



FACTORS AFFECTING DISTRIBUTION AND HABITAT ASSOCIATION OF RED PANDA IN BHOJPUR DISTRICT, NEPAL

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Abstract.

Status and distribution of red panda outside the protected area are poorly explored in Nepal despite of occupying the large share of potential red panda habitat. This study attempted to identify the factors affecting distribution and habitat association of red panda in Bhojpur district, Nepal. Bhalukhola Forest Patch, Kholakharka Forest Patch and Silichung Forest Patches were selected as intensive study sites. Altitudinal line intercepts method and sign surveys were applied to determine the distribution of red panda along different elevations. Quadrature method was implemented to explore the habitat association of the species. Twenty-four altitudinal transects each of 1,000 m on every 100 m altitude were surveyed following contour lines from the elevation of 2,400 m to 3,550 m. All the data were analysed by using Microsoft Excel 2016, ArcGIS 10.4, and Past 3.26 Software. Generalized Linear Model (GLM) was used to assess the influence of elevation and habitat parameters (predictor variables) with presence of red panda i.e., pellet frequency (response variable). Red panda was confirmed in all the surveyed forest patches between 2,700 m to 3,000 m altitude. In addition, 44 tree species were documented from red panda sign plots, out of which most common was *Pinus roxburghii* (77.39), *Rhododendron arboretum* (29.35), *Tsuga dumosa* (28.51) and *Rhododendron grande* (22.06). Based on the habitat association analysis, GLM revealed that elevation ($R^2=0.23$), bamboo canopy cover ($P < 0.01$), tree canopy cover ($P < 0.01$), bamboo density ($P < 0.01$), and distance to settlement ($P < 0.01$) were positively associated with red panda presence. Likewise, tree height ($P < 0.01$), distance to water source ($P < 0.01$) and DBH of tree ($P < 0.01$) were negatively associated. The most preferred aspect was found to be North-West (31%) with the average slope of 30°. Tree branches were mostly used substrate by the red panda for defecation (56.36%). Mostly used tree species for defecation was *Hymenodictyon excelsum* (26%). This study has provided vivid information about the presence of red panda in one of the potential regions outside protected area. Further research should be conducted to find out distribution pattern, abundance, and association of red panda with different habitat characteristics throughout the Bhojpur district.

Key words: Bhojpur; Distribution; Habitat association; Habitat categorization; Red Panda

1. INTRODUCTION

The red panda, *Ailurus fulgens* (Cuvier 1825), an arboreal mammal belongs to Ailuridae family, adapted to the herbivorous diet and highly specialized as bamboo feeder (Glatston 1994; Wei et al. 1999). They occur in subalpine habitats of five Asian countries; Nepal, India, Bhutan, Northern Myanmar and China (Glatston 1994; Wei et al. 1999; Choudhary 2001; Dorji et al. 2012) with *around 10,000 individuals* (Glatston et al. 2015) within a preferred altitudinal range of 2300 m to 4000 m. Red panda (Endangered – IUCN Red List, Appendix I – CITES) is also categorized as protected priority species by Nepal Government's National Parks and Wildlife Conservation Act 1973.

In Nepal, red panda occupies middle altitudinal range of 2,800 m to 3,000 m in east and mid to high altitudinal range of 2,800 m to 3,900 m in Central Nepal (Yonzon & Hunter 1991a; Williams 2004). The major habitats of red panda in Nepal are Langtang National Park (LNP), Makalu Barun National Park (MBNP), Rara National Park (RNP), Sagarmatha National Park (SNP), Annapurna Conservation Area (ACA), Gaurishankar Conservation Area (GCA), Kanchenjunga Conservation Area (KCA), Manaslu Conservation Area (MCA), and Dhorpatan Hunting Reserve (DHR) (Yonzon 1989; Williams 2003; Jnawali et al. 2011; Jnawali et al. 2012). Its presence has been documented from Taplejung, Panchthar, Ilam, Sankhuwasabha, Bhojpur, Khotang, Solukhumbu, Ramechhap, Dolakha, Sindhupalchok, Rasuwa, Nuwakot, Dhading, Gorkha, Kaski, Manang, Baglung, Myagdi, East Rukum, West Rukum, Rolpa, Dolpa, Jajarkot, Jumla, Mugu and Kalikot (Suwal & Verheugt 1995; Steffens 2004; William 2006; Paudel 2009; RPN 2010; Joshi & Sangam 2011; Jnawali et al. 2012; Panthi et al. 2012; Thapa et al. 2014; Bhatta et al. 2014; Dangol 2014; Panthi et al. 2015; Bista et al. 2016; Rai et al. 2018; Bista et al. 2018) with the majority of habitat falling outside the PA networks.

Evergreen forests, evergreen and deciduous mixed broad-leaf forests, deciduous forests, deciduous and coniferous mixed forests, and coniferous forests characterized by dense bamboo understory are the characteristics of red panda habitat (Yonzon et al. 1991; Wei et al. 1999). Proximity to water sources (within 100-200 m), higher bamboo cover (> 37%), bamboo height (2.9 m) and tree canopy (> 30%) are significant habitat components affecting distribution of red panda (Yonzon et al. 1991; Pradhan et al.

