Conservation status of Red panda *Ailurus fulgens* in south-western Bhutan

Nature Conservation Division
Department of Forests and Park Services
2022

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The red panda conservation status report for south-western Bhutan is a milestone accomplished towards realizing our commitment to conservation and survey of red panda in Bhutan as per the Red Panda Action Plan and Red panda survey protocols, Convention on Biological Diversity (CBD) and other important international conventions and agreements. This crucial and timely report for fostering species conservation is the outcome of valuable contributions of many institutions and individuals.

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Nature Conservation Division, 2022

EXECUTIVE SUMMARY

The globally threatened red panda *Ailurus fulgens* is a totally protected species in Bhutan, being listed under Schedule I species of the Forests and Nature Conservation Act 1995. Despite being a protected species, the information on red panda in Bhutan is sparse, with limited information confined to certain protected areas. In order to fill the information gap on red panda distribution and conservation, a red panda distribution survey was conducted in three divisions of Dagana, Gedu and Samtse, and Jigme Khesar Strict Nature Reserve (JKSNR), using a red panda survey protocol developed by the Department of Forests and Park Services. A social survey was also conducted to ascertain people's perception towards red panda conservation.

The study confirmed the presence of red panda in Gedu Forest Division (GFD), Dagana Forest Division (DFD), Samtse Forest Division (SFD), and JKSNR, either through direct sighting, indirect evidences, or through camera trap photo captures. They were distributed within the forest types of Fir, Mixed conifer and Cool-broadleaf Forest with thick bamboo undergrowth. Only 4.4% (n = 48) of the total plots had red panda signs with the majority (58%, n = 28) of the signs encountered in JKSNR.

Species distribution modelling using MaxEnt showed that in the study landscape comprising of 6365.35 km2, only 10% of the area is predicted as the potential habitat for red panda. Amongst the landscape, GFD (4.2%) has the maximum potential habitat followed by JKSNR (3.1%), SFD (1.6%) and least in DFD (1.1%). Potential suitable habitats were also found in disturbed regimes such as the Forests Management Units. The study identified 12 prime habitats in the study landscape and mapped 14 potential habitat linkages. Anthropogenic disturbances such as timber harvesting, livestock grazing and prevalence of stray dogs were found to be major threats in the red panda habitats.

People's knowledge on red panda were low, with very less respondents having direct sighting of red panda (n=29). However, people valued conservation of the species because the species does not come in conflict with people. Increased awareness programme is expected to further influence positive attitude of the local people towards red panda conservation.

The study recommends periodic monitoring of the species in the landscape, spatial conservation planning, strengthening partnership with local communities to strengthen conservation, and exploring other non-invasive methods such as genetics to enhance red panda information in Bhutan.

CONTENTS

01 INDRODUCTION

1.1 General background

Red panda *Ailurus fulgens* is an elusive, arboreal mammal endemic to the Eastern Himalayas and found in five Asian countries, namely Nepal, India, Bhutan, Myanmar, and China (Glatston *et al.* 2015). It belongs to the Order Carnivora, yet it is an herbivorous species and it exhibits a distinct phylogeny. The global red panda population is estimated at less than 10,000 matured individuals over the entire range countries. It is listed as Endangered in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species due to the declining population and shrinkage of natural habitat (Glatston *et al.* 2015). Red panda has remained as the only species under the family Ailuridae, until recently when Hu *et al.* (2020) recognized the red panda of Nepal, Bhutan, northern India, northern Myanmar, Tibet and western Yunnan Province of China as the Himalayan red panda (*Ailurus fulgens*), and its relative in Yunnan and Sichuan provinces of China as the Chinese red panda (*Ailurus styani*).

Despite its wide geographic range across the Himalayas (Fig. 1), red panda is distributed patchily and occurs at low densities (Wei et al. 1999; Thapa *et al.* 2018a). Red panda are habitat specialists occupying a highly specialized niche and prefers habitat with proximity to water sources, forest with thicket bamboo understory, fallen logs, tree stumps, and snags. Bamboo leaves and shoots form the main bulk of the red panda diet with insects, grubs, lichens, and fruits acting as supplements (Yonzon and Hunter 1991). Red pandas are known to avoid areas close to human settlements and areas disturbed by livestock (Dendup et al., 2016; Sharma et al., 2014; Wei *et al.,* 2000). Threats such as habitat loss, fragmentation, and degradation adversely impact the survival of red panda in the wild (Yonzon and Hunter 1991; Dendup *et al.* 2016; Thapa *et al.* 2018a; Tobgay and Mahavik 2020).

In Bhutan, red panda is amongst the totally protected species listed under Schedule-I of the 'Forest and Nature and Conservation Act of Bhutan 1995' (RGoB 1995). Locally known as *Achu Dongka*, the recent review of information and data found that red pandas are present in 19 of the 20 districts in Bhutan excepting for Pemagatshel district. This distribution range also covers eight protected areas namely, Jigme Khesar Strict Nature Reserve (JKSNR), Jigme Dorji National Park (JDNP), Jigme Singye Wangchuck National Park (JSWNP), Phrumsengla National Park (PNP), Wangchuck Centennial National Park, Bumdeling Wildlife Sanctuary (BWS), Sakteng Wildlife Sanctuary (SWS), Royal Botanical Park (RBP) and four BCs namely, BC3, BC4, BC7 and BC8. Along the elevation gradient red panda are present between elevation range of 1515 m under Zhemgang District and 4337 m in JSWNP under Trongsa District (Letro *et al.* 2022). The species is also culturally associated with local communities with some people believing it is an incarnation of the Buddhist monk (Dorji *et al.* 2012).

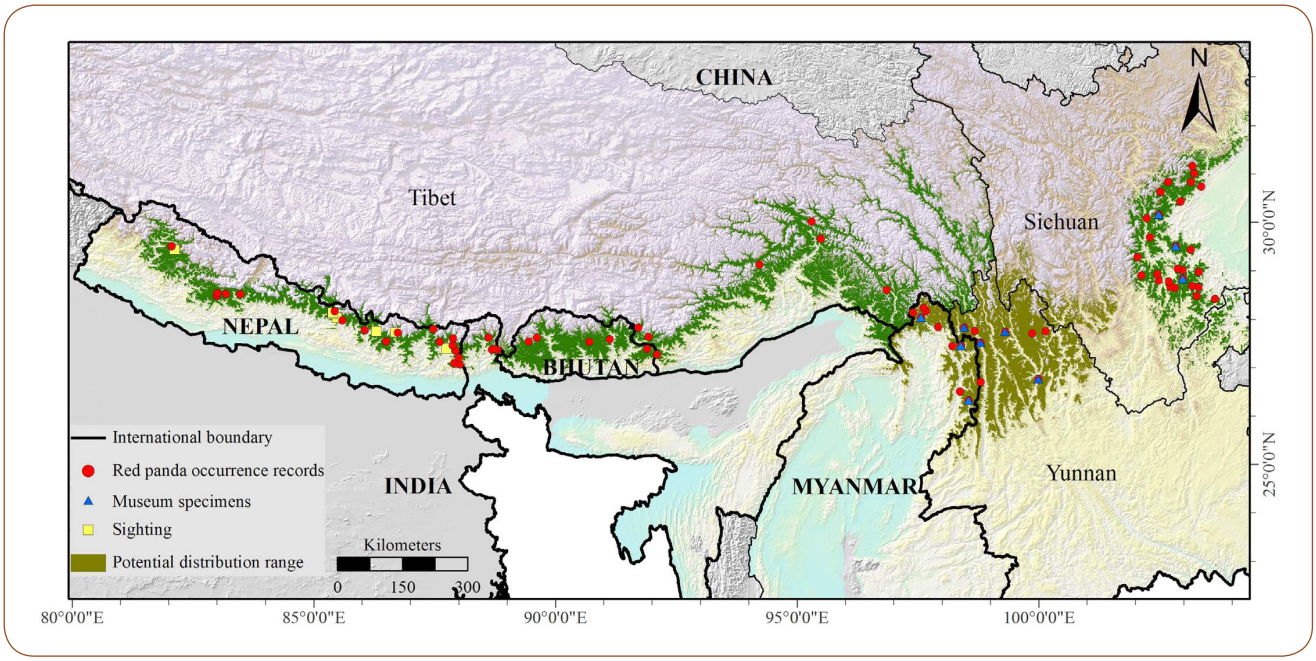


Figure 1. Geographical range of the red panda *Ailurus fulgens* (Dark green color: built in MaxEnt Model) (Thapa *et al.* 2018a)

A red panda conservation action plan 2018-2023 (NCD 2019) has been developed to guide the conservation of this threatened species in Bhutan but not many actions has been implemented due to limited funding. Therefore, conservation actions exclusively oriented towards red panda conservation in Bhutan are limited. A few studies conducted by individual researchers are confined to protected areas and a distribution study across the region or at a national scale has not been conducted. Therefore, proper understanding of red panda distribution and habitat components, and people's perception towards conservation of this threatened species is necessary for effective conservation and management.

1.2 Study objectives

With funding support from WWF Bhutan and Red Panda Network, Nepal through Royal Society for Protection of Nature, a red panda conservation project was implemented by the Department of Forests and Park Services between 2020-2021. The project covered four jurisdictions of JKSNR, Dagana Forest Division (DFD), Gedu Forest Division (GFD), and Samtse Forests Division (SFD). The main objectives of the projects were;

1. To ascertain the distribution status, habitat use and threats of concern in south-western Bhutan.
2. To ascertain people's perception towards red panda conservation.
3. To educate the people on the importance of red panda conservation.

Therefore, in this report, we present an account of (1) the distribution and habitat use of red panda in south-western Bhutan as obtained from robust survey and field methods following the red panda survey protocol of Bhutan; (2) model suitable habitats of red panda and potential connectivity between the prime habitats; (3) people's perception towards red panda as ascertained from a questionnaire survey; and (4) the status of conservation awareness programme conducted in the project area during the survey period.

