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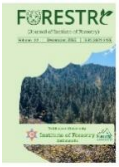

Original article

Effects of habitat correlates on Himalayan red panda distribution in Mewa Watershed, Taplejung, Nepal

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A R T I C L E I N F O

Key words:
Endangered carnivore
Fecal pellet
Threat
Eastern Nepal
Conservation strategy

A B S T R A C T

The Himalayan red panda (*Ailurus fulgens*), belonging to Ailuridae family, is an endangered and habitat specialist carnivore with a peculiar feeding behaviour. A large proportion of potential habitat of the Himalayan red panda lies outside protected areas, which is inadequately assessed on the local scale. Mewa watershed in Taplejung District, eastern Nepal harbors a part of potential habitat of the Himalayan red panda, which has not been explored in terms of habitat requirement attributes of the species. Thus, the study attempted to determine habitat variables affecting distribution and habitat association of the Himalayan red panda in the Mewa watershed. Based on a grid-based survey design, the study deployed altitudinal transects (n = 45; 0.5 to 1 km length) to record animals' evidence and ecological attributes and circular plots (n = 146) for vegetation assessment. Data were analyzed in ArcGIS 10.4.1 for mapping, and binary logistic regression analysis to determine the important habitat correlates. Signs of the Himalayan red panda were recorded in eight grids of the 14 survey grids between the range of 2,500 and 3,500 m elevation in the northeast and northwest aspects and between 15° and 40° slope. A total of 90.32% indirect and 9.67% direct evidence of the species were recorded in 31 plots. The Himalayan red panda defecates mostly in tree branches (56.36%) as the main substrate. Distance to water sources, bamboo clump presence and livestock activity were the important habitat components of the Himalayan red panda, which showed positive association with their distribution and marginal significance, whereas human trails and shrub richness were associated negatively. The study identified livestock activity and human trails as major threats to the Himalayan red panda and its habitat in the Mewa watershed. This study provides valuable insights into the important habitat attributes and potential threats faced by the species in the study area.

INTRODUCTION

The Himalayan red panda (*Ailurus fulgens*) has a wide geographic range in the Himalayas, being distributed across five Asian countries: Nepal, India, Bhutan, northern Myanmar and China. Their distribution is scattered and only exists at low densities in fragmented and isolated forest patches under high anthropogenic pressure (Thapa et al., 2018; Panthi et al., 2017; Wei et al., 1999; Yonzon & Hunter, 1991). Globally, the Himalayan red panda distribution is estimated to cover an area of 134,975 km^2 (Thapa et al., 2018). Six Himalayan red panda conservation complexes in Nepal, with a combined estimated size of 23,977 km^2, were identified by the Conservation Breeding Specialist Group as part of a Himalayan red panda Population and Habitat Viability Analysis (Jnawali et al., 2012). The conservation issues covered in several research on these complexes include scale-dependent distribution, habitat utilization, diet ecology (Thapa et al., 2018; Kandel et al., 2016). Himalayan red pandas were found in 24 out of

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37 potential districts, which is the only data that can be used to establish their presence in a national assessment. At the landscape level (Chitwan Annapurna Landscape) and the protected area level (Dhorpatan Hunting Reserve), rigorous survey has previously been conducted (Bista et al., 2017). Additionally, a community-based approach to landscape-level conservation has been studied in eastern Nepal in 2010, which was extended to western Nepal in 2017 (Sherpa et al., 2020). With an estimated global population of around 10,000 mature individuals, Himalayan red pandas are primarily threatened by habitat loss, hunting for trade, fragmentation, degradation and other anthropogenic disturbances, such as grazing, resource collection and development activities (Wei et al., 1999; Glatston et al., 2015; Thapa et al., 2018). Over the past three generations, there has been a plausible 50% drop in the Himalayan red panda population, because of which the IUCN Red List of Threatened Species has categorized it as Endangered (Glatston et al. 2015). Hence, in order to conserve the natural world amid the rapid growth in human populations, it is crucial to comprehend the habitat needs of the region's threatened biota, especially those of the umbrella, indicator and flagship species.

Himalayan red pandas are represented by two species: the Himalayan red panda (*Ailurus fulgens*) and the Chinese red panda (*Ailurus styani*) (Hu et al., 2020). The Himalayan red panda is a small and charismatic mammal found in Nepal, Bhutan, India and southern Tibet, whereas the Chinese Himalayan red panda is distributed across China, Myanmar and India (Hu et al., 2020). Of these, the former species inhabits Nepal and is more vulnerable to threats compared to its Chinese relative (Hu et al., 2020). Despite being classified as a carnivore, Himalayan red pandas have evolved as herbivores, primarily feeding on bamboo leaves and shoots (Yonzon & Hunter, 1991; Wei et al., 1999). Himalayan red pandas have specific microhabitat requirements, preferring moderate to steep slopes, fallen logs, tree stems, high bamboo understorey cover, within the altitudinal range of 2,000–4,000 m and areas close to water sources (Bista et al., 2017; Dendup et al., 2020; Thapa et al., 2020). They spend their time on feeding and sleeping on tree branches or in tree hollows and use specific sites for defecation (Yonzon & Hunter, 1991; Wei & Zhang, 2011). Their usual places of defecation are tree branches, consecutively followed by the ground, fallen logs, tree stumps and rocks (Bista et al. 2017a; Bista et al. 2019; Thapa et al. 2020). The suitability of a habitat for the Himalayan red panda may be ascertained with the right understanding of these habitat variables, which is critical for species conservation planning.