2001a; Williams 2004; Dorji et al. 2012). Similarly, the habitat with gentle to steep slopes, with fallen logs, tree stumps, and snags and the north, north-west and south-west aspects have been found to be significantly preferred by the species (Yonzon et al. 1991; Pradhan et al. 2001a; Dorji et al. 2012).

In Nepal, a very limited number of studies on the red panda have been carried out so far, most of them focused within protected area. The species has been sparsely studied outside the protected area (PAs), although it covers the large share of red panda habitat (about 70%) (Bista et al. 2016). This study aimed to find out the distribution in different elevation and habitat association of red panda in Bhojpur district of Nepal and provide the detailed information on red panda ensuring long term conservation of species and its associated habitats.

2. MATERIAL AND METHODS

2.1. Study Area

The Bhojpur district is a hilly region of Province No.1 (26°53'N to 27°46'N and 86°53'E to 87°17'E) in eastern Nepal. It covers an area of 1507 km² with an elevation range from 153 m to 4153 m a.s.l. The world's famous Arun Valley (world's deepest valley and an important Bird and Biodiversity Area, IBA) is also located in an adjacent region of this district. The study area comprises three forest patches of Bhojpur district including Silichung Forest Patch (SFP), Kholakharka Forest Patch (KFP) and Bhalukhola Forest Patch (BFP). BFP lies within the boundary of Shadananda municipality and Tyamkemaikum rural municipality. Likewise, SFP lies in Salpasilichho rural municipality and KFP lies in Shadananda municipality and Salpasilichho rural municipality of Bhojpur District (**Figure 1**).

2.2. Preliminary Survey

A preliminary survey of the study area was conducted from 13th-20th of Feb 2018 to obtain the information on the presence/ absence of red panda within potential sites. After assessing the large area of northern part of Bhojpur via ground truthing using ICIMOD land use map (<http://geoportal.icimod.org/>) and information collected from locals, core study site (BFP, KFP and SFP) were selected for more intensive investigation of distribution and habitat association of red panda. A reconnaissance survey was carried out with the interaction with various representative offices and people as the key informants

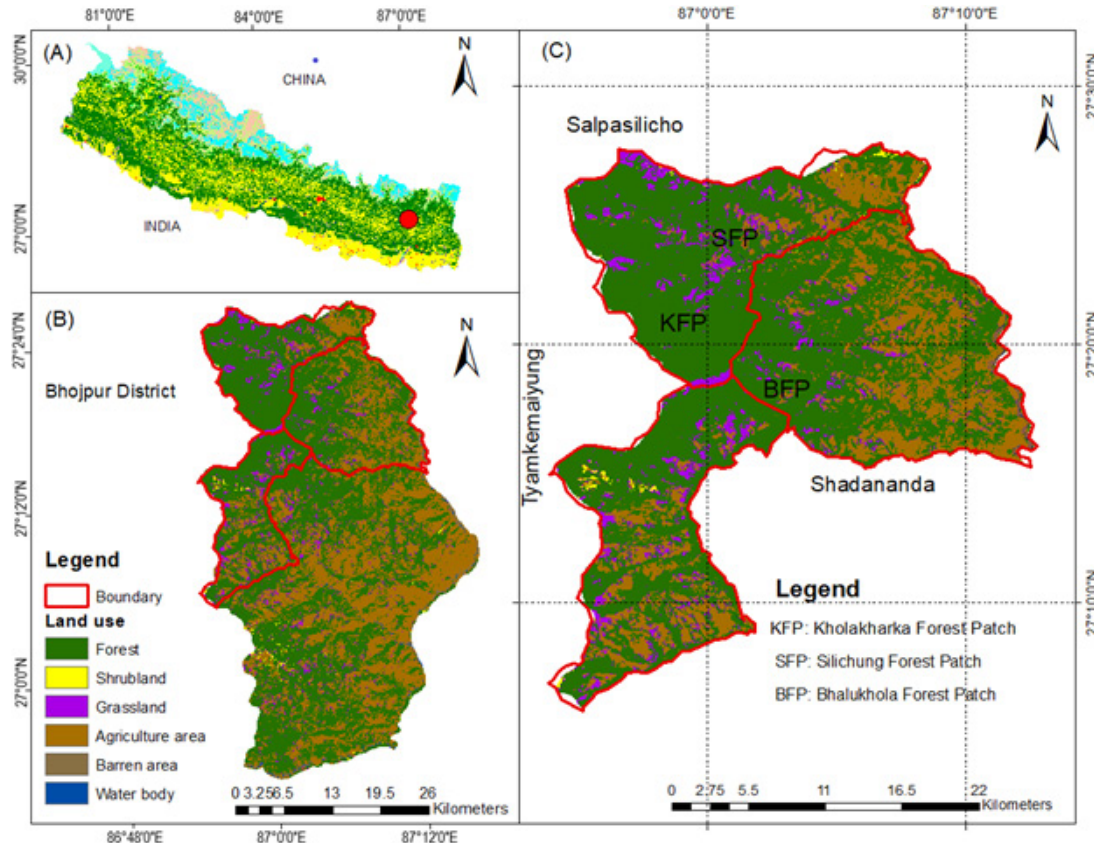


Figure 1: Map of the study area showing (A) Land cover map of Nepal indicating study area, (B) Land cover map of Bhojpur district, (C) Land cover map showing the study area with three forests namely SFP, KFP and BFP within Salpasilicho rural municipality, Tyamkemaityung rural municipality and Shadananda Municipality of Bhojpur District.

including District Forest Office (DFO), and Rural municipalities of Bhojpur district. Similarly, local villagers, herders, village level conservation committee and community forest user groups were interacted through consultation meeting and focused group discussions regarding presence and distribution of red panda which further helped for the identification and exploration of the potential habitat of the species within the study area. The field survey was conducted extensively from February 2018 to March 2019.