02 MATERIAL AND METHODS

2.1 Study area

The study was conducted in the south-western part of the Bhutan and covers the landscape of Jigme Khesar Strict Nature Reserve, Dagana Forest Division, Gedu Forest Division, and Samtse Forest Division (Fig. 2) which expands across four districts of Haa, Dagana, Chhukha and Samtse respectively. Major forest types found in the region includes sub-tropical forests in the low elevation regions of DFD, GFD, SFD, warm-broadleaf and cool-broadleaf forest in the mid-elevation regions, conifer forests in temperate regions and sub-alpine and scrub forests in the high-elevation regions specially in JKSNR and DFD. The key mammalian species of conservation concern that were recorded in the past in this landscape are Asian elephant *Elephas maximus*, tiger *Panthera tigris*, snow leopard *Panthera uncia*, common leopard *Panthera pardus*, gaur *Bos gaurus*, Himalayan black bear *Ursus thibetanus*, clouded leopard *Neofelis nebulosa*, and red panda. Except for JKSNR where there are no permanent settlements, the three divisions have human settlements who depend on forests and natural resources for their livelihoods. Most of the settlers are also subsistence farmers but there are also pastoralists in this landscape. The survey was conducted in these four divisions considering the paucity of red panda information especially from the three divisions of Dagana, Gedu and Samtse, and the border areas with Sikkim. For field survey, efforts were focussed within the elevation range of 1040 masl to 3865 masl in the temperate regions which are probable red panda habitats and the habitat varied from warm-broadleaf forest, cool broadleaf forest, and fir forests.

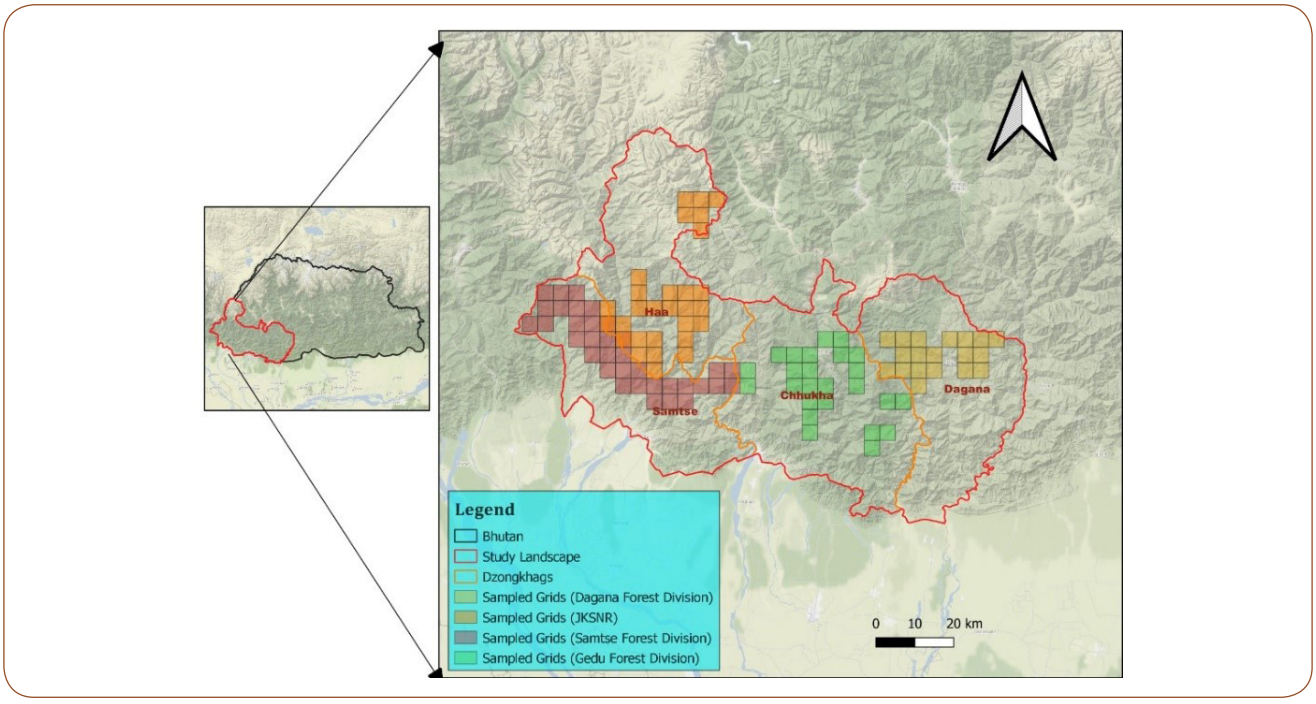
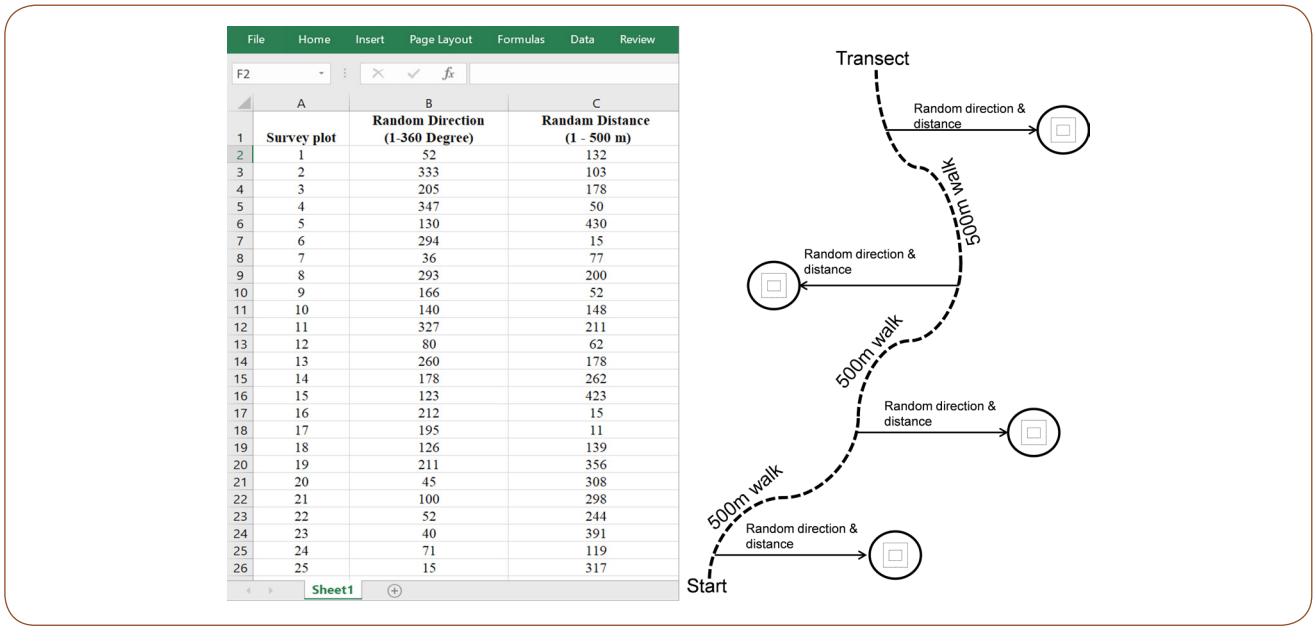


Figure 2. Study landscape with sampled grids of 4x4 km in each jurisdiction

2.2 Field survey and data analysis methods

2.2.1 Transect survey

Transect surveys were conducted to ascertain the distribution of red panda, its habitat utilization and characteristics, and threats prevalent in the study landscape. The identified survey area was referenced to the national biodiversity monitoring grid cells of 4x4 km (DoFPS 2020) and survey were confined to the sampled grids. Line transect methods as described in the red panda survey protocol of Bhutan (NCD 2020) were used for data collection from February 2020 – June 2020 (Fig. 3). Since it was difficult to create new transects due to rugged terrain and thick forest, existing foot trails were used as transect lines. After every 500-meter interval along each transect, we established a plot center in a random direction and at a random distance (0 – 1000 meters) from the transect. The maximum random distance was set at 1000 m which is double the length of setting transect intervals. Circular plots of 25 m radius were used to study red panda presence. Vegetation of the study site was studied using tree quadrats 10 x 10 m which were superimposed on the center of each 25 m radius plot, understorey quadrats 4 x 4 m superimposed on the center of the tree quadrats and ground cover quadrats 1 x 1 m were superimposed on the center of the understory quadrats (Fig. 4; Fig. 5). Habitat measurements followed Schemnitz (1980) as cited in NCD (2020). In tree quadrats (tree species, tree diameter, and fallen logs or tree stump > 30 cm diameter), understorey quadrats (shrub species and the number of bamboo culms) and ground quadrats (% cover of herbs or saplings) were recorded. Since water is an essential requirement for red pandas (Yonzon and Hunter 1991), we also recorded distance to nearest water source defined as flowing streams or ponds (Dendup *et al.* 2016).



Survey plot	Random Direction (1-360 Degree)	Randam Distance (1 - 500 m)
1	52	132
2	333	103
3	205	178
4	347	50
5	130	430
6	294	15
7	36	77
8	293	200
9	166	52
10	140	148
11	327	211
12	80	62
13	260	178
14	178	262
15	123	423
16	212	15
17	195	11
18	126	139
19	211	356
20	45	308
21	100	298
22	52	244
23	40	391
24	71	119
25	15	317

Figure 3. Diagrammatic representation of trail transect survey and plot layout

To assess anthropogenic disturbances in red panda habitat, we recorded the presence-absence signs of plant disturbance (e.g. harvesting, lopping, girdling), livestock (sighting, droppings, hoof prints), infrastructure (power transmission lines, telecom tower, houses, roads) and the presence of stray dogs. To assess natural disturbances, we recorded the presence-absence of naturally fallen logs/trees (wind throw, snow damage, etc..,) and number of tree stumps (Table 1).