The stress of livestock grazing in Nepal poses a threat to wildlife in mountainous protected areas, such as Langtang National Park, Gaurishankar Conservation Area, Dhorpatan Hunting Reserve and Rara National Park (Yonzon and Hunter, 1991; Panthi et al., 2017). A growing human population and equally quick-paced development projects, such as road construction, eg in Panchthar–Ilam–Taplejung (PIT) in the east, and high-altitude hydropower projects, eg., in Gaurishankar Conservation Area in central Nepal, use huge amounts of natural resources and have an impact on local-level biodiversity (Rawal and Adhikary, 2025). Understanding the Himalayan red panda's habitat needs at both large and small scales is crucial for establishing its range, as well as for directing effective and efficient conservation efforts. However, adequate information about the habitat preferences, ecology and conservation threats to Himalayan red pandas at local level is limited. Thus, this study aimed to determine the potential distribution and identify the key habitat features that influence the distribution of the Himalayan red panda on a local scale in the Mewa watershed, Taplejung District, in eastern Nepal. The area is situated outside of a protected area and is relatively unexplored in terms of its faunal diversity. This focused approach ensures accurate and actionable information for effective conservation management, addressing local challenges and promoting the survival of Himalayan red panda population. Furthermore, the information will be valuable to local government bodies and local conservation organizations to design data-based Himalayan red panda conservation strategies and ensuring long-term conservation and associated habitats of the species.

MATERIALS AND METHODS

Study area

Meringden is a rural municipality in Taplejung District, Koshi Province of Nepal, at a latitude 27° 34' 47" N and longitude 87° 34' 54" E. Currently, Meringden consists of total six wards, which are scattered across 210 km^2. The population of the rural municipality is 11,838 in 2021. This study was carried out in the Mewa Khola watershed, a significant tributary of the Tamor River, which offers ecosystem services to a significant portion of the population living downstream (Figure 1). Himalayan red pandas have been seen in the area, which is close to the Kanchenjunga Conservation Area. The variables that influence the Himalayan red panda distribution in the area remain mostly unidentified.

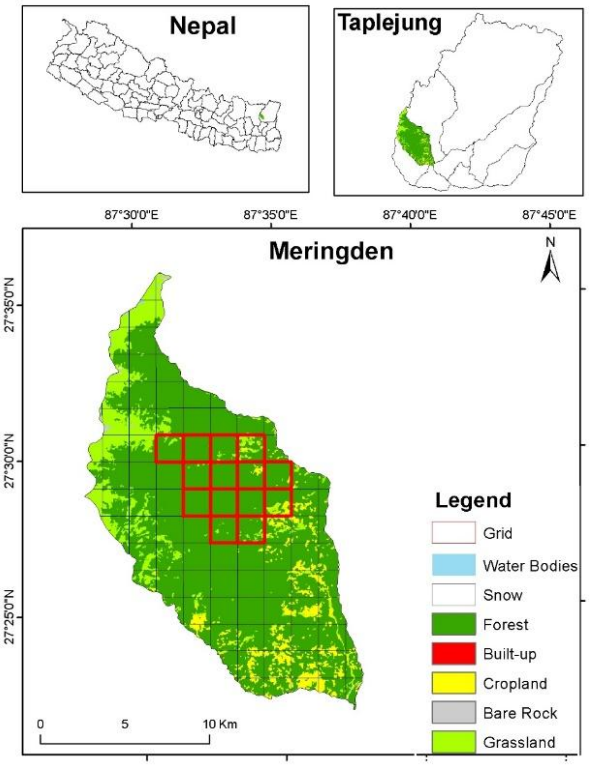

Figure 1: Meringden Rural Municipality, the study area in Taplejung District, Nepal

Methods

Data collection

The fishnet tool in ArcGIS 10.4.1 was used to make grids of the entire research area, which was between an elevation of 2,000 m and 4,000 m. The grids of 9.6 km^2, the maximum area of a Himalayan red panda's home range, were overlaid on the map to represent the potential habitat (Yonzon, 1989). Each grid, with a 9.6 × 9.6 km^2 size, was further divided into six sub-grids, each with a 1.6×1.6 km^2 area. With the Geospatial Modelling Environment included in ArcGIS software, at least 50% of the total grids for the survey were chosen. After eliminating a few grids because of their steepness and rough terrain, a total of 14 grids were chosen across the habitat that reflects the Meringden Rural Municipality. The survey used a methodology that was based on the Himalayan red panda field survey and protocol for community-based data collection monitoring (MFSC, 2015). It was ensured that these selected sub-grids covered the entire potential habitat in the specific grid, including the range of possible elevations and the availability of water. Each sub-grid was traversed using all available transects (MFSC, 2015).