2.3. Distribution

Altitudinal Line Intercept Method

Altitudinal line intercept method (Kaiser 1983) followed by (Williams 2004) and (Mahato 2004) was applied to find out the red panda distribution. Eight horizontal line transects were laid out in each forest patches (all together 24) within altitude range of 2400 m to 3550 m a.s.l. at every 100 m rise in elevation. The existing trails within the selected blocks were also used as transects. The transects were followed and observed directly on both sides up to 5m

to identify occurrence, presence or absence of red panda and the habitat conditions. Whenever red panda signs encountered while walking along transects, the coordinates were recorded in GPS (Garmin Etrex 10). Similarly, 1:25000 survey maps were used as altitudinal guides. Silva compass and inclinometer were also used to record the direction and slope of the sampling plots.

2.4. Habitat association

Concentric sampling plot of 10 m radius was established at the starting point of each transects and successive plots were established at an interval of 500 m to assess the habitat characteristics. For vegetation sampling, 46 concentric quadrats were laid in sign locations. The quadrat size was selected as used by (Schemnitz 1980) for vegetation analysis: 10 m× 10 m for trees, 3 m×3 m for bamboo from which number of tree species, tree height, DBH tree canopy cover, bamboo species, bamboo canopy cover and bamboo density were recorded within the sign plots. The information on landscape covariates including eleva-

tion, slope and aspect was based on GPS coordinates were retrieved by using ArcGIS 10.4 Version, whereas distance to settlement, water source and livestock shed were estimated on visual estimation. We considered vegetation investigation regarding IVI of trees, bamboo cover, density and height. Number of pellet groups and substrate used were also recorded within sign plots.

2.5. Data analysis

The collected data were categorized and tabulated based on the information on the distribution and habitat association of the red panda in Bhojpur district, Nepal. Data were manually processed and analysed in descriptive way as well as using statistical tools.

2.5.1 Distribution

Distribution estimation and mapping was done using ArcGIS 10.4 software and species locations (GPS coordinates of sign plots) were overlapped with Google Earth and Landsat imagery to provide information of the spatial distribution. The GPS coordinates of sign locations recorded at different elevation within selected forest patches of the study area were used to overlay GIS layers to prepare altitudinal distribution map of red panda.

2.5.2 Habitat Association

Importance Value Index

To observe the importance of tree taxa to red panda, Important Value Index (IVI) of tree species in each plot irrespective of forest type was generated. To calculate the IVI of tree species, relative density, relative frequency and relative abundance were calculated following the formula mentioned by (Kapur and Govil 2000).

Important value index (IVI) = Relative Density + Relative Frequency + Relative Dominance

2.5.3 Digital Elevation Model

The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) was downloaded from earth explorer with 30 m spatial resolution (1 Arc Second Global). DEM was used to find terrain characteristics of the red panda sign plots using ArcGIS 10.4. Geographical location of transects, detected signs and study plots limits were recorded together with details of the habitat during the field work and incorporated as layers in the GIS. Slope was

categorized as gentle slope (0-10°), moderately steep slope (10-20°) and (20-30°), steep slope (30-40°) and very steep slope (>40°). Aspect was categorized into flat, north, northeast, east, southeast, south, southwest, west and northwest. Analytical maps of study sites were prepared by using 2010 land cover map of ICIMOD, DEM, ArcGIS 10.4 and GPS coordinates collected from study area.

2.5.4. Generalized Linear Model (GLM) for habitat analysis

Generalized Linear Model (GLM) was used to examine the relationships between habitat variables (independent (predictor) variables) with red panda presence (dependent (response) variable). The ten different habitat variables (slope, distance to settlement, distance to livestock shed, distance to water sources, DBH of tree, tree height, tree canopy cover, bamboo height, bamboo canopy cover and bamboo density) recorded from red panda sign plots were used to perform Generalized Linear Model (Nelder 1972) with pellet frequency using Past 3.26 (Hammer 2001). Data were plotted with dependent variable on Y-axis and independent variables on X-axis to investigate the correlations or impact of factors. To determine whether the association between the response variable and predictor variable in the model is statistically significant, the p-value was compared. Generally, a significance level (denoted as α or alpha) of 0.05 works well. With the p-value is less than or equal to the significance level, it was concluded that there is a statistically significant association between the variables. Similarly, the p-value greater than the significance level concluded there is no statistically significant association between variables in model set.

3. RESULTS

3.1 Distribution of red panda

Presence of red panda was confirmed in border region of three forest patches including SFP, KFP, and BFP of Bhojpur district (**Figure 2**). The red panda signs were found to be distributed in altitude range from 2,700 m to 3,000 m. Out of 46 pellets groups recorded, 17.77% were observed in 2,700 m, and 34.07% were in 2800 m. However, relatively high signs (35.55%) were recorded at the altitude of 2,900 m and least sign (13.33%) were in 3,000 m. The suitable habitat for the red panda was observed to be forest as all the red panda presence GPS coordinates

Table 1: Signs of red panda encountered in three different forests of Bhojpur district.