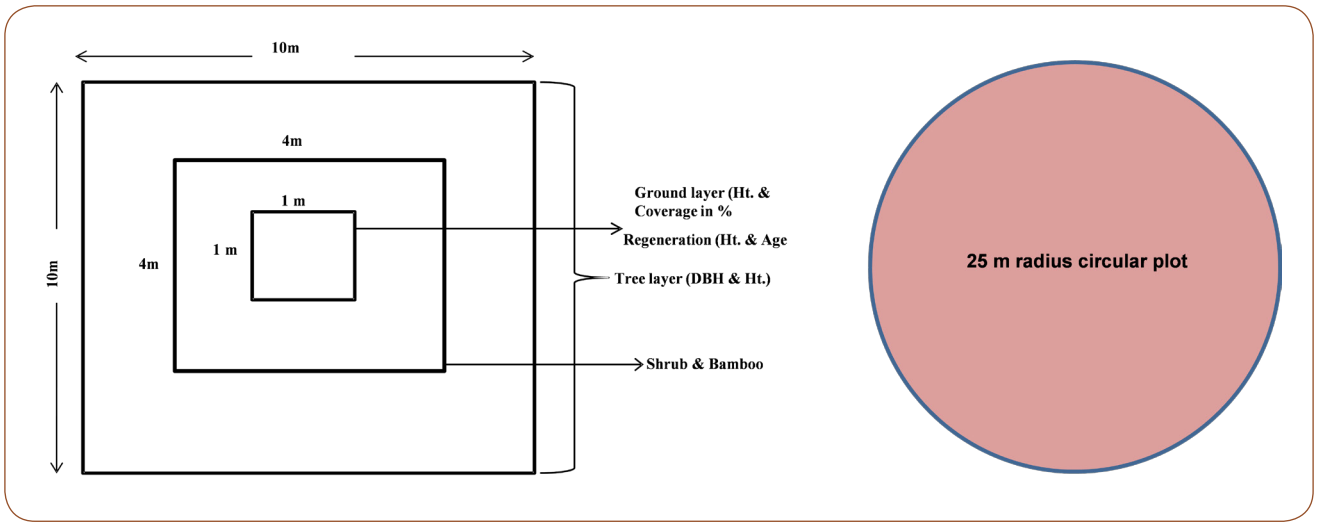


Figure 4: A. Vegetation survey design in a plot; B. Sign survey in a plot of 25m

To calculate tree species diversity in different forest types (Mixed conifer forest (MCF), Cool broadleaf forest (CBL), Fir forest, Bluepine and Meadows), following (Margalef (1968), we calculated the Shannon – Wiener Diversity Index (H') using the following formula:

$$H' = -\Sigma[(ni/N)\ln(ni/N)] \quad (1)$$

where:

H' = the Shannon diversity index
ni = number of individuals for each species (i)
N = total number of individuals of all species for the site

To evaluate tree species' dominance, following (Phillips 1959), we calculated the Importance Value Index (IVI) using the following formula:
IVI = relative density + relative frequency + relative basal area (2)

Variables	Unit of measurement	Plot size	Method/Instrument used
Geographical Location	Degree Minute Second	25 m radius	GPS (Garmin eTrex Vista HCx)
Altitude	meter	25 m radius	Altimeter
Aspect	East, West, North, South, southeast, south-west, northeast, northwest	25 m radius	Suunto Compass
Slope	Degree	25 m radius	Suunto Clinometer
Livestock	Yes/No	25 m radius	Visual
Timber harvesting	Numbers	25 m radius	Visual
NWFP harvest	Yes/No	25 m radius	Visual
Presence of stray dogs	Numbers	25 m radius	Visual
Infrastructures	Yes/No	25 m radius	Visual

Fallen logs and stumps	Numbers	25 m radius	Visual & Count
Distance to the nearest water source	meter	25 m radius	Measuring Tape
Habitat type	Fir, CBL, MCF, WBL, Meadows	25 m radius	Visual
Tree species	Numbers	10 x 10 meter	Visual & Count
Tree diameter at breast height (DBH)	cm	10 x 10 meter	Diameter Tape
Canopy cover	%	10 x 10 meter	Densitometer
Bamboo cover	%	4 x 4 meter	Visual estimation
Shrub cover	%	4 x 4 meter	Visual estimation
Herb cover	%	1 x 1 meter	Visual estimation

Table 1. Habitat, vegetation and disturbance variables recorded in each different plot

Figure 5. Field surveyors observing red panda signs and assessing vegetation at the plot

2.2.2 Camera trapping

Camera traps were set up in the study area to detect the true presence of red panda in the given habitat of the sampled grids to augment sign indicators as recommended in the red panda survey protocol of Bhutan (NCD 2020). Since camera traps were limited in numbers at least ten camera traps were set up in each jurisdiction and the placing of camera traps in the sampled grids were determined by the presence of red panda signs. We placed one camera trap per sampled grid at an appropriate location expected to be frequented by red panda (Fig. 6). Camera traps were mostly placed along the trail transect or the circular vegetation plots. Cameras were placed at 2-4 m from the center of the focus point, and at 20-40 cm off the ground in plain area. However, on sloppy terrain, adjustment was made to best suit the field of view. Date and time were set up in the camera and memory cards were erased before putting the camera into action. Camera trapping were initiated from 10th February 2020

in Gedu Forest Division and completed by 23rd January 2021 in Samtse Forest Division. For each camera trap location, a vegetation plot as described earlier was laid to record the information at the given site. Therefore, we recorded the GPS location, elevation, slope, aspect, vegetation type, etc., at the camera trap location.

After the retrieval of the cameras, for each camera trap station, the images were sorted species-wise and kept in different folder. Using *ReNamer 6.8* (Sanderson and Harris 2013), we obtained the preliminary information of the photo-capture information such as number of trap nights, number of species, number of independent images, etc. We defined independent images of a species as those that were taken at least 30 minutes apart.

Figure 6. Surveyors recording environmental variables at camera trap station and setting up the camera trap

2.3 Red panda occurrences and habitat distribution modelling

Red panda occurrence records were compiled from Jigme Khesar Strict Nature Reserve and Forest Divisions of Samtse, Gedu and Dagana. Occurrence records were based on the presence location of the red panda obtained from camera traps and sign indicators across the survey area. Using ArcGIS 10.8 (ESRI 2020) occurrence records were rarified to assign only one record per pixel to reduce spatial autocorrelation.

We used different predictor variables for modelling red panda suitability in the study area (Thapa *et al.* 2018b). Topographic variables such as elevation, aspect and slope were derived from the 12.5 m resolution Digital Elevation Model raster downloaded from the USSS (USGS 2018). Land use and land cover variable representing the different forest types and land use types of Bhutan was obtained from the Department of Forests and Park Service (FRMD 2017). Climatic variables were downloaded from the WorldClim data hub (Fick and Hijmans 2017) and collinearity among 19 variables were minimized using variance of inflation factor (VIF). Predictor variable with VIFs value more than 10 were categorized under strong collinearity and were excluded from the model. Finally, the model

was executed using four climatic variables [Isothermality (Bio3), Temperature Annual Range (Bio7), Precipitation of Driest Month (Bio14) and Precipitation of Coldest Quarter (Bio19)] and the topographic and land use variables.

We used MaxEnt software version 3.4.3 (Phillips *et al.* 2020) to execute the maximum entropy algorithm with 70% training and 30% test data and rest in default setting. The pixel value equals to or higher than the ten-percentile training presence threshold were considered as the suitable habitat. We assessed model performance using AUC (Area under the Receiver Operating Curve) whereby values ≤0.5 indicate very poor fit, >0.5 indicate good fit, and equal to 1 indicate perfect fit (Fielding and Bell 1997).

From the suitability map, value > 0.7 of the predicted habitats were identified as the prime habitats in the study landscape. The potential landscape connectivity among those prime habitats were identified in linkage mapper (Gallo and Greene 2018). Potential linkage was identified over the resistance surface developed based on road network, settlements density, major river and land use types in the landscape.

2.4 Social survey

Social surveys to ascertain the people's perception towards red panda conservation were conducted in the four divisions using the semi-structured questionnaires adapted from Letro and Fischer (2020) and Sharma et al. (2019). Surveys were confined to the villages where red panda is expected to be present in forests surrounding their village periphery in the districts of Chukha, Dagana, Haa and Samtse. We collected demographic and socio-economic data, including gender, age, education, family size, source of livelihood, whether the interviewee owned livestock, the number of livestock owned. Therefore, both agro-pastoralist, pastoralists, and people engaged in non-farm activities such as business, day-wagers etc.., were interviewed. While most of the respondents didn't attend any formal education, quite a few attended non-formal education programme and others attended monastic school or modern education as high as high school level. We also collected data on conservation attitudes such as people's knowledge about red panda, red panda sightings, perceptions on red panda population trends if sighted, awareness about Forests and Nature Conservation Rules (FNCRR), socio-cultural values, and perceptions towards red panda conservation.

We identified three response variables namely (1) people's knowledge about red panda; (2) people's awareness about FNCRR, and (3) people's perception towards red panda conservation. The factors identified were age, gender (male/female), location with respective to protected area (location closer to the protected areas and away from the protected areas), location by district (Chukha, Dagana, Haa, Samtse), livestock holding, source of livelihoods, and attendance to awareness programmes. Multivariate logistic regressions were used to determine factors affecting the three responses. When 'people's perception towards red panda conservation' was used as response variable, the other two response variables identified were also used as predictor variable. Results are reported as estimated coefficient (β), standard error of the coefficient (s.e.), and the level of statistical significance (*P*), which was considered to be significant if the *P*-value was <0.05.

2.5 Awareness programmes

Biodiversity conservation awareness programs are important to ensure the protection of the rare, threatened and endangered species. Stakeholder involvement is crucial for the protection and conservation of the wildlife. Awareness and advocacy programs with strict enforcement of law are key intervention to address the wildlife poaching in Himalayas (Thapa *et al.* 2018a). However, in Bhutan, red panda conservation awareness and education has not been earnestly implemented. People in Bhutan claim to know red panda but they have misidentified it with other species of wildlife like red fox and the majority of the people have not seen red panda (Dorji *et al.* 2011). The first official record of awareness program dedicated to red panda conservation was done by JDNP in early 2000 to the students of Damji Community School (NCD 2019). In recent times, an awareness and advocacy program were organized in Merak wherein 15 students of Merak Primary School were identified as "Junior Rangers" to promote red panda conservation in the area (NCD 2019). There is an urgent requirement to strengthen awareness education to secure red panda habitat and bolster its conservation in natural landscapes (NCD 2019).

Awareness programmes for red panda conservation in the project landscape were conducted through Focused Group Discussions during the time of social survey data collection; through awareness campaigns to farmers and schools, and dissemination of awareness messages through signage installation in the red panda habitat areas.

Red panda habitat

03 RESULTS

3.1 Red panda distribution and habitat characteristics

A total of 1083 plots (25 m radius) were surveyed in the study landscape. The transects were located within an elevation range of 1040 – 3865 m with an average elevation of 2550.3 m (mean ± SD = 2550.3 ± 773.92). Other habitat variables measured were aspect (0° – 360°, mean aspect = 173.09°) with majority (33%) facing SE (90° – 180°) direction; slope with degree of 2° – 67° with mean slope of 28.58° (SD 33.50°); and distance from nearest water source (average distance of 362.6 m, SD = 365.63 m).

The study confirmed the presence of red panda in Gedu Forest Division, Dagana Forest Division, Samtse Forest Division, and Jigme Khesar Strict Nature Reserve. The existence of this charismatic species was ascertained through direct sightings, from camera trap images, signs and anecdotal evidence. They were distributed within the forest type of Fir, Mixed conifer and Cool-broadleaf Forest with thick bamboo undergrowth. Only 4.4% (n = 48) of the total plots had red panda signs with the majority (58%, n = 28) of the signs encountered in JKSNR. Of 28 presence signs, 10 were direct sightings made only in JKSNR (Table 2, Fig. 7, Fig. 8). All red panda evidences were observed between an elevation of 2100 – 3700 m, and in gradients less than 35° (79%, n = 38). Red panda signs and sightings were recorded between 5 to 1,500 m from the nearest water sources with majority of red panda records (54%, n = 12) found within 200 m from water sources.