Previous studies have used faeces as an effective indicator of species occurrence due to a limited chance of sightings, and they are distinct from the rest of the animals (Wei et al., 2000; Zhang et al., 2004, Thapa et al., 2018). Himalayan red pandas typically leave shiny greenish faeces in groups, with occasional sightings (MFSC, 2015). Along with the specified transects, opportunistically discovered Himalayan red panda signs were also observed. A completely random sampling approach is infeasible due to the steep mountain terrain (Qi et al., 2009). This research adopted random line transects in the field, representing all habitat types, to record the Himalayan red panda signs. The survey involved walking along transects ranging from 0.5 to 1 km length, with 10 m width, across the elevation range of the species (2,200–4,000 m) (Thapa et al., 2018). To evaluate the habitat characteristics, a circular sampling plot with a 10 m radius was established at the beginning of each transect and subsequent plots were built at intervals of 500 m. In both sign and non-sign plots, the point location was georeferenced with a handheld GPS (Garmin eTrex® 10), and habitat variables were recorded in concentric sampling plots with a predetermined size (Area = 314.28 m^2, 10 m radius). For vegetation analysis, 3 m radius (A = 28.28 m^2) for bamboo and shrubs richness, 10 m radius (area = 314.28 m^2) for trees, from which the number of tree species, tree height, DBH, canopy cover and bamboo density were recorded within the plots (MFSC, 2015). The information on topographic variables such as slope and aspect was based on the GPS coordinates and were obtained using ArcGIS software. In total, the study covered a 45-km transect consisting of 146 plots, including 31 occurrence and 115 non-occurrence plots. All the field data was collected in two phases, October 2022 and January 2023.

Data analysis

All the data collected in the field were input in a Microsoft Excel spreadsheet for processing and mining. The Himalayan red panda distribution map in the Mewa watershed was created using ArcGIS software (version 10.4.1), and the species recorded coordinates and open access land covered data from the International Centre for Integrated Mountain Development (ICIMOD). The Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) was obtained from Earth Explorer (http:// earthexplorer.usgs.gov) with a spatial resolution of 30 m and was used to extract topographic variables (elevation, aspect and slope). The terrain characteristics of the Himalayan red panda sign plots were assessed by employing the DEM data in ArcGIS software.

During the fieldwork, the geographical locations of transects and detected signs, that is faecal pellets of Himalayan red panda, were recorded using GPS, along with habitat details, and incorporated as layers within the GIS. The slope of the terrain was categorized into several classes, including gentle slope (0–10°), moderately steep slope (10–20°), steep slope (20–30°), and very steep slope (> 40°). Similarly, aspects were categorized into various categories, such as flat, north, northeast, east, southeast, south, southwest, west, and northwest. Analytical maps of the study sites were prepared by combining the 2020 land cover map from ICIMOD, DEM data, ArcGIS and GPS coordinates collected from the study area. Jeffrey's Amazing Statistics Program Version 0.17.2 was used for descriptive analysis (JASP Team, 2023). The result was presented in the form of tables and boxplots for both quantitative and qualitative data.

Binary logistic regression for habitat analysis

The associations between habitat factors (predictor variables) and presence or absence of Himalayan red panda sign (response variable) were investigated using a binary logistic regression. Influencing environmental covariates were analyzed using binary logistic regression in R (Statistical Analysis) with the GLM (Generalized Linear Models) function. The GLM function is part of the base R package and does not require any additional installation. To examine correlations or the effects of factors, data were displayed with the dependent variable on the Y-axis and the independent variables on the X-axis.

RESULTS

Distribution of Himalayan red panda

The distribution of Himalayan red pandas in the study area was assessed using the Himalayan red panda variables. Signs of the Himalayan red panda were recorded in 8 grids out of the 14 survey grids (Figure 2). A total of 28 (90.32%) indirect signs and 3 (9.67%) direct signs were recorded in 31 of the 146 surveyed plots.