Blocks	Encounter rate (per km) of red panda signs	Percentage (%)
SFP	0.04	2.17
KFP	0.27	15.2
BFP	1.46	82.61

3.2 Habitat association of red panda

3.2.1 Importance Value Index (IVI) of tree species in red panda sign and non-sign plots

Altogether 24 species of trees were recorded in the 91 plots within the survey area, where all the 21 species were recorded in sign plots and 17 species in non-sign plots. Important plant species in the red panda sign plots were *Pinus roxburghii* (77.39), *Rhododendron arboretum* (29.35), *Tsuga dumosa* (28.51), *Rhododendron grande* (22.06) and *Lyonia ovalifolia* (11.82) on the basis of IVI values (Figure 4).

3.3.2 Analysis for bamboo species

Altogether four species of bamboo were recorded from sign plots. Among them *Arundinaria maling* was the most common bamboo species with frequency of occurrence 93.08 and density with 26.06 Culm/

m². Other bamboo species were *Thamnocalamus aristatus* with frequency 63.02 and density 17.21 Culm/m², *Drepanostachyum falcatum* with frequency 32.79 and density 13.46/m² and *Yushania maling* 38.22 and density 17.04 Culm/m².

3.3.3 Substrate use by red panda

The overall substrates used for defecation by red panda were found mostly on tree branches (56%) followed by ground (25%), tree logs (16%) and rocks (2%) (Table 2). Pellets were recorded on rock in SFP. Similarly, they were found deposited on tree branches, ground and tree logs in KFP and BFP of the study area.

Red panda used 12 species of plants namely *Hymenodictyon excelsum* (26%), *Magnolia grandiflora* (16%), *Rhododendron grande* (13%), *Osmanthus suavis* (10%), *Pinus roxburghii* (6%), *Schefflera im-*

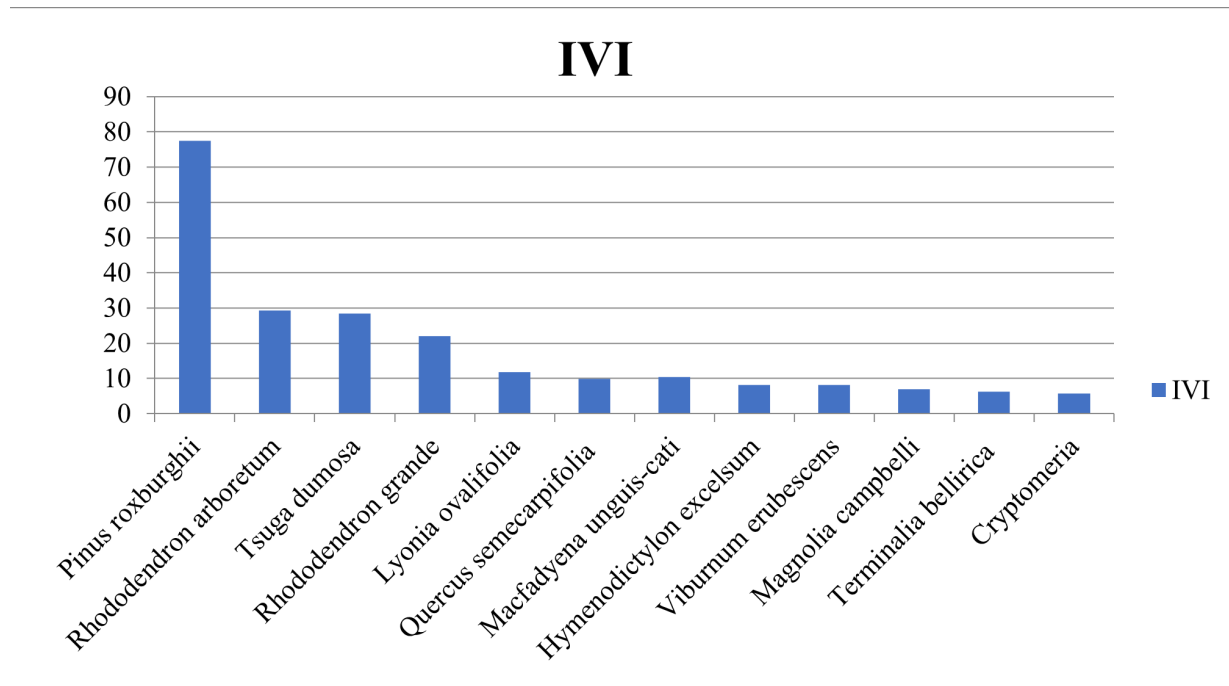


Figure 4: Bar chart showing IVI values of the dominant trees (IVI > 5) in red panda sign plots.