Sl. #	Study sites	Plots surveyed	Plots with red panda signs and sightings	% of plots with red panda signs and sightings
1	Gedu Forest Division	178	4	2.25
2	JKSNR, Haa	194	28	14.43
3	Samtse Forest Division	278	12	4.32
4	Dagana Forest Division	433	4	0.92

Table 2. Information on total plots surveyed and red panda presence recorded under each study site

Figure 7. Direct sighting of red panda in Rhododendron and Fir forest under JKSNR, Haa

Figure 8. Red panda evidence encountered and recorded during survey in JKSNR

3.2 Floristic composition

Within the study landscape, vegetation habitat comprised of fir forest, cool-broadleaf forest (CBL), warm-broadleaf forest (WBL), mixed-conifer forest (MCF), Bluepine and Meadows. A total of 190 species of tree vegetation belonging to 49 families were recorded in the red panda habitat. Generally, species diversity is one of the most important indices used to evaluate an ecosystem. A rich ecosystem with high diversity has a large value of H' while an ecosystem with low H' value will have low species diversity. Maximum diversity of tree species was recorded in CBL (*H' = 8.54*) followed by MCF (*H' = 2.80*), Fir forest (*H'= 1.27*), WBL (*H'= 1.26*), Bluepine (*H' = 0.05*) and Meadows (*H' = 0.007*). Canopy cover with a range of 25 - 50% showed the highest number of plots with signs of red panda presence (n = 16). The most dominating tree species within the study site is *Abies densa* (IVI = 19.76) followed by *Acer campbellii* (IVI = 10.13) and *Quercus lamellosa* (IVI = 8.74). The detailed information on top 10 dominant tree species within the study site is given in table 3.

Species	Relative Density	Relative Dominance	Relative Frequency	IVI
Abies densa	5.49	8.78	5.49	19.76
Acer campbellii	3.08	7.51	3.53	10.13
Quercus lamellosa	2.86	5.86	0.02	8.74
Tsuga dumosa	2.68	5.48	0.2	8.37
Rhododendron falconeri	3.02	1.43	3.82	8.27
Quercus spp.	2.4	5.66	0.09	8.15
Rhododendron spp.	5.75	1.8	0,02	7.57
Symplocos spp.	5.43	1.66	0.07	7.17
Persea spp.	3.34	3.71	0.09	7.14
Sorbus tibetica	0.27	0.09	6.58	6.95

Table 3. Ten dominating tree species in the study site

The majority of the red panda presences plots had herbs (58%, n = 28) with <25% cover, shrubs (83%, n = 40) with <25% cover, bamboos (58%, n = 28) with <25% cover, stumps (96%, n = 46) with <5 numbers and fallen logs (67%, n = 32) with <5 numbers. The overall density of fallen logs and stumps in the study site was 5.70 logs/ha and 0.02 stumps/ha, respectively. The density of fallen logs in the red panda presences plots was 7.75 logs/ha and the stump was 4.25 stumps/ha.

The common understory shrub species includes *Symplocos* spp., *Viburnum* spp., *Persicaria* spp., *Rhododendron* spp., and *Viburnum nervosum*. The tree layer was uniformly dominated by Lauraceae (19 species, 10%), Ericaceae (16 species, 8.42%), Fagaceae (15 species, 7.89%), Araliaceae (14 species, 7.37%), Magnoliaceae and Rosaceae (10 species, 5.26% each), Aceraceae and Euphorbiaceae (7 species, 3.68%), Anacardiaceae and Leguminosae family with 6 species, 3.16% each (Figure 9).

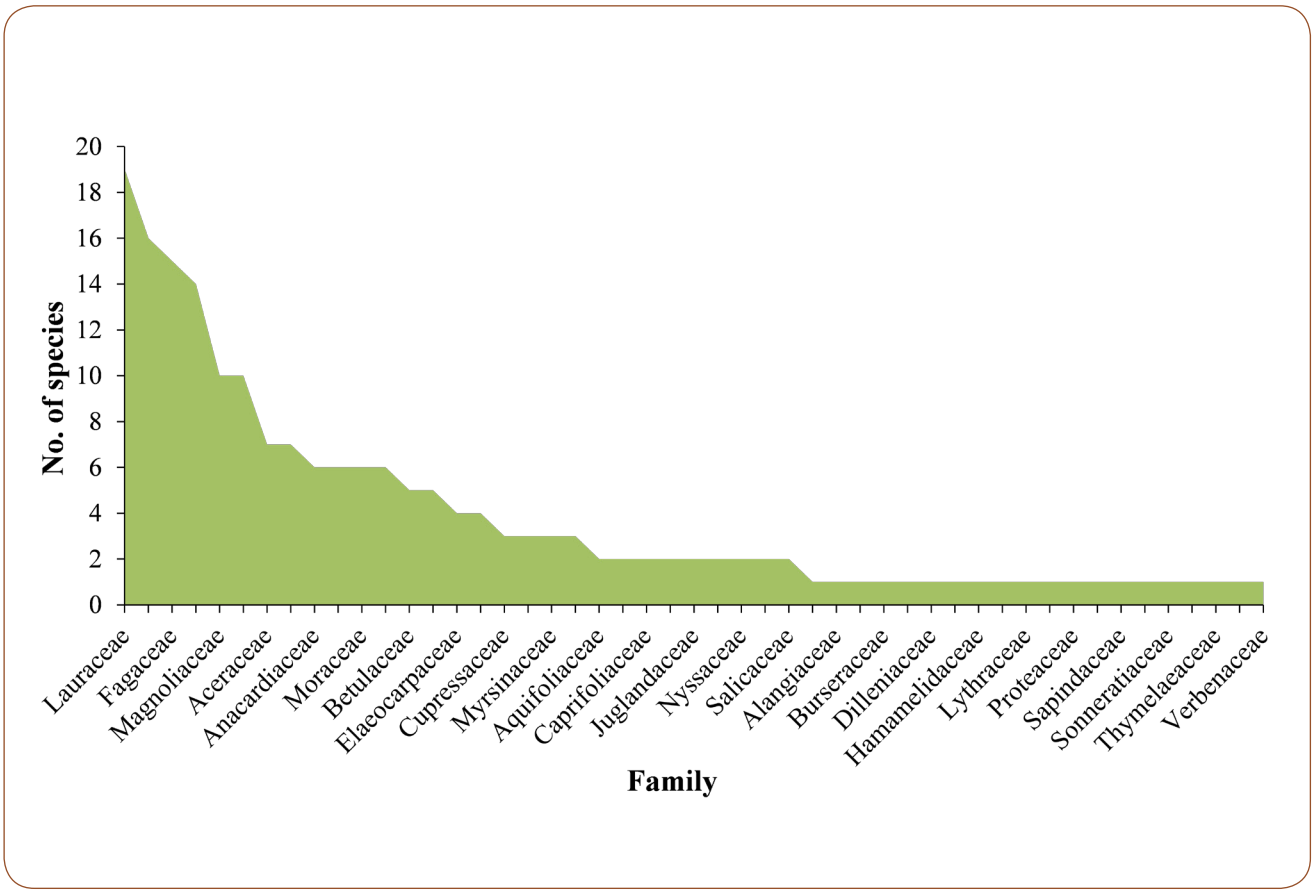


Figure 9. Family distribution in four study area landscape

The common understory bamboo recorded in almost all the sampled plots include *Thamlocalamus spathiflorus*, *Yushania maling*, *Y. hirsuta*, *Y. pantlingii*, *Y. yadongensis*, *Arundinaria racemosa*, and *Chimonobambusa callosa*. The presence of red panda evidence in these 48 plots was all related to the presence of live bamboo which indicates they forage on live bamboo. Almost 69% (n=33) plots were covered by live bamboo and 31% (n=15) without bamboo in the red panda evidence plots.

The study by Choudhury, (2001) recorded that the commonly consumed bamboo by red panda were *Arundinaria* spp., *Phyllostachys* spp., *Thanocalamus* spp., *Yushania* spp., *Chimonobambusa* spp., *Semiarundinaria* spp., *Pseudosyachyum* spp. and *Qiongzhuea* spp. in Nepal.

3.3 Camera trap results

We retrieved a total of 60 camera traps from the four Divisions, nine each in Dagana and Samtse and 21 each in Gedu and JKSNR. The 60 camera trap stations yielded a total of 5,428 camera trap days with an average camera trap days of 90 days per station and captured as many as 22,858 images.

Nineteen different mammal species were captured by the camera traps (Table 4) but red panda was captured only at six locations with 28 independent images. Of the six camera trap stations that captured red panda, four were at JKSNR and one each in Gedu and Dagana (Fig. 10). Images were considered independent when the successive image was captured after 30 minutes.

Common name	Scientific name	Family	IUCN Status	Occupied stations (60)	Naïve occupancy
Himalayan serow	*Capricornis thar*	Bovidae	Vulnerable	31	0.517
Sambar	*Rusa unicolor*	Cervidae	Vulnerable	28	0.467
Barking deer	*Muntiacus muntjak*	Cervidae	Least Concern	26	0.433
Himalayan black bear	*Ursus thibetanus*	Ursidae	Vulnerable	18	0.3
Wild pig	*Sus scrofa*	Suidae	Least Concern	18	0.3
Yellow-throated marten	*Martes flavigula*	Mustelidae	Least Concern	17	0.283
Dhole	*Cuon alpinus*	Canidae	Endangered	11	0.183
Asian golden cat	*Catopuma temminckii*	Felidae	Near Threatened	10	0.167
Marbled cat	*Pardofelis marmorata*	Felidae	Near Threatened	9	0.15
Red panda	*Ailurus fulgens*	Ailuridae	Endangered	6	0.1
Leopard cat	*Prionailurus bengalensis*	Felidae	Least Concern	4	0.067
Tiger	*Panthera tigris*	Felidae	Endangered	4	0.067
Himalayan goral	*Naemorhedus goral*	Bovidae	Near Threatened	4	0.067
Assamese macaque	*Macaca assamensis*	Cercopithecidae	Near Threatened	4	0.067
Clouded leopard	*Neofelis nebulosa*	Felidae	Vulnerable	1	0.017
Common leopard	*Panthera pardus*	Felidae	Vulnerable	1	0.017
Masked palm civet	*Paguma larvata*	Viverridae	Least Concern	1	0.017
Gaur	*Bos gaurus*	Bovidae	Vulnerable	1	0.017

Table 4. Table showing the mammal species recorded in the camera traps and their naïve occupancy

Capture frequency showed red panda was most active during the day from 7:00 AM till 2:00 PM (Fig. 11) though it was also captured during the night. Ten other mammals were also recorded in the camera trap stations that captured red panda (Fig. 12).

