foraging burrows, dug primarily for searching food, which vary seasonally due to termite distribution shifts, and resting burrows, utilized for more extended durations [14], reflecting their habitat preferences linked to environmental factors [3].

The distribution of the Chinese pangolin is shaped by a diverse array of anthropogenic and environmental factors. Recent escalations in human activities, encompassing urban expansion, road and dam construction, forest conversion to agriculture, forest fires, overgrazing, soil extraction for domestic purposes, and the degradation of natural water sources [11,15], have emerged as substantial threats to biodiversity conservation, particularly affecting the Chinese pangolin. While human settlements, roads, and noise can exert negative pressures on the species, environmental factors such as water resources, slope, canopy cover, and ground cover can contribute positively to their presence [2,4,16,17]. Typically, burrows are situated in proximity to water sources due to their frequent water requirements [18]. However, the species tends to avoid human settlements due to there being a heightened risk of human interaction and potential adversities like hunting and poaching. Chinese pangolins exhibit a preference for burrows on gentle slopes with easily workable clay and sandy loam soil, conserving energy during excavation [3,14,16]. These burrows offer added safeguards against predators and mitigate flood risks during periods of heavy rainfall [4]. Moreover, the species favors dense ground cover, providing protection for their offspring and burrow entrances, along with moderate to dense canopy cover, which enhances the availability of their primary prey: ants and termites [19,20]. Nevertheless, the impact of these ecological and anthropogenic factors on burrow selection manifests diversely at the local level, and several unknown variables may yet influence their habitat needs. Hence, comprehending localized habitat requirements remains imperative for the effective safeguarding of Chinese pangolin populations.

Currently, many studies are focused on understanding the trade nexus associated with pangolin [21–24], while their habitat requirements have received less attention at the local level. Gaining insight into the local ecological and anthropogenic drivers that shape the selection of foraging and resting sites by pangolins can yield invaluable perspectives into their habitat needs. Within the Kathmandu Valley, the Chandragiri-Champadevi Hills, recognized tourist destinations [25], have received relatively limited attention in

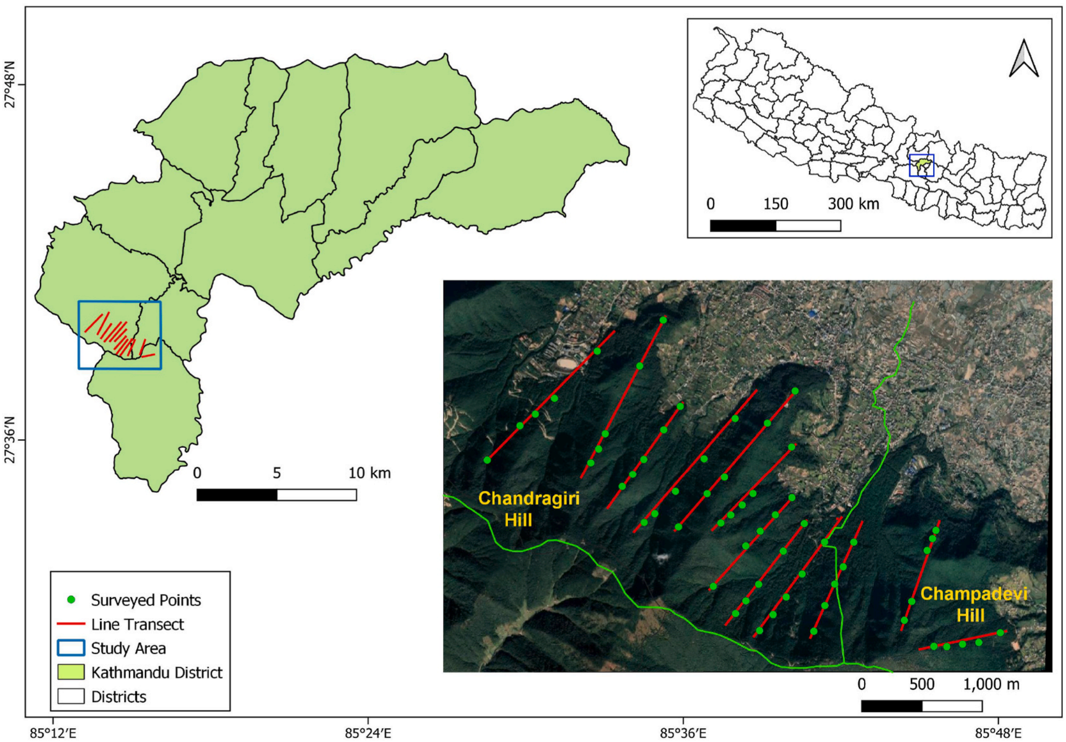

Fig. 1. Chinese pangolin survey plots along the transects in Chandragri-Champadevi Hills, Kathmandu Valley.