Table 2: Deposition of Red panda fecal matter in different categories of substrates (in %)

Substrates use (%)				
Name of blocks	Ground	Rock	Tree branches	Logs
SFP	0	100	0	0
KFP	22	0	66	11
BFP	27	0	52	19
Overall	25	2	56	16

Table 3: Deposition of Red Panda fecal matter in different tree species as substrate (in %)

S.N.	Common Name	Scientific Name	Percentage (%)
1.	Setikath	<i>Hymenodictyon excelsum</i>	26
2.	Ghonge Chap	<i>Magnolia grandiflora</i>	16
3.	Chimal	<i>Rhododendron grande</i>	13
4.	Silinge	<i>Osmanthus suavis</i>	10
5.	Gobresalla	<i>Pinus roxburghii</i>	6
6.	Balu Chinde	<i>Schefflera impressa</i>	6
7.	Khasru	<i>Quercus semecarpifolia</i>	3
8.	Chap	<i>Magnolia campbelli</i>	3
9.	Keshari	<i>Mahonia acanthifolia</i>	3
10.	Lekhpaiyo	<i>Prunus cerasoides</i>	3
11.	Chhapo	<i>Michelia champaca</i>	3
12.	Kukurpile	<i>N/I</i>	3

pressa (6%), *Quercus semecarpifolia* (3%), *Magnolia campbelli* (3%), *Mahonia acanthifolia* (3%), *Prunus cerasoides* (3%), and *Michelia champaca* (3%) for defecation (**Table 3**).

3.3.4 Deposition of faecal matter (in %) by red panda in different slopes, aspects and elevations categories

Most of the red panda signs (33.55%) were recorded from elevation of 2900 m followed by 2800 m (34.07%), 2700 m (17.77%) and 3000 m (13.33%) and no signs were found below 2700 m and above

3100 m [**Figure 5(B)**]. Higher percentage (31.11%) of red panda signs was recorded from north-west facing aspect followed by north-east (26.6%), north (15.5%) and east (15.5%) facing aspect respectively. Only 2.22% sign observed from west facing aspect and no red panda signs were found from flat, south and south-west facing aspect [**Figure 5(C)**]. Similarly, majority (46.8%) of the red panda signs were recorded both in slope of 20-30° and 30-40° followed by 4.25% signs in 10-20° slope and 2.12% in steep slope (40-50°). No red panda signs were recorded in gentle slope (0-10°) and very steep slope (>50°) [**Figure 5(D)**].

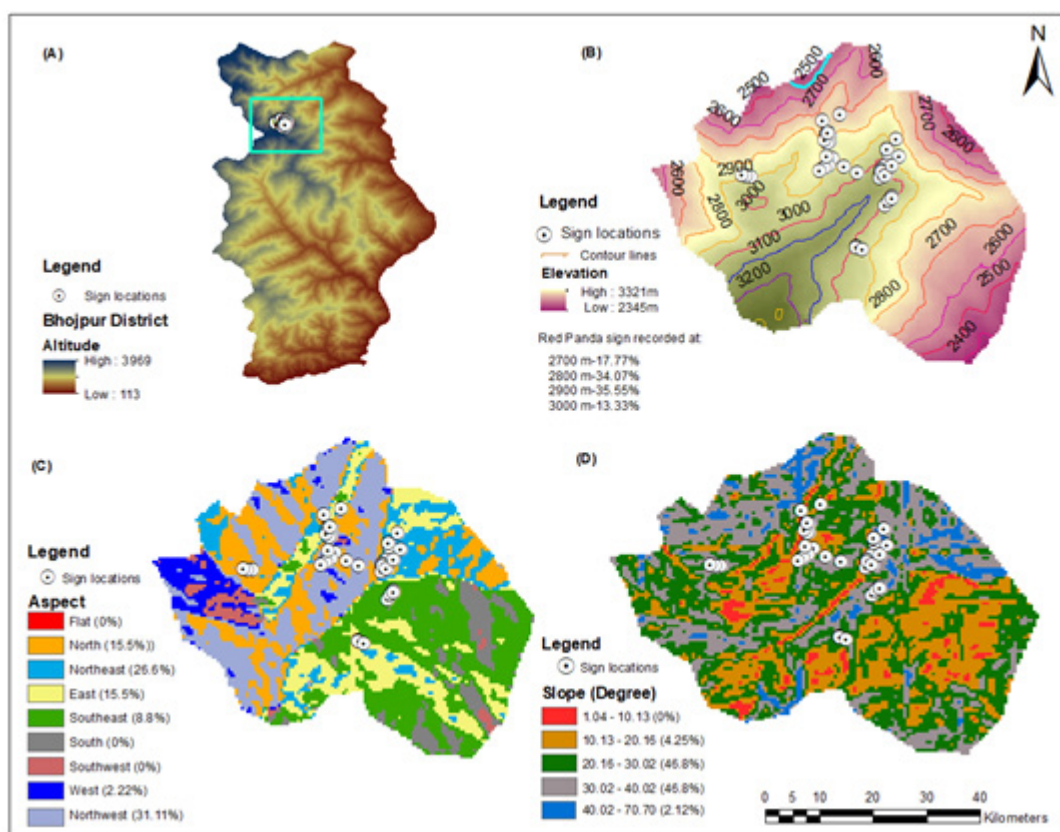


Figure 5: (A) Map showing the Study area (Bhojpur District), (B) Deposition of faecal matter (in %) by red panda in different elevation categories, (C) Deposition of faecal matter (in %) by red panda in different aspect categories and (D) Deposition of faecal matter (in %) by red panda in different slope categories.