Figure 10 . Red panda photo captured on camera traps

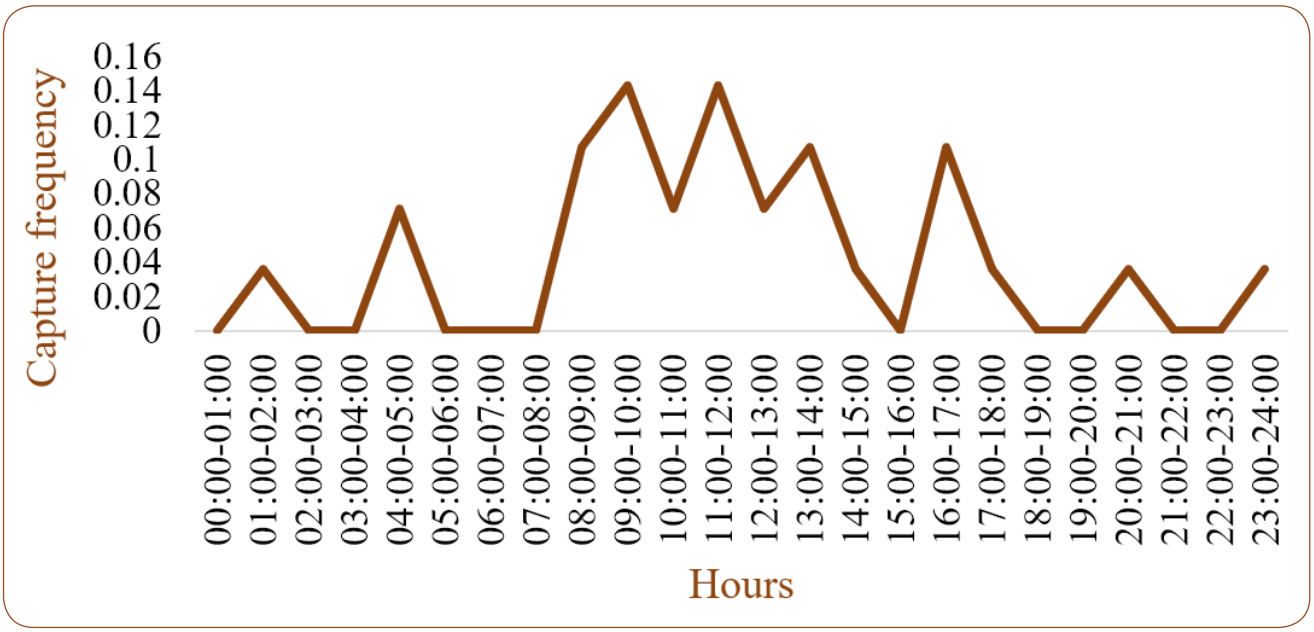


Figure 11. Activity pattern of red panda based on independent capture frequency

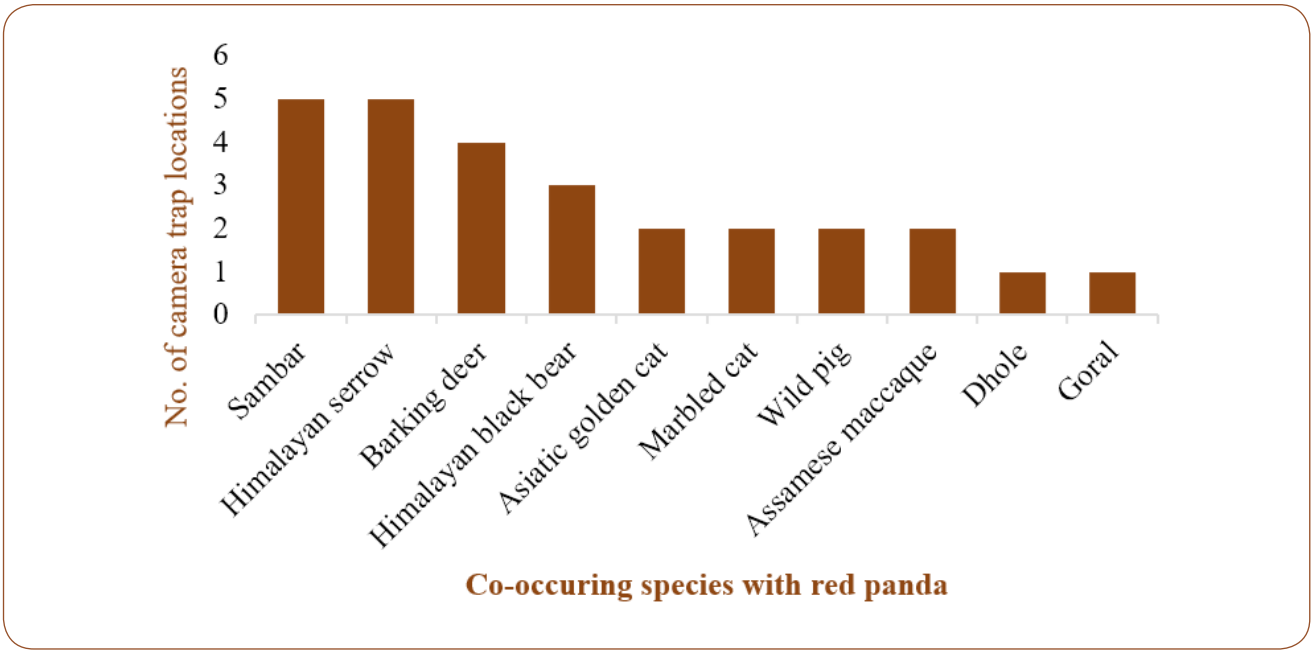


Figure 12. Other mammals recorded by camera traps that captured red panda

3.4 Potential habitat distribution

The model exhibited relatively high AUC value (train = 0.95 & test = 0.94) indicating the good performance of it in predicting the habitat suitability of red panda in the landscape. Prediction of habitat suitability was highly influenced by the elevation followed by the temperature annual range (Bio7), precipitation of driest month (Bio14), slope, precipitation of coldest quarter (Bio19), Isothermality (Bio3), LULC and least by aspect accounting to relative contribution of 59.7%, 14.8%, 10.6%, 7.8% and remaining less than 3% respectively. Overall, topographic variables had the maximum contribution (68.4%) in comparison to climatic variables (Fig. 113).

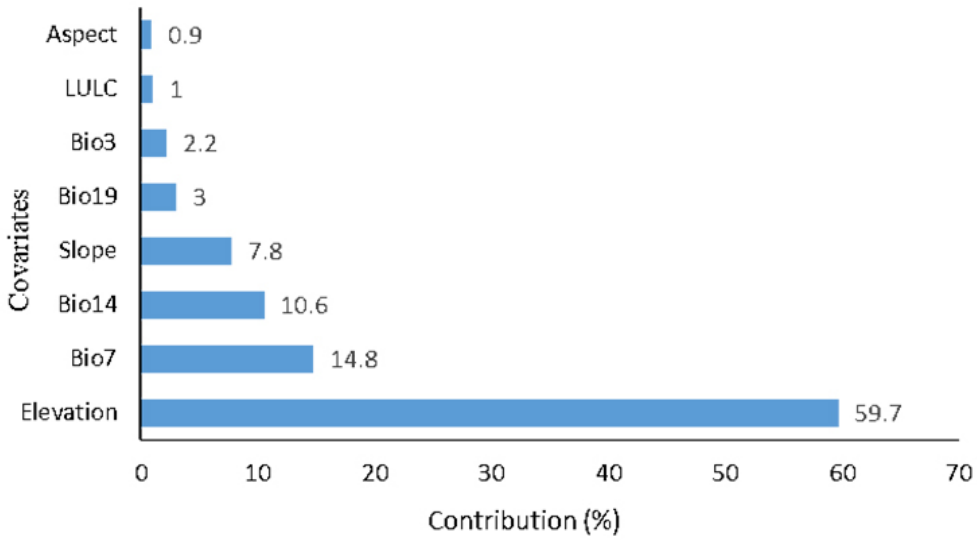


Figure 13. Contribution of different covariates in predicting habitat suitability

In the study landscape comprising of 6365.35 km^2, only 10% of the area is predicted as the potential habitat for red panda (Fig. 14). Amongst the landscape, GFD (4.2%) has the maximum potential habitat followed by JKSNR (3.1%), SFD (1.6%) and least in DFD (1.1%) (Table 5). Based on the Land Use and Land Cover map of 2016, broadleaf (60.9%) and mixed conifer forest (27.9%) are identified as the dominant forest types within the predicted potential habitats. Forest management regime analysis shows that 20.7km^2 (3.2%) of the total predicted habitat falls within the Metapchhu forest management unit (FMU) under GFD and another 9.6km^2 (1.5%) falls within the local forest management area (LFMA) across the study landscape. JKSNR is the only protected area in the landscape and harbor 53.8km^2 (8.4%) of the predicted potential habitat. Since, it is expected that higher the predictive suitability value, better is the site for the survival of the species. Suitability value >0.7 is categorized as the highly suitable/prime habitat. Of the total predicted potential habitats (637.67 km^2) only 186.3km^2 falls in the category of prime habitats.