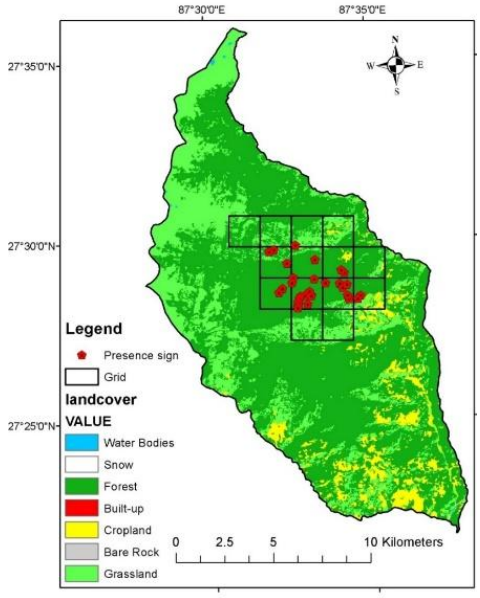

Figure 2: Map depicting the study area, Meringden Rural Municipality, of the Himalayan red panda signs in grids

The signs indicated the presence of Himalayan red pandas within an elevation range of 2,500 to 3,300 m (Figure 3), with a mean elevation of 2,856 ± 238.26 m. Statistical analysis revealed a significant difference in elevation between areas with the presence and absence of Himalayan red panda signs (p=0.006), suggesting that the Himalayan red panda presence was more consistently observed at higher elevations compared to lower elevations (Table 3).

Similarly, presence of the Himalayan red panda signs was observed along the slopes ranging from 15° to 40°(Figure 4). The mean slope value was slightly higher in areas without Himalayan red panda signs (22.143) compared to areas with Himalayan red panda signs (21.960), indicating that Himalayan red pandas prefer gentle slopes rather than steeper ones.

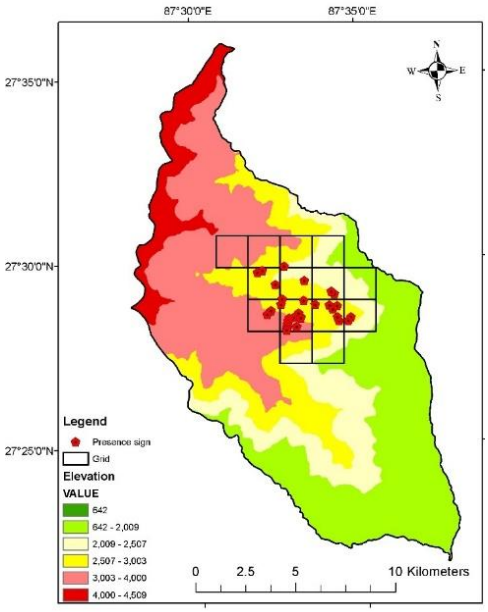

Figure 3: Sign of Himalayan red panda presence in different elevation categories

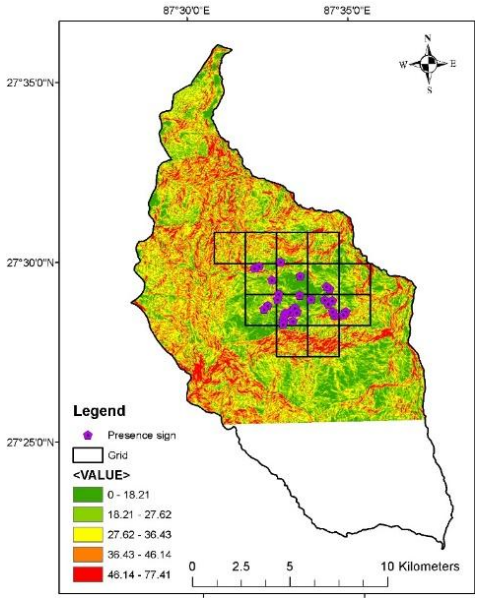

Figure 4: Sign of Himalayan red panda presence in different slope categories

Himalayan red panda signs were observed along the north, northeast and northwest aspects (Figure 5). Himalayan red pandas favoured low aspect, as shown by the fact that the mean aspect value in Himalayan red panda's absence signs (122.472) was higher than in their presence signs (116.050).

In the study sites, the overall substrates used for defecation by the Himalayan red panda were found mostly on tree branches (56%), followed by ground (34%), and the fewest on fallen logs (10%), with no signs on rocks.