Table 4: GLMs results showing the most significant factors influencing habitat association of red panda

S.N.	Environmental Variables	Intercept	Std. Error	P-value
1.	Slope	43.097	0.445	0.536
2.	Distance to settlement	-19.438	0.012	0.012
3.	Distance to livestock shed	54.834	0.034	0.253
4.	Distance to water source	55.718	0.046	0.006
5.	DBH of tree	104.16	0.303	0.021
6.	Bamboo height	30.687	4.691	0.786
7.	Tree height	83.105	2.092	0.050
8.	Tree canopy cover	-18.087	0.257	< 0.001
9.	Bamboo Density	-18.708	11.954	<0.001
10.	Bamboo canopy cover	-19.997	0.368	<0.001

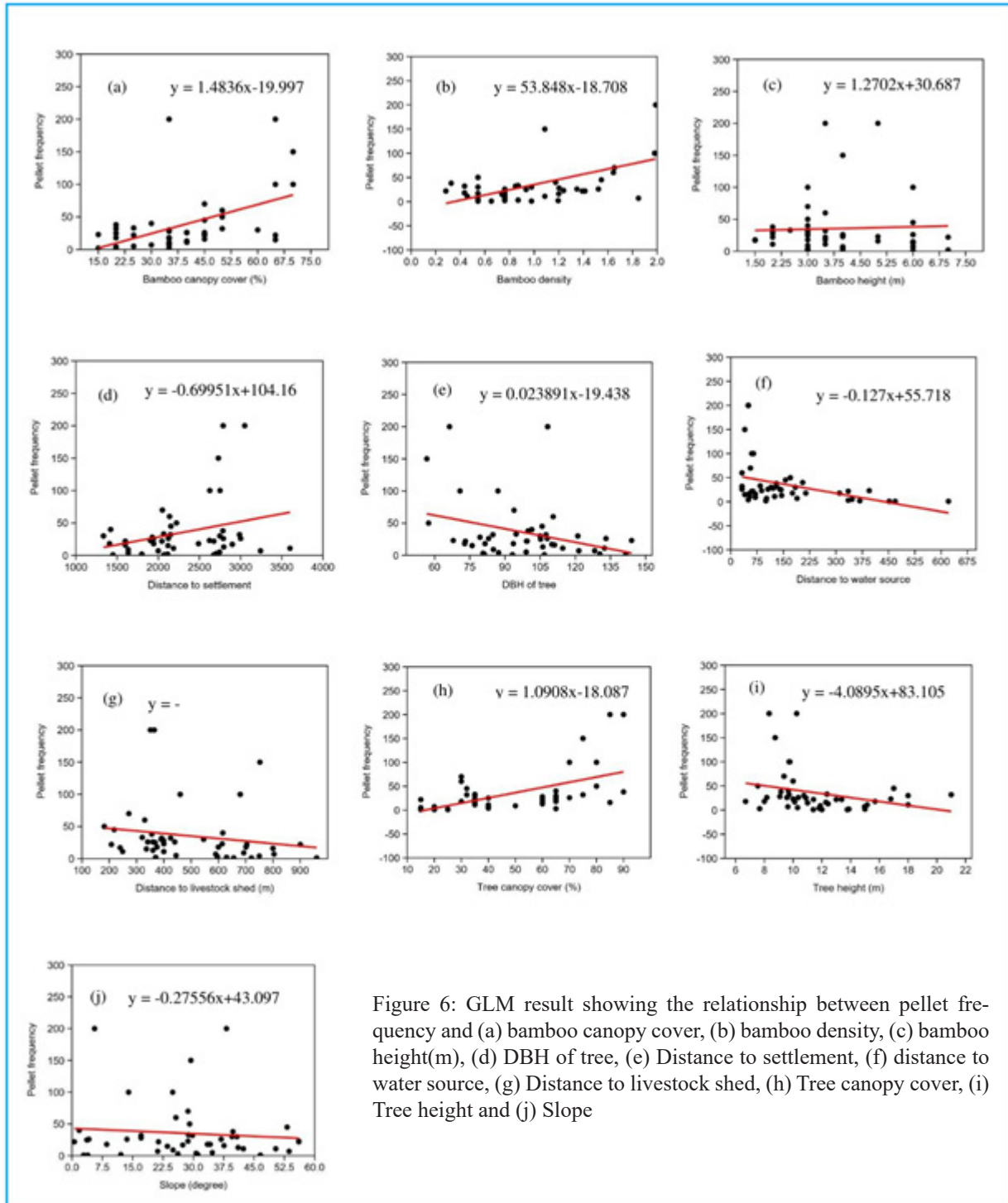
3.3.5 Factors affecting habitat association

Among the ten habitat variables (slope, distance to settlement, distance to livestock shed, distance to water sources, DBH of tree, tree height, tree canopy cover, bamboo height, bamboo canopy cover and bamboo density), GLMs illustrated that only six variables including bamboo canopy cover ($P < 0.01$), bamboo density ($P < 0.01$), tree canopy cover

($P < 0.01$), DBH of tree ($P < 0.01$), distance to water source ($P < 0.01$) and distance to settlement ($P < 0.01$) showed significant influence on the habitat association of red panda. The major ecological factors causing significant impact on habitat association of red panda were bamboo density ($P < 0.001$), tree canopy cover ($P < 0.001$), and bamboo cover ($P < 0.001$) (Table 4). Tree canopy cover, distance to settlement,

bamboo density and bamboo cover showed positive response indicating red panda presence increases with the increase in bamboo density, tree canopy cover and bamboo cover [Figure 6 (a), (b) and (h)]. Similarly, DBH of tree, distance to water source, dis-

tance to livestock shed and tree height showed negative correlation with red panda habitat association [Figure 6 (d), (f), (g), (i) and (j)]. However, bamboo height and slope were not strongly associated [Figure 6 (c) and (j)].