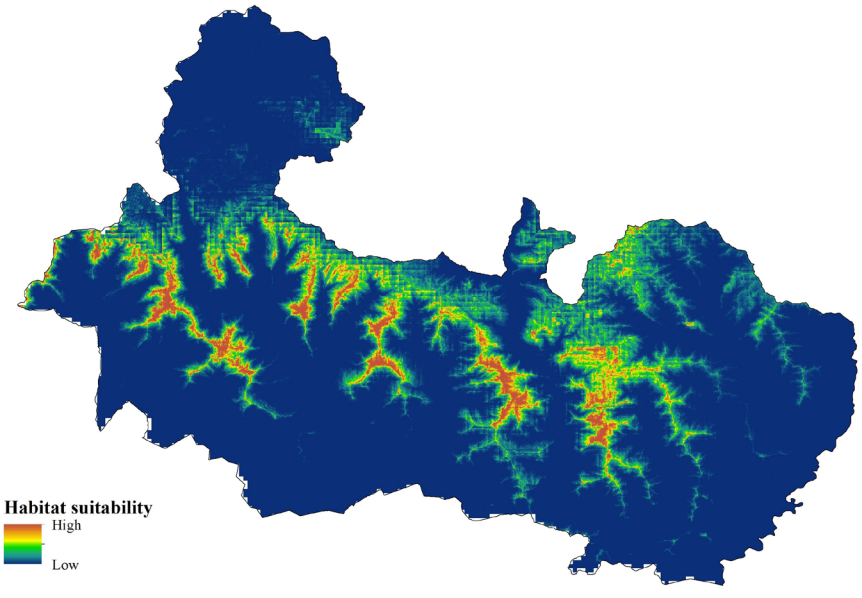


Figure 14. Potential habitat for red panda in the landscape

Sl. no	Landscape	Landscape area (km²)	Predicted suitable area (km²)
1	Dagana Forest Division	1583.85	73.82
2	Gedu Forest Division	1879.85	265.92
3	JKSNR	1596.8	194.31
4	Samtse Forest Division	1304.85	103.62

Table 5. Distribution of potential habitats in different jurisdictions of the study landscape

3.5 Potential connectivity between prime habitats

Across the landscape, 12 numbers of prime habitats (hereafter PH) were identified with an area ranging from 2.5km² to 33.5km² (mean 12.7km²) (Table 6). Twenty-four linkages were mapped between the different pairs of PH in the landscape. The mean least cost path (LCP) is 36.4km (SD=19.3, Range= 15.8 – 71.9km), mean Euclidian distance (EucD) is 21.2km (SD=13.9km, Range= 8.4 – 47.5km), mean cost weighted distance (CWD) is 737.7 weighted km (SD=519.9km, Range= 181 – 1601.6.5). The mean CWD:EucD and CWD:LCP is 0.34 (SD=0.02) and 0.25 (SD=0.01) respectively. From the 24 linkages, 14 active linkages were identified (Table 7, Fig. 12), which are expected to keep the prime habitats of the landscape connected. The higher value for CWD:EucD indicates more difficulties to move between the habitat pairs relative to how close they are or after accounting the Euclidean distance. CWD:LCP metrics describes average resistance animal has to encountered while moving along the LCP identified as the optimal or least resistance path.

Prime habitat (PH)	Current flow centrality (amps)	Area (sq.km)
1	35	18.74
2	26.7	5.44
3	11	5.36
4	13.3	4.73
5	29.26	30.05
6	16.15	33.52
7	39	6.24
8	42.32	13.01
9	29.53	2.57
10	28.38	4.99
11	23.92	11.76
12	31.73	16.88

Table 6. The characteristics of 12 PHs with respective area and current flow centrality score

The highest CWD:EucD (0.06) and CWD:LCP (0.05) was recorded for PH8-PH11 which indicates that the cost of species movement between them is relatively higher than other pairs of PHs. PH11-PH12, on the other hand has a better quality illustrated by lowest CWD:EucD (0.007) and CWD:LCP (0.005).

PH8 has the highest current flow centrality score followed by PH7 and PH1. Current flow centrality is a measure of how important a link or core area is for keeping the overall network connected. Importance of the PH in landscape is directly proportional to the value of current flow centrality. The PH with highest current flow centrally (PH8 and PH7) is located in the landscape of JKSNR and PH with third highest current flow centrality (PH1) shares the landscape with JKSNR, Gedu and small portion with Samtse. Thus, conservation and protection of habitats in the JKSNR will play critical role in keeping the overall network of habitats interconnected in the landscape corresponding to their centrality score. PH with lowest current flow centrality (PH3 and PH4) are located in landscape of Dagana and Samtse which plays minimum role in maintenance of overall connectivity.

Prime habitat (PH)		EucD (km)	CWD (km)	LCP (km)	CWD:EucD	CWD:LCP	Current Flow Centrality (Amps)
From	To						
8	11	9.2	613.1	10.4	0.07	0.06	16.4
5	6	8.8	448.9	9.4	0.05	0.05	13.1
9	12	5.8	243.6	6.9	0.04	0.04	12.6
4	5	25.9	1006.5	33.2	0.04	0.03	7.4
1	**7**	**5.5**	**202.8**	**6.9**	**0.04**	**0.03**	**32**
2	9	9.7	282.8	10.9	0.03	0.03	11.9
8	**10**	**7.2**	**380**	**14.8**	**0.05**	**0.03**	**22.2**
4	6	17	500.4	22.9	0.03	0.02	8.2
7	**8**	**3.4**	**118.7**	**6.3**	**0.03**	**0.02**	**35**
9	**10**	**2.5**	**52.5**	**3.1**	**0.02**	**0.02**	**23.6**
1	**5**	**11.2**	**274.2**	**19.3**	**0.02**	**0.01**	**27**
2	3	4.9	112.5	8.9	0.02	0.01	11
2	12	3.1	55.1	5.7	0.02	0.01	19.5
11	**12**	**6.4**	**47.1**	**7.9**	**0.01**	**0.01**	**20.4**

Table 7. The characteristics of 14 active linkages between 12 PHs in decreasing current flow centrality scores to illustrate their importance in keeping the landscape connected

Pinch point identifies the bottle neck or constriction in movement of animals between the PH without much alternative routes. Even small loss of areas in identified pinch points would result in compromise of the connectivity. Thus, pinch points play pivotal role in keeping the connectivity intact. Almost all pairs of PHs have pinch points (Fig. 15), and some of them are extremely narrow indicated by section with high lighting (current flow) and are important for keeping the entire network connected.

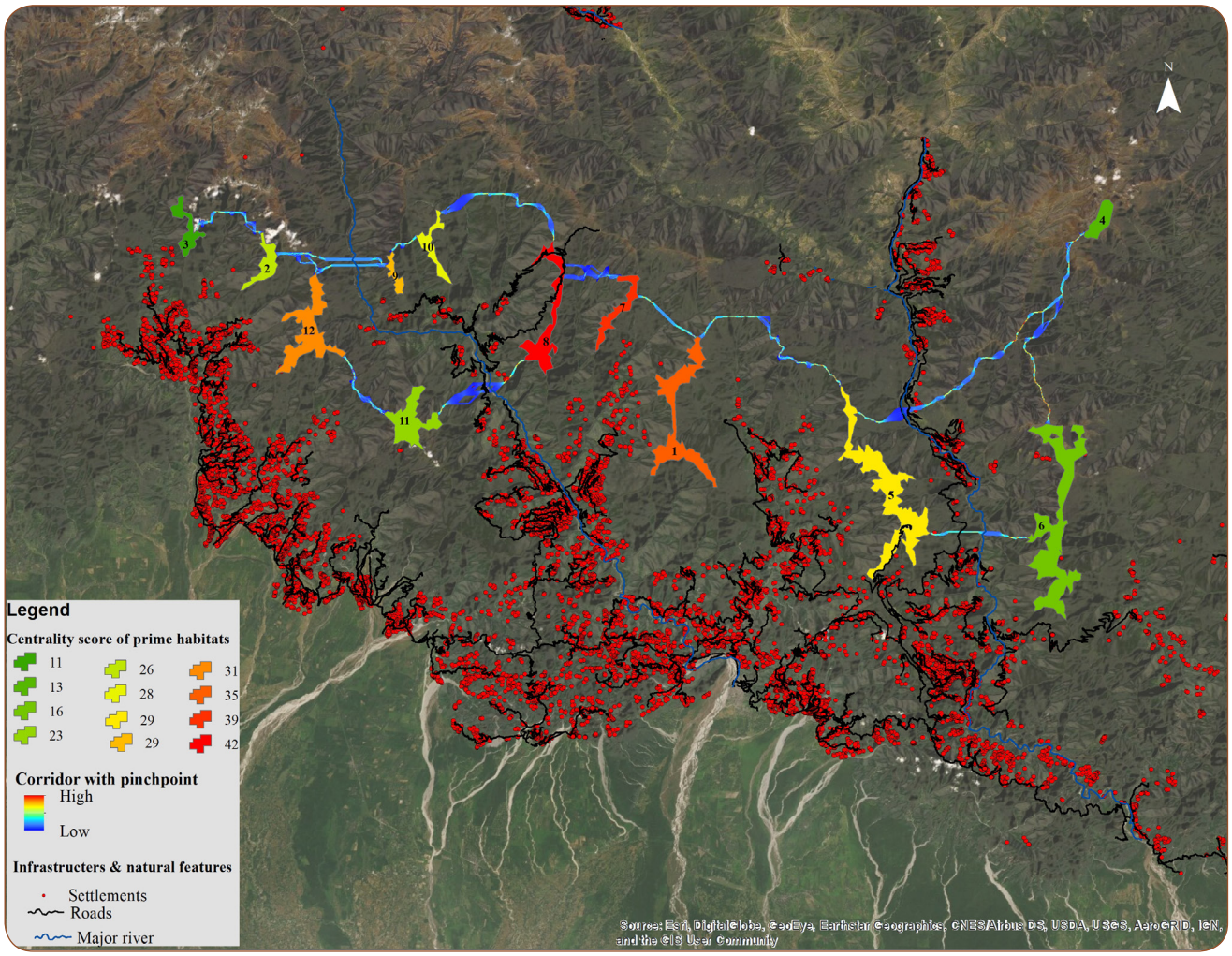


Figure 15. Overview of the landscape with potential corridor connectivity among the PHs. Shade of brighter color along the corridor indicates pinch points

3.6 Conservation threats

Red panda not only responds to the availability of live bamboos but also potentially negatively to anthropogenic disturbances. Since Red panda is a shy, timid and crepuscular animal, they may be very much sensitive to the disturbances made by anthropogenic agents. Overall, we recorded 50.5% (n = 547) of the surveyed plots with signs of conservation threats such as timber harvesting (13.2%, n = 143), NWFP collection (16.5%, n = 179), livestock signs (37.1%, n = 402), stray dogs (2.4%, n = 26) and infrastructure (5.7%, n = 62). Hunting signs were not recorded during the entire survey period in the study landscape. Red panda used habitat within both disturbed and undisturbed sites with the presence sign in 56.3% (27/48) and 43.7% (21/48) of plots respectively. In JKSNR, almost 32% of the plots fall in dead bamboo, however bamboo regeneration is rigorously taking place. Road construction along the red panda habitat area was recorded at the periphery of JKSNR (27%).

3.7 People's perception towards red panda conservation

A total of 350 people were interviewed to ascertain their perception towards red panda and conservation from the four districts. Of them 70.57% were male and 29.43% female. The age range of respondents

were between 17 and 90 years with median age of 45 years. 252 respondents own either cattle, sheep/goat or horses and the remaining does not own any livestock. In terms of source of livelihood, 82.57% of the respondents relied on farming, 10.29% on livestock rearing, and the remaining 7.14% were engaged in other livelihood options such as business or earning daily wages (Fig. 16).