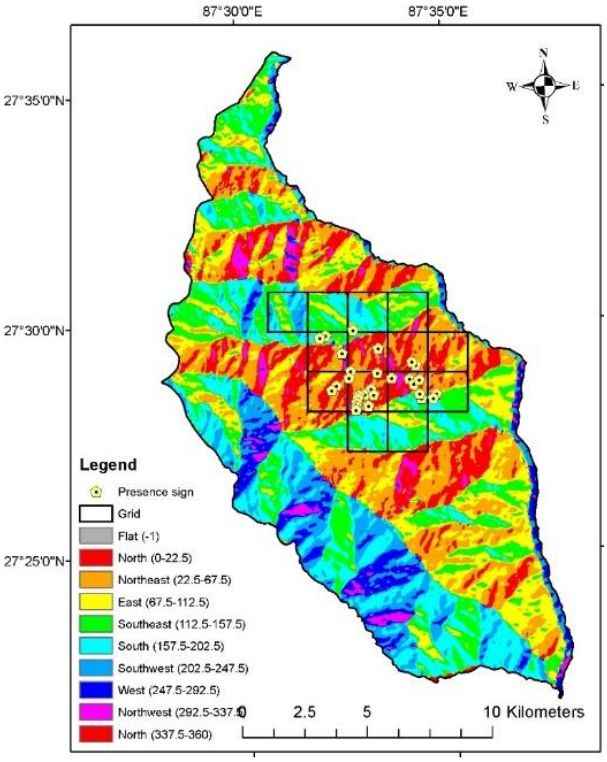

Figure 5: Sign of Himalayan red panda in different aspect categories

Habitat characteristics

Himalayan Himalayan red panda signs were recorded across a wide range of canopy cover, varying from 0 to 77.72%. No significant difference in canopy cover was detected between plots with and without Himalayan red panda signs. Mean canopy cover was comparable between presence plots (45.62 ± 18.16%) and absence plots (47.40 ± 21.28%). The average distance from Himalayan red panda signs to water sources in presence plots was 28.74 ± 37.52 m, which was marginally greater than that observed in absence plots. Bamboo density was slightly lower in sign-presence plots (15.62 ± 27.94) compared to non-sign plots (16.66 ± 34.83), indicating that Himalayan red panda signs were more frequently associated with areas of relatively low bamboo density. Structural vegetation attributes differed between the two plot types. Mean tree height was higher in presence plots (15.98 ± 5.41 m) than in absence plots (14.67 ± 7.35 m). Similarly, average tree diameter at breast height (DBH) was greater in presence plots (65.36 ± 78.90 cm) compared to non-sign plots (49.31 ± 41.84 cm), suggesting a preference for habitats dominated by taller trees with larger DBH. In addition, signs of other wildlife activity were more frequent in Himalayan red panda sign plots (0.74 ± 0.45) than in non-sign plots (0.31 ± 0.47). Shrub species richness was also higher in sign plots (0.60 ± 0.77) relative to absence plots (0.29 ± 0.59). Furthermore, the number of fallen logs was notably greater in sign-presence plots (7.68 ± 6.13) than in plots without signs (3.13 ± 4.93), highlighting the importance of structurally complex forest habitats for Himalayan red pandas.

Statistical analysis revealed no significant difference in canopy cover between plots with and without Himalayan red panda signs. In contrast, distance to water sources showed a statistically significant effect. Results from the Mann–Whitney U-test indicated a significant difference in distance to water between sign presence and absence plots, with the observed difference in mean distance being statistically significant ($p < 0.05$). The Mann–Whitney U-test was further applied to assess differences in various ecological variables between sign and non-sign plots. Most habitat variables including bamboo height, bamboo density, tree height, tree diameter at breast height (DBH), and shrub height did not differ significantly between the two plot categories. However, the number of fallen logs, shrub species richness, and the presence of other wildlife signs showed statistically significant differences between sign presence and sign absence plots in the study area (Table 1).

Table 1: Descriptive statistics of selected variables to explain Himalayan red panda habitat in terms of presence and absence of signs in sample plots

Environmental variables	Presence	Absence	Significance(P)
Elevation (m)	2500-3300(2856.09 ± 238.26)	2200-3254(2685.31 ± 275.61)	0.06
Aspect (degree)	7.125-356.91(116.05 ± 2127.52)	2.18-359.44(122.47 ± 116.21)	0.364
Slope (degree)	9.38-50.5(21.96 ± 9.91)	3.28-51.13(22.14 ± 29.90)	0.491
Canopy (%)	0-77.72(45.62 ± 18.163)	0-82.42(47.4 ± 21.279)	0.809
Water source (m)	0-175(28.74 ± 37.52)	0-170(13.57 ± 28.72)	0.050
Bamboo height (m)	0-7(4.09 ± 2.08)	0-7(3.46 ± 2.31)	0.198
Bamboo density (culm/m^2)	0-122.03(15.61 ± 27.93)	0-247.52(16.65 ± 34.82)	0.21
Tree species	0-5(3.03 ± 1.11)	0-6(2.62 ± 1.41)	0.11
Tree height (m)	6.4-29(15.98 ± 5.41)	0-46(14.67 ± 7.35)	0.097
Tree DBH (cm)	5-520(65.36 ± 78.9)	0-41(49.31 ± 41.84)	0.788
Bamboo density (culm/m^2)	0-122.03(15.61 ± 27.93)	0-247.52(16.65 ± 34.82)	0.21
Other wildlife sign	0-1(0.74 ± 044)	0-1(0.31 ± 0.46)	0 .001
Shrubs richness	0-2(0.29 ± 0.58)	0-3(0.60 ± 0.76)	0.022
Shrub number	1-70(6.91 ± 14.60)	1-87(8.90 ± 17.54)	0.403
Shrub height (m)	0.5-9(3.87 ± 2.68)	0.5-8(4.04 ± 2.10)	0.648
Logs	0-27(7.67 ± 6.13)	0-30(3.12 ± 4.93)	< .001