4. DISCUSSION

4.1 Distribution of Red panda

The presence of red panda was confirmed in the Bhojpur district of Nepal, one of the potential habitat outside protected area. While some pandas can be found in Nepal's Langtang National Park, Annapurna Conservation Area, Sagarmatha National Park, Manaslu Conservation Area, Makalu Barun National Park, and Kangchenjunga Conservation Area, more than 75 percent of potential red panda habitat falls outside of protected area. The presence had also been recorded outside PAs from the Kalikot district (Nabin Shahi, pers. comm. 2012), Khotang district (www.ekantipur.com 2012) and Jajarkot district (www.myrepublica.com 2012). Outside PAs, the Panchthar-Ilam-Taplejung (PIT) Corridor has been considered as a significant habitat for the red panda because it comprises 178 square kilometres or nearly 20% of total potential red panda habitat, which support approximately 25% of Nepal's red panda population, with an estimated 100 individuals (Williams 2006; Williams 2004; Yonzon 2001). Higher abundance of red panda was revealed in the east compared to the western part of Nepal. Ghimire & Bhatta (2010) reported that a Choyatar Community Forest within Jamuna VDC in Ilam District of eastern Nepal is inhabited by red pandas. William (2004) has recorded the species from the community managed and national forest of Jamuna and Mabu VDCs of Ilam district in eastern Nepal. In the Taplejung district, Williams et al. (2011) confirmed the presence red pandas from three VDCs: Kalikhola, Surumkhim, and Yamphudin. The first two of them are not covered by the PAs. The altitudinal distribution of red panda ranged between 2,700 m and 3,000 m with relatively high frequency in the elevation range of 2,800 m and 3,000 m. Elevation, the most significant factor, showed positive association with the red panda presence i.e., pellet frequency. Pellet frequency increased with the increasing elevation in the study area explaining the altitudinal distribution pattern of the species. The altitudinal range of 2,700 m to 3,000 m with most favoured range of 2,800 m to 2,900 m observed in our study is similar to the findings of Yonzon et al. (1991). Red panda preferred the mid elevation range because the lower region of the study area was disturbed area with its proximity to human settlement while the upper range was least preferred as it is open grassland with scarce vegetation cover, very steep slope and unsuitable habitat

conditions with no bamboo cover. Generally, red panda occurred in the temperate forests of Himalayas at an altitudinal range between 2,200 m and 4,800 m (Yonzon & Hunter 1989). Various studies in different location have revealed that the red panda is restricted within narrow range of elevation (Panthi 2011; Ghose et al. 2011; Sharma 2012; Bhatta et al. 2014) indicating that factors like topography, local microclimatic condition, resources availability and anthropogenic factors play an important role in the distribution of red panda. The lowest altitude where red panda was reported in Singalila National Park was at 2,400 m asl (Pradhan et al. 2001a) and 2,442 m asl in eastern Ilam (Williams 2004). Likewise, Chalise (2009) and Kandel (2009) recorded red panda at 2,280 m asl in Hangetham and Choyatar community forests of Ilam. In this study, red panda signs were recorded during transect walk in KFP block at an altitude of 2,750 m. The uneven distribution of red panda within the study area may be due to topographic variation and availability of resources like food, water and cover.

4.2 Habitat association of red panda

In this study, occurrence of red panda pellets within the study sites were used to assess the habitat characteristics and association of the species. Based on signs presence, its habitat was explored. Red panda was found to prefer broad-leaved-mixed forest with bamboo understory. Preference to dense forest with bamboo cover may be due to shy nature of the species as well as to minimize risk and help feeding behaviour. Availability of resources may be another reason it inhabits in dense forest area. Among the 44 species of trees recorded, most important plant species for the red panda on the basis of DBH and IVI were *Pinus roxburghii*, *Rhododendron arboreum*, *Tsuga dumosa*, *Lyonia ovalifolia*, *Macfadyena unguis-cati* etc. Bamboo species recorded were *Arundinaria maling*, *Thamnocalamus aristatus*, *Yushania maling* and *Drepanostachyum falcatum*. Such vegetation with bamboo in understory was found to be prominently preferred by red panda in the study area. Preference of such species was also reported in previous studies from central and western Nepal (Panthi et al. 2012). This is probable because number of other habitat variables played important role for red panda survival in these forests. However, in eastern Nepal and Singhalila in India, red panda prefers broad-leaf deciduous and sub-alpine forests (Dorji et al 2011; Sharma et al. 2014).

Observation of their dropping piles during this study showed they spent most of their time on trees. Majority of the pellet groups recorded were on the tree branches which might be attributed to their defence mechanism to avoid predators on the ground and as well as to bask on the sun. The red panda being an arboreal mammal spends most of its time on trees, foraging and resting (Yonzon & Hunter 1991a). This statement was further supported by Pradhan et al. (2001a) who reported deposition of fecal matter on trees (81.25%) indicating tree branches as most preferred defecation site during pre- monsoon (March-May). Tree as the most preferred site for defecation was also recorded in other studies (Williams 2004; Kandel 2009; Bista et al. 2017). This study showed that 12 plant species including *Hymenodictyon excelsum*, *Magnolia grandiflora*, *Rhododendron grande* and *Osmanthus suavis* etc were found to be highly used tree species for defecation. That might be due to higher DBH and large trunk of the trees that provide good sites for resting, nesting, and escaping from predators (Yonzon & Hunter 1991b; Williams 2004). Similar types of tree species used for defecation were also recorded by Pradhan et al. (2001b), Williams (2004) and Kandel (2009) in Singhalila National Park, India; Illam and Eastern Nepal respectively.