terms of pangolin occurrences. While limited overview of foraging site selection in the Chandragiri region was provided in recent research [2], our study expanded the scope to include the Champadevi Hills, providing comprehensive insights into the ecological and anthropogenic factors governing pangolin habitat requirements in this area. Given that pangolins cover substantial distances (~1.5–5 km) during their nocturnal foraging [26,27], a thorough exploration of the potential landscapes in this region becomes pivotal. Hence, our study aims to unravel the factors influencing the foraging and resting burrows selection by Chinese pangolins across the elevational gradients of the Chandragiri-Champadevi Hills in the Kathmandu Valley, Nepal. We hypothesized that their distribution is positively influenced by elevation, owing to reduced disturbances at higher elevations. Furthermore, we anticipate a positive correlation with ecological factors and, conversely, a negative association with anthropogenic factors in shaping the burrow distribution patterns of the Chinese pangolin within our study domain.

2. Materials and methods

2.1. Study area

The Chandragiri-Champadevi Hills are situated in the southwestern part of the Kathmandu District, within the Bagmati Province of Nepal (Fig. 1). This region is characterized by predominantly hilly terrain, encompassing elevations from 1310 to 2551 m above sea level. The area is situated approximately 20 km from the center of Kathmandu city and is well-accessible via major roads. It is renowned for its scenic beauty, offering views of the Himalayan range, temples, and opportunities for day hiking within the valley. Consequently, the region features numerous hiking routes, and notably, a cable car service has been in operation since 2016 in the Chandragiri Hills.

The vegetation in the area is mixed forest and includes the Nepalese alder (*Alnus nepalensis*), needlewood (*Schima wallichii*), chinkapin (*Castanopsis tribuloides*), pine (*Pinus roxburghii*), oak (*Quercus* spp.), rhododendron (*Rhododendron arboretum*), Himalayan ash (*Fraxinus floribunda*), and marking nut (*Semicarpus anacardium*). Major mammal species of the study area includes the Large Indian civet (*Viverra zibetha*), Yellow-throated marten (*Martes flavigula*), Jungle cat (*Felis chaus*), Golden jackal (*Canis aureus*), Chinese pangolin (*Manis pentadactyla*), Hoary-bellied squirrel (*Callosciurus pygerythrus*), Leopard cat (*Prionailurus bengalensis*), Leopard (*Panthera pardus*), Masked palm civet (*Paguma larvata*) and Wild boar (*Sus scrofa*), among others [10,25,28].

2.2. Data collection

In October of 2022, we conducted an initial survey to gather information about the presence of Chinese pangolins. Subsequently, from November to December 2022, we carried out a field survey for 20 days. We randomly established 12 line transects along elevational gradient in Champadevi-Chandragiri hills using QGIS and our results indicated that the elevation of the transects ranged from 1500 to 2100 m above sea level. The transects were designed in such a way that a minimum aerial distance of 200 m was maintained between neighbor line transects.

Within each transect, we positioned 50 × 50 m^2 plots at intervals of 100 m in elevation to facilitate burrow counts. Our approach to determining the optimal plot size was experimental in nature. We commenced by creating 10 × 10 m^2 plots, tallying burrows across various transects. Subsequently, we repeated this process with increasing plot sizes: 20 × 20, 30 × 30, 40 × 40, 50 × 50, 60 × 60, and

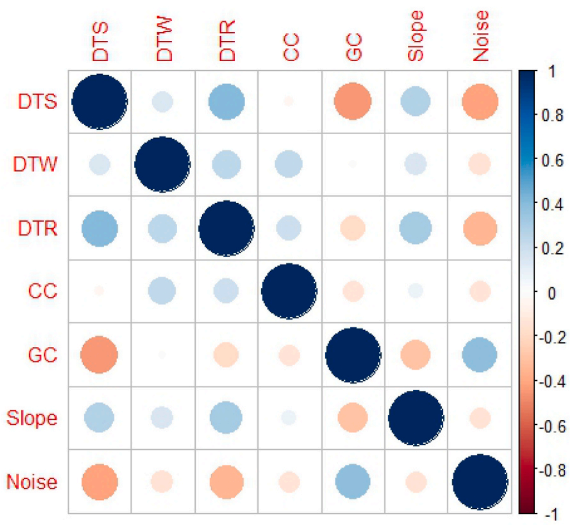

Fig. 2. Correlation matrix between predictive variables to estimate factors influencing the foraging and resting burrow selection by Chinese pangolin in Chandragiri-Champadevi Hills, Kathmandu, Nepal in 2023. DTS = distance to settlement, DTW = distance to water body, DTR = distance to road, CC = canopy cover (%) and GC = ground cover (%).