Among the variables, tree stumps exhibited a significant difference in their presence sign (3.032 ± 2.588) compared to their absence sign (1.940 ± 3.247) ($p = 0.003$). In contrast, looped trees did not show a significant difference in their presence sign (0.194 ± 0.654) compared to their absence sign (1.552 ± 4.737) ($p = 0.091$). Similarly, grazing and livestock signs did not exhibit significant differences between their presence and absence signs ($p = 0.086$ and 0.511 respectively). Bamboo die-off and landslide also did not show significant differences between the Himalayan red panda sign presence and absence plots ($p = 0.786$ and 0.936 respectively). However, human trail showed a significant difference in the Himalayan red panda sign presence (0.192 ± 0.341) compared to their absence sign (0.336 ± 0.475) ($p = 0.008$).

Influencing variables associated with Himalayan red panda distribution

Binary logistic regression analysis identified key habitat-related variables influencing the distribution of Himalayan red panda signs, including livestock signs, distance to water sources, bamboo clump presence, and shrub richness, which were retained in the final model. Among these predictors, livestock signs, proximity to water sources, and the presence of bamboo clumps showed positive relationships with Himalayan red panda sign occurrence, whereas human trails and shrub richness were negatively associated with Himalayan red panda distribution. Livestock activity ($p = 0.140$) and distance to water sources ($p = 0.107$) emerged as marginally significant predictors. A total of six livestock sheds were recorded within Himalayan red panda habitats, extending up to an elevation of 2,801 m. The Himalayan red panda signs were more frequently detected in areas closer to water sources and with higher bamboo availability, with bamboo presence showing a statistically significant positive effect ($p = 0.0398$). In contrast, Himalayan red panda occurrence was significantly associated with lower shrub richness ($\beta = -0.916$, $p = 0.0257$). Additionally, sign presence was significantly lower in areas with greater human trail density ($\beta = -1.307$, $p = 0.032$), indicating a preference for habitats located farther away from human trails (Table 2).

The most important ecological variables affecting Himalayan red panda sign distribution were habitat components: livestock sign, water sources, bamboo presence and shrub richness, which were used for the final model in the binary logistic regression analysis. Among the selected variables in the model, livestock sign, distance to water sources and bamboo clump presence exhibited positive associations with the Himalayan red panda distribution, while human trail and shrub richness showed a negative association. Livestock activity ($p = 0.140$) and distance to water sources ($p = 0.107$) were marginally significant factors. Six livestock sheds were observed within the Himalayan red panda habitat, up to an elevation of 2,801 m. The Himalayan red panda showed a preference for living in close proximity to water sources and areas with high bamboo presence ($p = 0.039$).

Additionally, the Himalayan red pandas favoured sites with low shrub richness ($\beta = -0.91$, $p = 0.025$). Moreover, the presence sign of the Himalayan red panda was found to be more prevalent in areas with fewer human trails ($\beta = -1.307$, $p = 0.032$), indicating that they preferred to inhabit areas that were far from human trails (Table 2).

Table 2: Summary table showing habitat correlates of Himalayan red panda sign presence

Environmental variables	Estimate	Std Error	Z-value	p-value
Livestock sign	0.724	0.491	1.475	0.140
Water source (m)	0.010	0.006	1.612	0.107
Bamboo presence	2.231	1.085	2.056	0.039
Shrubs richness	–0.916	0.410	–2.231	0.025
Human trail	–1.307	0.612	–2.136	0.032

DISCUSSION

Distribution of Himalayan red panda

The occurrence of the Himalayan red pandas was confirmed in the Mewa watershed in Taplejung District, which an important habitat located outside the protected area network within PIT community forest corridor. Owing to its large spatial extend of approximately 178 km^2, which accounts for almost 20% of Nepal's potential Himalayan red panda habitat. This corridor supports approximately 25% of Nepal's Himalayan red panda population, estimated at about 100 individuals (Williams, 2006; Williams, 2004). Despite its conservation importance, comprehensive population assessments necessary for effective monitoring of the Himalayan red pandas outside protected areas remain lacking in this landscape. Available evidence from direct sighting and indirect sign records suggests that Himalayan red panda abundance is generally higher in eastern Nepal compared to western region of the country.