Slope and aspects are also the prime factors influencing red panda distribution. An average slope i.e., 30° was reported to be preferred in this study which is almost similar (34±16°) to another study in Bhutan (Dorji et al. 2011). But this observation contradicts with the finding of a study in China which shows the preference of slope more than 45° and avoids areas with slopes of 15 to 30° (Yonzon & Hunter 1991a). Red panda presence signs were observed in north-east, east and northern aspects, which is quite similar to Yonzon et al. (1991). Their preference towards these aspects may be because of availability of more food and water unlike in the southern and eastern aspects where the micro-habitat condition could not be supportive for abundant growth of bamboo; water availability and canopy cover (Dorji et al. 2011). In the case of moderately steep slope, trees and shrub branches intersect with leaf layer of bamboo and are accessible to the species. However, there is high competition between red panda and livestock in gentle slopes as lowest range was mostly used by livestock for grazing in the study area. The result was similar with the findings of Panthi (2011) in Dhorpatan Hunting Reserve, Bhatta et al. (2014) in Jumla and Ghose et al. (2011) in Sikkim as they also found

moderate slope as important habitat features ideally suited to the red panda.

The bamboo density, bamboo canopy cover, tree canopy cover and distance to settlement were positively correlated with the distribution of red panda. Positive response of high bamboo density might be due to feeding habit of red panda as bamboo leaves and shoots together constitute 83% of its diet (Yonzon & Hunter 1991b). Red panda also occupies dense bamboo forests as shelter as discussed by Yonzon & Hunter (1991) and Pradhan et al. (2001b). Similarly, bamboo was recorded in nearly 89% of the sign plots in CHAL, with density ranging from 0.21 to 31.81 bamboos culm/m² and an average value of 6.01±5.59 Culm/m² (Bista et al. 2017). Panthi (2011) reported that red panda was recorded from the areas having the dominant trees with large DBH, greater height and broader canopy cover as they used crown cover for resting, hiding and thermoregulation. The results contradict with present findings in case of DBH of tree and tree height. This might be because of the preference of moderate DBH and height of tree by red panda in the study area which facilitates the species to climb up and down easily and forage bamboo shoots by sitting on the tree branches of moderate tree height. Similarly, distance to water source and distance to livestock shed showed negative correlation with red panda habitat association. This might be due to the presence of many livestock sheds inside the forest area that overlap the habitat of red panda. Similarly, red panda preferred habitat close to water resources, hence, as distance to water sources increased within the study area, red panda signs were encountered less.

In conclusion, the study confirmed the presence of red panda in Bhojpur district within the elevation range of 2,800 m -3,000 m. Its associated habitat was explored to be broad-leaved-mixed forest with bamboo understory within north-west and north-east aspect with moderate slope (20-40°). The distribution and habitat association of red panda is significantly associated with factors including elevation, tree canopy, bamboo density, bamboo canopy cover and distance to settlement, while negatively correlated with tree height, DBH of tree, distance to water source and distance to livestock shed. Understanding the effects of habitat factors and significant ecological needs of the red panda is critical for effective habitat management, as revealed by this study. The potential habitat of red panda spread across the border region of three community forest patches of Bhojpur district.

Such prospective habitat would be very vulnerable to anthropogenic activity and habitat overlapping; hence management measures should be prioritized to conserve these habitats. Our findings clearly show that the incidence and distribution of red panda is affected by a variety of factors like elevation, slope, aspect, and vegetation types. Preference to dense broadleaved mixed forest with bamboo cover with an altitude range of 2700 m to 3000 m, moderate slope, higher bamboo density, canopy cover, proximity to water resources are all key factors in red panda habitat selection. Implementing habitat management strategies that consider these critical ecological requirements will be critical for the conservation of the red panda in Nepal especially outside protected area. Due to poverty and a lack of awareness, local people rely heavily on forest resources for subsistence and livelihood, which increases the rate of deforestation, resulting in further deterioration of red panda habitat. So, the concerned authorities must think to generate the new livelihood options for the local people along with the conservation awareness activities and strict implementation of rules and regulations. Furthermore, detailed study of red panda on the seasonal monitoring should be conducted covering all potential sites in Bhojpur district.

ACKNOWLEDGEMENTS

We acknowledge support from the Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal. We are also thankful to the Rufford Foundation, Katie Adamson Conservation Fund for financial support and Idea Wild for equipment support. We are equally indebted to Ministry of Forest and environment, Department of Forest and soil conservation, Nepal and Division Forest office, Bhojpur for granting permission to carry out the research work. We also appreciate Red Panda Network for the technical support and co-operation. We would like to thank Dave Johnson, Sonia Holmstrom, Brendan, Arielle Schepmoes and An Nguyen for field support and all the local people for their co-operation during the field work.

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