$70 \times 70 m^2$. Given the comparable burrow counts observed in plots above $50 \times 50 m^2$, we adopted this size as optimal for our burrow count analysis.

We categorized each pangolin burrow by measuring its depth and diameter into either foraging or resting burrow [29,30]. Furthermore, resting burrows were further divided into active and inactive categories following the pangolin monitoring guidelines [11]. Geographic coordinates, along with elevation data, were acquired using a handheld Garmin GPS device from the center of each plot. Additionally, we measured the slopes of the plots utilizing a clinometer, originating from the center of the plot. The Gap Light Analysis Mobile Application (GLAMA) was employed to measure the canopy cover percentage [31]. For this measurement, an average value of canopy cover was determined from the center and four corners of each plot. Similarly, ground cover percentage was assessed utilizing the Canopeo mobile app [32], employing the same methodology as canopy cover assessment. Distances to water bodies, settlements, and roads were measured from the center of each plot using a measuring tape. In cases where distances exceeded 200 m, QGIS was utilized for measurements. Lastly, noise levels were measured in decible using mobile app Decible X [33].

2.3. Data analysis

We conducted data summarization and analysis within the R programming, employing the tidyverse [34], corrplot [35], ggplot2 [36], and MuMIn [37] packages. We calculated Pearson's correlation coefficient to identify the correlation among predictor variables as correlation among variables severely impacts the analysis. We set a threshold of 0.70 for the correlation. From correlation analysis we observed that none of the variables were correlated as all values remained below the threshold set (Fig. 2). We used generalized linear modeling (GLM) with Poisson distribution to identify the factors associated with foraging and resting burrow selection by Chinese pangolin across our study sites. We used number of foraging burrows and resting burrows as response variables for the analysis. Our ecological predictors were distance to water body, canopy cover (%), ground cover (%), and slope (°), whereas anthropogenic predictors were distance to settlement (m) and road (m) and noise level (dB). We used same variables as predictors for both the foraging and resting site selection by the species to see if the factors act differently on our response variables.

3. Results

We found Chinese pangolins utilizing burrows across an elevation range of 1550 m to 2095 m asl. The observed burrows were situated on slopes varying from 7° to 48°, with an average slope of 32.31 ± 8.45° within the study plots. The average canopy cover parentage was 52.59 ± 22.18. However, the ground cover percentages exhibited variability, ranging from a minimum of 1.36% to a maximum of 95.65%. Noise levels within the study area averaged between 22.67 dB and 58.00 dB, with an overall mean of 39.16 ± 6.68 dB. The average minimum distances from settlements, water bodies, and roads were 333.30 ± 277.52 m, 64.64 ± 53.82 m, and 169.26 ± 159.41 m, respectively.

We recorded a total of 103 resting and 203 foraging burrows from 72 plots in 12 transects in our study area. Among the 103 resting sites, only 16 were used as active burrows while others were older burrows. We found maximum 15 foraging burrows and eight resting

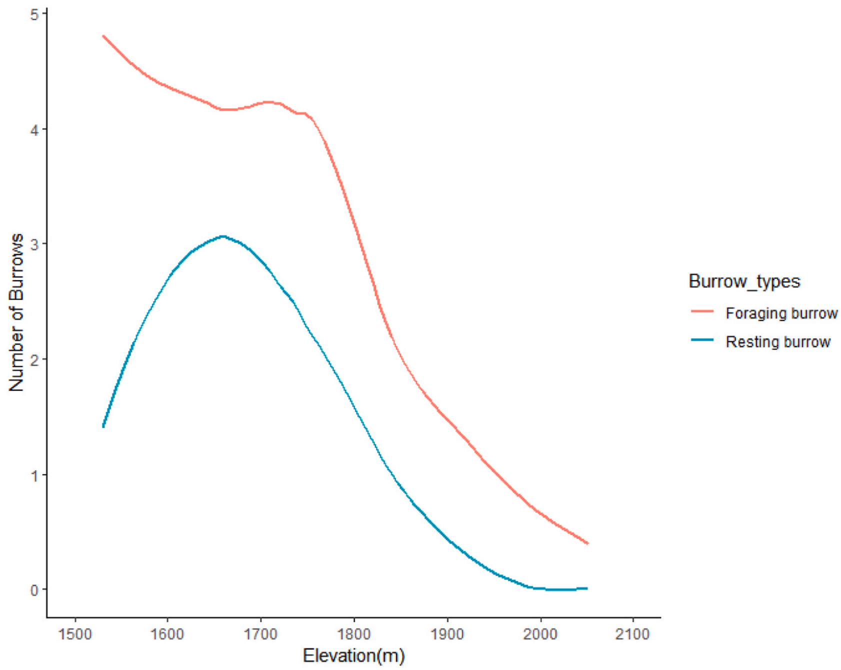

Fig. 3. Number of pangolin burrows types along elevation with smoothing lines for each types.