Most of the Himalayan of the Himalayan red panda pellet groups were recorded on tree branches, which might be attributed to the Himalayan red panda's defensive mechanism to avoid ground dweller predators and also for thermoregulation. As a predominantly arboreal species, the Himalayan red panda spends a substantial proportion of its time in trees, engaging in activities, like foraging and resting (Yonzon & Hunter, 1991). This observation is consistent with earlier studies by Pradhan et al. (2001), Williams (2004) and Kandel (2009). The results further indicate a strong association between feeding behavior and the selection of specific tree branches for defecation, suggesting that arboreal structures play a multifunctional role in the Himalayan red panda ecology. According, conservation strategies should priorities the protection and restoration of suitable tree habitats to maintain both foraging resources and safe resting sites. Safeguarding these preferred arboreal environments is likely to be critical for the long-term persistence of the Himalayan red panda

The abundance of Himalayan red panda signs showed a positive association with elevation, which was identified as the most significant factor influencing their presence. This study is comparable to the studies on Himalayan red pandas conducted in various parts of Nepal by different authors (Yonzon, 1989; Thapa et al.,

2018). This study found limited evidence of the presence of the Himalayan red panda at higher elevations, which may be due to the availability of large grasslands. Higher elevations are marked by open areas and absence of bamboo, both of which are unsuitable for the Himalayan red panda. Himalayan red pandas are generally found in the temperate forests of the Himalayas within a specific altitudinal range between 2,100 and 3,800 m (Thapa et al., 2018). Overall, elevational distribution ranges of the Himalayan red panda are varied across its distribution range. Several studies conducted in different locations have consistently shown that Himalayan red pandas have a restricted distribution within a narrow elevation range (Panthi, 2011; Ghose et al., 2011; Sharma, 2012; Bhatta et al., 2014). This suggests that factors such as topography, resource availability and human-related factors play crucial roles in determining the distribution of Himalayan red pandas.

In the study, most of the faecal pellets were observed in slightly steep slope. This preference aligns with previous studies by Dorji et al. (2012), Panthi et al. (2012), Pradhan et al. (2001) and Yonzon & Hunter (1991), which also suggest a preference for slopes below 45%. This might be to avoid competition with livestock, which mostly grazed in gentle slopes in the study area.

The Himalayan red panda showed the highest preference for the northeast aspect and the least preference for the southern and western aspects, indicating the significant role of aspects in Himalayan red panda distribution (Bista et al*.,* 2017). Additionally, Himalayan red pandas avoid south-facing slopes in favour of the cooler climate of the north, northwest and northeast aspects (Dorji et al., 2012; Panthi et al., 2012; Pradhan et al., 2001). This study also found similar results, showing that the Himalayan red panda mostly preferred north-, northeast- and northwest-facing slopes, which is quite similar to Yonzon et al. (1991). Likewise, they avoided southeast and southwest slopes. The preference for these aspects could be due to the greater availability of food and water compared to the southern and eastern aspects, where the micro-habitat conditions may not support abundant bamboo growth, water availability and canopy cover (Dorji et al., 2011).

This study showed that the Himalayan Himalayan red panda shared habitats with other wildlife. There might be a significant overlap in the resources shared by other wildlife and the Himalayan red panda. Additionally, despite the somewhat different range and habitat preferences of Himalayan red pandas from other wildlife species, their signs may still be found in close proximity to other species due to habitat overlaps or ecological relationships between species. The findings of this study are consistent with previous studies (Thapa et al., 2018; Zhang et al., 2008) in demonstrating that Himalayan red pandas exhibit a preference for high densities of fallen logs. The significant p-value (< 0.01) confirms a strong association between the presence of Himalayan red pandas and the abundance of fallen logs. These results further emphasize that habitats with abundant resources, such as food, shelter and transportation provided by fallen logs, are more favourable for Himalayan red pandas.

Threats to Himalayan red panda

Despite being recognized as "Endangered" by the national conservation status in Nepal (Glatston et al., 2015; Jnawali et al., 2011), the Himalayan red panda continues to face numerous threats that pose significant challenges to its conservation (Glatston et al., 2015).

In the study site, livestock activity and human trail are the major threats faced by the Himalayan Himalayan red panda. Similarly, livestock herding was found to induce negative impacts on the habitat of the Himalayan red panda. The marginal significance of the presence of livestock activity in the study aligns with similar findings from previous research (Lama et al., 2020), These findings suggest that Himalayan red pandas, cattle and herders may have a preference for habitats that are relatively close to water sources. This correlation could be attributed to the availability of water supplies in these areas, which is essential for various species, including Himalayan red pandas. In line with these observations, Panthi et al. (2012) reported livestock grazing activities in 53% of the Himalayan red panda habitat range in the Dhorpatan Hunting Reserve. Additionally, Acharya et al. (2018) found a positive correlation between the presence of livestock faeces and Himalayan red pandas in the central Himalayas. However, it is crucial to recognize that the high grazing intensity associated with livestock activities poses a potential threat to the habitat and long-term survival of Himalayan red pandas.