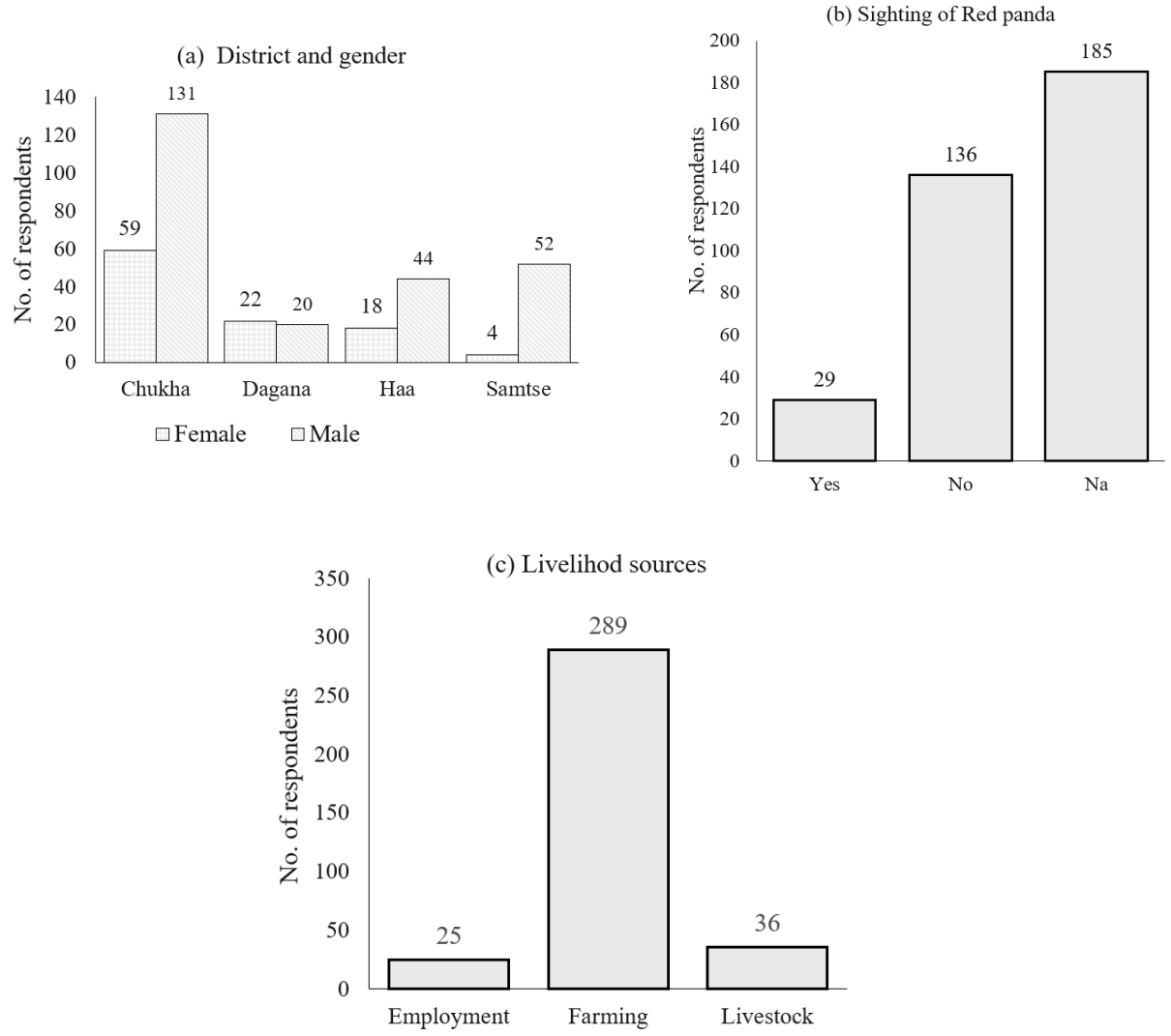


Figure 16. Frequency of responses among interview respondents for different variables

Our results showed that almost 50% of the respondents does not have any knowledge about red panda while those who know about the animal either experienced direct sighting or heard about the animal from secondary sources. At least 29 respondents had direct sighting of the red panda, and most of the sightings happened inside the broadleaf forests. 92.29% (n=323) of the respondents were well aware about the provisions of forests and nature conservation rules such as killing of wildlife being an offence. On asking about the importance of red panda conservation, 67.14% (n=235) respondents had a positive response (Table 8).

Perception statements	Response in % (n=350)	
	Yes	No
A. Do you have knowledge on red panda?	47.14	52.86
B. Are you aware that wildlife killing is an offence under FNCRR?	92.29	7.71
C. Do you think conservation of red panda is important?	67.14	32.86

Table 8. Summary of answers to fixed-response attitude statements concerning red panda conservation (n = sample size)

The respondent's knowledge on red panda was influenced by gender, age and their location with respect to the protected area (Table 9, Fig. 17). The respondents' attitudes towards red panda conservation, on the other hand was significantly more positive in people who were aware of red panda, farming as livelihood source, and who attended awareness programmes (Table 10, Fig. 18).

	Coefficient (β)	s.e	z value	*P*-value	2.50% CI	97.50% CI
(Intercept)	-0.118	0.112	1.058	0.29	-0.338	0.101
Gender	-0.561	0.253	2.22	**0.026**	-1.056	-0.066
PA/Non-PA	1.258	0.337	3.735	**0**	0.598	1.918
Age	0.488	0.23	2.122	**0.034**	0.037	0.938
Livelihood sources	-0.417	0.238	1.751	0.08	-0.884	0.05
Awareness	-0.197	0.239	0.822	0.411	-0.666	0.272

Table 9. Results of multivariate analyses on the respondents' knowledge on red panda. Significant *P*-values are in bold

	Coefficient (β)	s.e	z value	*P*-value	2.50% CI	97.50% CI
(Intercept)	0.959	0.142	6.747	0	0.68	1.237
Attended Awareness programme	0.63	0.306	2.062	**0.039**	0.031	1.23
Knowledge on red panda	1.694	0.287	5.893	**0**	1.13	2.257
Age	0.543	0.271	2.005	**0.045**	0.012	1.074
Livelihood sources	0.972	0.283	3.438	**0.001**	0.418	1.526
Livestock holding	-0.34	0.279	1.218	0.223	-0.888	0.207
Aware of FNCRR	0.544	0.368	1.48	0.139	-0.176	1.265
Gender	-0.246	0.284	0.866	0.387	-0.804	0.311
PA/Non-PA	0.156	0.451	0.346	0.729	-0.728	1.04

Table 10. Results of multivariate analyses on the respondents' attitude towards red panda conservation. Significant *P*-values are in bold

3.8 Conservation awareness programme

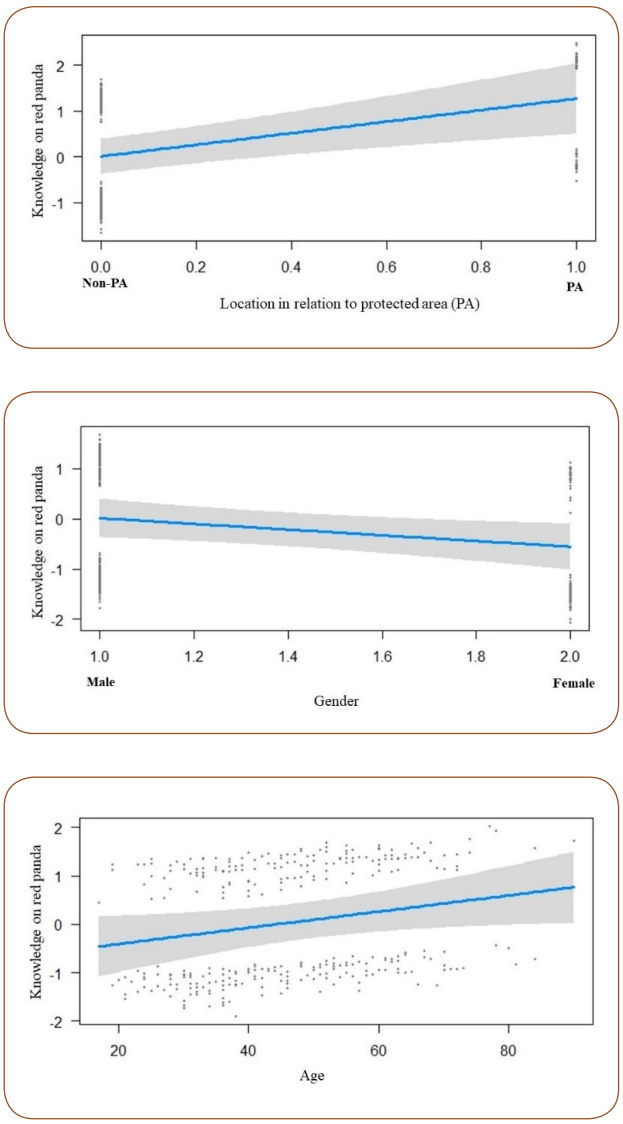


Figure 17. Influence of significant variables on people's knowledge on red panda

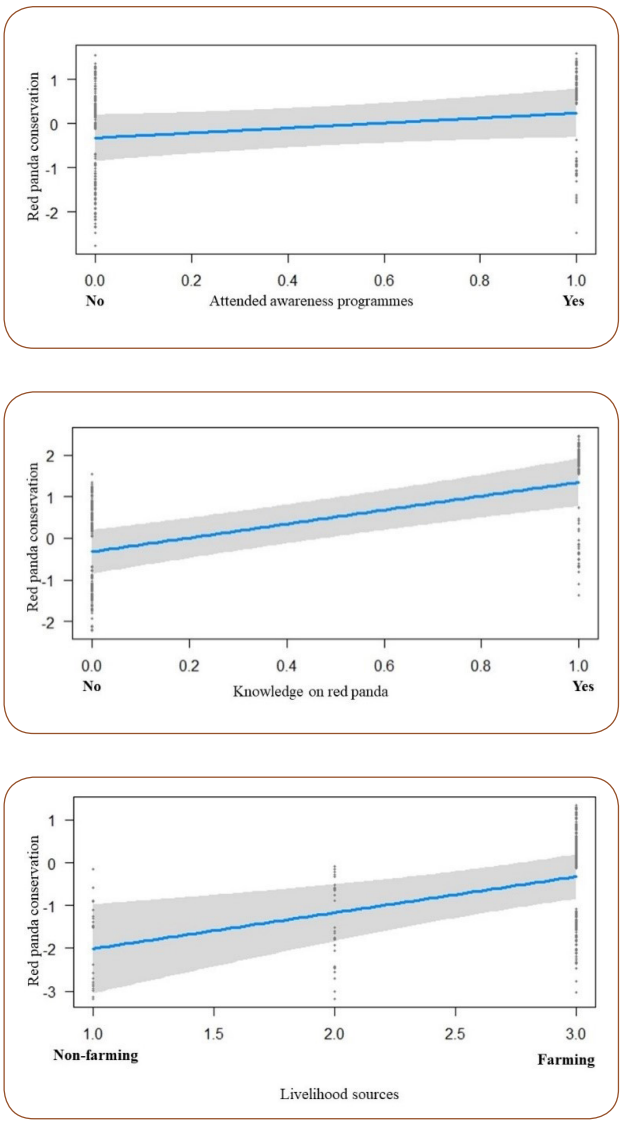


Figure 18. Influence of top three significant variables on people's perception towards red panda conservation

3.8.1 Awareness through focused group discussions

Awareness on red panda conservation was carried out to the local communities during the household level social survey data collection through focused group discussions opportunistically in four Dzongkhags viz.: Chukha, Dagana, Haa and Samtse (Table 11).