burrows in a plot. We recorded a maximum of two active nests in a plot during this period. In most of the plot (n = 51) the active nest was not in existence. We observed a decline in all pangolins burrow types with an increase in elevation (Fig. 3). The most significant decline was apparent in foraging burrows, followed by resting burrows. In contrast, a comparatively consistent pattern was evident in the case of active resting burrows (Fig. 3).

We identified a mixed impact of our predictive variables on the foraging burrows selection. Among these variables, distance to road (0.359 ± 0.115 m), distance to settlement (−0.428 ± 0.137 m), noise (0.285 ± 0.073 m), and slope (−0.277 ± 0.077 m) displayed significant influence on the count of foraging burrows within our study area (Table 1). Conversely, when examining resting site selection, we found significant impacts arising from distance to settlement (−0.566 ± 0.221 m), ground cover (0.292 ± 0.012 m), and canopy cover (0.258 ± 0.105 m) (Table 1). It's noteworthy that both foraging and resting burrows exhibited an increase in numbers with an increasing in distance from roads, whereas a decrease in burrow counts occurred with increasing distances from human settlements. Specifically, for foraging burrows, we noted an increase in numbers corresponding to elevated noise levels, but a reduction in numbers with steeper slopes. In contrast, the impact of noise and slope on resting burrow selection by Chinese pangolins was deemed insignificant. The presence of resting burrows showed a notable augmentation in response to heightened canopy and ground cover percentages, whereas this effect was deemed insignificant when it came to foraging burrows.

4. Discussion

Our study showed a higher occurrence of foraging burrows for the Chinese pangolin compared to resting burrows, with the later category predominately composed of inactive ones. This preponderance of inactive burrows aligns with findings from other studies [38], potentially indicating the various impact of factors influence Chinese pangolin burrow selection. Both foraging and resting burrows exhibited a negative correlation with elevation. Notably, the selection of foraging burrows was influenced by variables including distance to road, settlement, noise, and slope, while the selection of resting burrow was influenced by distance to settlement, ground cover, and canopy cover.

Elevation could potentially shape the distribution of the Chinese pangolin, as higher elevations typically entail steeper slopes, whereas the species is typically known to favor lower and intermediate slopes [2–4,14,30,39]. The decline in both burrow types with increasing elevation could be attributed to shifts in climatic factors such as precipitation, temperature, and solar radiation along the elevation gradient [40], leading to alterations in habitat characteristics and quality that subsequently influence species distribution patterns. Moreover, the declining abundance of termites with elevations could potentially contribute to the decrease in burrow numbers. Consequently, the collective evidence provides supports the proposition that the pangolin predominantly occupies mid-altitude ranges in Nepal [41].

The decline in the occurrence of foraging burrows near roads could be attributed to the inherent threats posed by these roadways to the species. The recent extensive road construction in the study areas may have led to habitat fragmentation for the species [25]. In addition, the extensive utilization of these pathways by hikers and cyclists may potentially induce the species to steer clear of these regions. Additionally, the species' nataurally reserved disposition could be another influencial factor in this regard. The observed increase in the number of both burrow types with a decrease in distance to settlements may be linked to the presence of agricultural lands near human habitations [2]. These agricultural lands offer an abundant supply of ants and termites for the species' foraging needs [13,32]. Indeed, Nepal's cultivated lands provide a substantial potential habitat for Chinese pangolins [5]. However, the proximity of the species to such anthropogenic disturbances on a larger scale often results in severe threats such as illegal hunting and trading [1,3,6].

Table 1

Generalized linear modeling (GLM) with Poisson distribution. Factors associated with foraging and resting burrows of Chinese pangolin in Chandragiri and Champadevi Hills of Kathmandu, Nepal. Values are in Standard errer (SE), Lower Confidence Interval (LCI) and Upper Confidence Interval (UCI).