The presence of Himalayan red panda signs was found to be more prevalent in areas with fewer human trails ($\beta = -1.307095$, $p = 0.0327$), indicating that Himalayan red pandas preferred to inhabit areas that were far from human trails. It might be due to their natural behaviour and the potential disturbance caused by human activities. Similar result was obtained in studies conducted by Bista et al. (2018) and Kandel et al. (2020) in Nepal.

The avoidance of human trails by Himalayan red pandas can be attributed to several factors. First, Himalayan red pandas are generally shy and elusive animals, preferring quieter and less disturbed environments for their activities (Bista et al., 2018). Human trails can introduce disturbances, such as noise and increased human presence, which may cause stress and disrupt their daily routine.

Secondly, the presence of human trails often indicates higher human activity, which can lead to increased habitat fragmentation and degradation. This can result in reduced habitat quality for Himalayan red pandas, as highlighted by a study conducted by Thapa et al. (2016) in Nepal. These findings emphasize the need for conservation strategies that prioritize the reduction of human disturbances.

Looped trees, grazing, landslides and bamboo die-off were statistically insignificant. Despite these factors not being found to be relevant in the study, there could be a number of explanations. It might be because, in

the study area, all of these non-significant variables occurred in fewer number and did not affect the Himalayan red panda.

Influencing variables associated with Himalayan red panda distribution

In this study, the presence of Himalayan red panda signs inside the study sites was used to evaluate the habitat qualities and species association. On the basis of presence information, their habitat was examined. Based on the Himalayan red panda sign survey, major habitat components, namely livestock sign, water sources, bamboo presence and shrub richness, were retained in the final model.

The study revealed a positive correlation between the distance to water sources and the association of Himalayan red pandas with their habitat. These findings are consistent with earlier studies conducted by Pradhan et al. (2001) and Thapa et al. (2018), which also indicated Himalayan red pandas' preference for inhabiting areas near water sources within a range of 100–200 m. In line with these studies, the majority of Himalayan red panda signs in this research area were found within a distance of less than 100 m. The presence of the Himalayan red panda may be more influenced by other factors in the model, such as the presence of bamboo, shrub richness, human trails and livestock activity, than by water sources. These results emphasize the importance of water availability in shaping the survival and habitat selection of Himalayan red pandas.

The study revealed that the Himalayan Himalayan red panda exhibits a strong preference for areas with a high presence of bamboo, emphasizing the significance of bamboo as a key factor influencing their distribution. The high significance of bamboo presence in the Himalayan red panda's habitat choice can be attributed to their feeding habits, as bamboo leaves and shoots account for approximately 83% of their diet (Yonzon & Hunter, 1991). This preference for bamboo-rich areas highlights the importance of bamboo as a primary food source for Himalayan red pandas and underscores its role in shaping their distribution patterns.

Himalayan red pandas tend to select areas where they can move more easily and find food more readily to conserve energy, stay warm and avoid shading. These results align with the findings of Zhang et al. (2016), which also highlighted Himalayan red pandas' preference for bamboo forests with lower shrub richness. These specific habitats were associated with higher bamboo density and biomass, providing an ample food supply for Himalayan red pandas. The overlap in these findings reinforces the idea that Himalayan red pandas prioritize areas with low shrub richness to optimize their foraging efficiency and energy conservation, especially in winter. By selecting habitats with lower shrub richness, Himalayan red pandas can overcome obstacles in movement, conserve energy and increase their chances of locating sufficient food resources. It is important to note that these findings are specific to the winter season when the study was conducted. Further research is needed to understand Himalayan red pandas' habitat preferences throughout different seasons and across various geographical locations.

CONCLUSION

This study confirmed the presence of the Himalayan red panda in the Mewa Khola watershed in Meringden Rural Municipality in eastern Nepal. Most signs of the presence of the species were recorded in elevations between 2,500 m and 3,300 m. The Himalayan red panda was found to inhabit a limited forest area, occurring in only 21% of the surveyed grids. The species showed a preference for habitats with a bamboo understorey, particularly in areas facing north, northwest, or northeast with moderately steep slopes, and most frequently used tree branches and trunks as defecation sites. Livestock activity and human trails were identified as the major threats to the Himalayan red panda population in the area. Livestock activity, proximity to water sources and the presence of bamboo clumps were among the variables positively associated with the signs of the Himalayan red panda, whereas human trails and shrub richness were negatively associated. These findings provide valuable insights into the habitat preferences and potential threats to the Himalayan Himalayan red panda in the region. Implementing effective management practices to mitigate the negative impacts of livestock grazing on bamboo abundance and regulating human activities within Himalayan red panda habitats are essential for the long-term conservation of the species.

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