Parameters	Estimate	SE	LCI	UCI	z value	Pr(>|z|)
Foraging Burrow						
Intercept	0.875	0.090	0.696	1.055	9.576	**< 0.001**
Distance to road (m)	0.359	0.115	0.128	0.589	3.047	**0.002**
Distance to settlement (m)	−0.428	0.137	−0.702	−0.153	3.054	**0.002**
Distance to water (m)	−0.175	0.096	−0.367	0.017	1.791	0.073
Noise (dB)	0.285	0.073	0.138	0.432	3.797	**<0.001**
Slope (°)	−0.277	0.077	−0.430	−0.123	3.535	**<0.001**
Ground cover (%)	0.096	0.081	−0.066	0.258	1.166	0.244
Canopy cover (%)	−0.057	0.072	−0.201	0.088	0.767	0.443
Resting Burrow						
Intercept	0.141	0.137	−0.130	0.420	1.005	0.315
Distance to road (m)	0.190	0.190	−0.176	0.597	0.980	0.327
Distance to settlement (m)	−0.566	0.221	−1.037	−0.131	2.524	**0.012**
Distance to water (m)	−0.257	0.140	−0.538	0.033	1.800	0.072
Noise (dB)	0.176	0.103	−0.027	0.389	1.669	0.095
Slope (°)	−0.175	0.110	−0.406	0.038	1.552	0.121
Ground cover (%)	0.292	0.114	0.052	0.521	2.515	**0.012**
Canopy cover (%)	0.258	0.105	0.047	0.469	2.418	**0.016**

The increase in pangolin burrows with increase in noise may be due to its optional preference of agricultural area [13,32]. Agricultural areas are potential habitats for the species [5] but are subject to regular human disturbances and noises. Anthropogenic noises are one of the major but overlooked threats for the wildlife resulting changes in their biological, ecological, and behavioral responses [42]. Species often tend to avoid noise disturbance as this may cause structural damage to their hearing parts as well increase their stress level by affecting their central nervous system [43].

Both foraging and resting burrow numbers were observed to decrease with an increase in slope, most likely due to difficult terrain. The species is notably influenced by slope gradients and tends to favor slopes of less than 50° for burrowing activities [2,3,14]. The range of slope selection within the span of 7–48° noted in this study could be linked to the presence of soft and loamy soil prevalent in the study sites, a substrate favored by the species for burrowing purposes [3]. Another plausible explanation for the preference towards less steep slopes could be attributed to the species' slow mobility, making it challenging for them to navigate steeper terrains [44].

Our observations indicate that pangolins exhibit a preference for areas characterized by dense canopy cover when selecting sites for resting. This tendency may arise due to the dense canopy's provision of concealment from predators, given the species' limited defensive capabilities [26], thereby reducing predation risks [20]. Another possible explanation might be the pangolin's nocturnal nature [45], as denser canopy cover creates a darker environment. Similarly, the species' preference for higher ground cover is evident. This preference is attributed to the species' tendency to opt for locations with heavy shrub undergrowth and dense ground cover for crafting resting burrows [1,4]. In addition, the previous study also mentioned the positive correlation between ground cover and the species occurrences at spatial scale [1]. This inclination is potentially linked to the study area's popularity as a trekking destination, leading to a moderate level of human disturbance, prompting the species to favor densely vegetated areas. Furthermore, dense ground cover provides added benefits for the species, aiding in avoiding potential predators [26] and offering protective measures for their offspring and burrow entrances [20].

5. Conclusions

Our research provides valuable insights into the complex interplay of multiple ecological and anthropogenic factors that influence the occurrence of Chinese pangolin burrows in the Chandragiri-Champadevi Hills. These factors significantly influence the choices made by the pangolins in selecting burrows for foraging and resting purposes. Our findings elucidate the discernible influence of human-induced disturbances and threats on the habitats of the species', underscoring the urgency for immediate and concerned conservation efforts. We strongly advocate that construction activities, such as road and building development, should avoid encroaching upon vital pangolin habitats. Considering that the study area ranks as a prominent trekking destination in and around the Kathmandu valley, it is crucial to implement effective management of tourist activities. This includes discouraging any form of tourist intrusion into the core habitat of the species. Furthermore, we strongly advocate for more comprehensive investigations into the species' ecology, both at local and broader spatial scales, to gain deeper insights into the array of human-associated threats and to ensure the species conservation in Nepal.

Ethical standards

This observational study did not require animal research ethics approval.

Data availability

The data used in this study are available from corresponding author on reasonable request.

CRediT authorship contribution statement

Kc Sabin: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Investigation. **Sandeep Regmi:** Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Bindu Pant:** Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Amrit Nepali:** Investigation, Methodology, Writing – review & editing. **Hem Bahadur Katuwal:** Data curation, Formal analysis, Writing – review & editing. **Hari Prasad Sharma:** Conceptualization, Data curation, Formal analysis, Supervision, Writing – original draft, Writing – review & editing, Methodology.

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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