Sl.No.	Dzongkhag	Number of People
1.	Chukha	190
2.	Dagana	42
3.	Haa	62
4.	Samtse	56
Total		350

Table 11. Number of people who attended Awareness on red panda conservation

3.8.2 Awareness campaigns and conservation signages

Awareness programs to the farmers in the selected gewogs of the project landscape were provided. The awareness campaigns were conducted in three gewogs and four schools under the project landscape. The target group for the awareness were those communities residing near to the red panda habitat and school students who are member of nature club and those who studies Environmental science subject. Total of 230 farmers residing near to the core red panda habitat and about 400 students attended awareness campaigns on red panda conservation (Table 12, Table 13, Fig. 19).

Sl.No.	Geogs	Dzongkhag	Number of People
1.	Bji *gewog*	Haa	50
2.	Sombaykha *gewog*	Haa	120
3.	Gakiling *gewog*	Haa	60
Total			**230**

Table 12. Awareness to farmers

Sl.No.	Schools	Dzongkhag	Number of Students	Target Group
1.	Katsho Lower Secondary School	Haa	300	Nature Club members and Environmental Science students
2.	Gongzim Ugyen Dorji High School	Haa		
3.	Sombaykha Lower secondary School	Haa		
	Daga Central School	Dagana	100	
Total			**400**	

Table 13. Awareness to school students

A total of 14 Signages were installed in the red panda habitat and along the roads that pass through red panda habitats inside JKSNR dissemination of the messages to the communities around and travellers along the roads (Fig. 19). No such signages were installed in the three forest divisions.

Figure 19. Conservation awareness programmes (First four images), and conservation signages (Later two)

04 DISCUSSIONS AND RECOMMENDATIONS

4.1 Red panda distribution and habitat characteristics

This study affirmed the presence of red panda in the two divisions of Gedu and Dagana through photographic evidences as captured by the camera traps. While direct sighting or photographic evidence were not recorded from Samtse, indirect evidences in the form of red panda scats were recorded, also confirming the presence of the species in the district. This finding suggests that conservation should not rely only in protected areas (Dendup *et al.* 2016) and that rigorous field surveys are vital to enhance baseline species for strengthening conservation (Dorji *et al.* 2012). While in JKSNR, the numerous incidences of direct sighting and photographic records indicates that the reserve is a safe haven for red panda conservation in western Bhutan. The fact that lesser signs were observed in Chukha, Dagana and Samtse can be attributed to lesser red panda habitats with more areas being under elevation gradient of below 2000 masl. Besides, all these divisions have major human settlements which indirectly leads to more disturbances and fragmentation into forest habitats. All the observed red panda evidence and photo captures were recorded between an elevation of 2100 – 3700 masl, an elevational range common for red panda distribution as reported by Dorji *et al.* (2011) and Dendup *et al.* (2020) in Bhutan and a range considered favourable in its entire global range (Thapa *et al.* 2018a).

Red panda was distributed in cool broadleaf forest, mixed conifer forest, and fir forest in the current study landscape, the forest type preferred by red panda in most of the study areas across its range (Dorji *et al.* 2011; Zhou *et al.* 2013; Dendup *et al.* 2016; Bista *et al.* 2017). Our finding also affirms that bamboo undergrowth is prerequisite for the red panda to inhabit as bamboo is the most preferred food of red panda (Wei 2022) though red panda may not be present in all habitats where bamboo is present. While dietary studies were not conducted in Bhutan, predominant bamboo species recorded in the red panda habitats are *Yushania* spp. and *Arundanaria* spp (Dorji *et al.* 2011; Dendup *et al.* 2016). In other Eastern Himalayan habitats, bamboo species such as *Arundinaria aristata* and *A. maling* were found to be the stable food items of red pandas (Pradhan *et al.* 2001). Other site characteristics of red panda presence plots were prevalence of shrubs, fallen logs and stumps, and canopy cover between 25-50%, attributes which were also described as favourable for red panda across its range (Yonzon and Hunter 1991; Pradhan *et al.* 2001; Dorji *et al.* 2011; Bista *et al.* 2019; Dendup *et al.* 2020). Red panda preferred the south and east facing slopes in our study landscape, which can be attributed to such slopes receiving direct sunlight during winter. It is reported that red panda rest in direct sunlight during winter to reduce heat loss (Reid and D Huang Yan 1991). Another important site characteristics is the proximity to water, suggesting that red panda need more water for its metabolism probably important to supplement the low water content associated with bamboo leaves (Pradhan *et al.* 2001; Bista *et al.* 2017).

The use of camera traps to augment sign survey in our study has helped us determine the presence of red panda in the study with certainty. Camera trapping has been a highly effective non-invasive tool for wildlife monitoring (Caravaggi *et al.* 2017) and its use for monitoring arboreal species has been on the rise (Gregory *et al.* 2014). Red panda being an arboreal species, camera traps were not rigorously used in the past for monitoring the species but its use is on the rise in recent years (Lama 2018; Aung Ko Linley *et al.* 2022). For our study we used the conventional method of setting camera traps on the trails so capture frequency must have reduced. Besides there are more disturbances on the trails from both humans and stary dogs. Stray dogs are a major threat to red panda. Camera trap records showed that other carnivores such as Himalayan black bear, marbled cat, Asiatic golden cat, and dhole were also recorded in stations where red panda were captured so these carnivores might serve as potential threat to the species as well. Setting up cameras on arboreal habitats of the red panda is expected to enhance the detection probability. Camera trap records, besides confirming the presence of species with certainty, also helps us assess the activity pattern and nature of interaction with co-occurring species.

4.2 Potential prime habitats and linkages

Our study affirms that the south-western landscape of Bhutan which is also a transboundary landscape adjoining Sikkim and West-Bengal of India have some of the most critical conservation landscape for red panda in the region. Habitat suitability modelling predicted over 600 km2 of areas as suitable red panda habitats in the study landscape with majority of the prime habitats (PH1, 7, 8, Fig. 15) located inside JKSNR, the lone protected area in the study landscape. The strict conservation measures put into place in the protected areas of Bhutan (RGoB 1995; Lham *et al.* 2018; Dorji *et al.* 2019) are expected to ensure that the prime habitats in JKSNR contribute immensely towards red panda conservation in the region. Of the diverse covariates used in modelling, the results showed that topographic variables such as elevation and slope had the maximum contribution (68.4%) in comparison to climatic variables. Elevation would have direct influence to climatic condition and vegetation composition of the locality while slope is known to influence the feeding strategies of the species (Thapa *et al.* 2018b; Bista *et al.* 2019; Shrestha *et al.* 2021). Among the climatic variables annual temperature and precipitation during the driest month had the highest influence on predicting potential red panda habitats, a finding similar to Thapa *et al.* (2018b) possibly because temperature and precipitation have a great influence over the growth rates of bamboo understories a primary food source for red pandas as reported by Thapa *et al.* (2018b). Most of the predicted habitats falls in the broadleaf forests (60.9%) and conifer forests (27.9%).

With certain potential habitats falling inside the Forest Management Units and Local Forests Management Areas which are prime areas for sustainable harvesting of timber, the habitats in these management regimes are likely to experience relatively high anthropogenic disturbances from forest management activities. It is therefore, vital that adequate conservation buffers are maintained around the potential habitats in these management regimes to protect the red panda habitats. Recent studies in Nepal suggests that current patterns of habitat fragmentation and forest exploitation might be adversely affecting red panda conservation efforts (Bista *et al.* 2021). In JDNP in northern Bhutan, human disturbances and infrastructure, such as power transmission lines, were identified as prominent anthropogenic threats (Dendup *et al.* 2020). With most of the red panda sightings recorded

from road construction sites in JKSNR, the risk of such development to red panda conservation is going to be immense.

Since prime habitats identified through prediction modelling falls in different divisions of the study landscape, the present study identified 14 active linkages between 12 prime habitats in the study landscape. The PH 8, PH7, and PH1 constitutes the critical prime habitats with highest current flow centrality and their location at the centre of the study landscape makes these prime habitats inevitable for red panda dispersal across the landscape. On the other hand, PH2 and PH3 are critical prime habitats at the transboundary region and PH5 and PH6 are expected to ensure further landscape connectivity towards the centre of the country. PH8 with the highest current flow centrality falls within the locality of Tergola ridge inside JKSNR from where frequent direct and indirect evidence of red panda is reported. Taking into account high current flow centrality and frequent red panda sighting, PH8 can also potentially serve as a source for dispersal despite its contribution to maintaining overall connectivity. However, simple geospatial analysis shows a network of newly constructed roads connecting Haa with Sangbaykha and Samtse in the south passing through PH8. Recently, incidences of red panda roadkill were also reported from the locality (personal communication with officials of JSKNR) which is likely to increase with an increasing number of road users.

Amongst the linkages, linkages connecting PH7 and PH8, PH1 and PH7, PH1 and PH5, PH9 and PH10, PH8 and PH10, and PH11 and PH12 are critical linkages with high current flow centrality. These linkages establish possible connectivity between different prime habitats from the four study sites across the landscape, thus establishing that the entire landscape is an important red panda conservation area. However, pinch points were observed in all most all pairs of PH, suggesting that predicted linkages in the landscape possess some kind of bottleneck in the movement of the red panda (Tobgay and Mahavik 2020). On the ground, the potential linkages are fragmented by road (primary highways), and major rivers, which will pose hinderance to safe dispersion of red panda amongst the prime habitats. It is therefore, imperative that green infrastructure principles are adopted in the critical linkages and wildlife signs are established to ensure safety to the red panda and other prevailing wildlife.

4.3 People's perception towards red panda conservation

The present study showed that people's knowledge on red panda were limited as just over 50% of the respondents are aware of the animal. This itself indicates the uniqueness and rareness of the species, for which advocacy and conservation measures are important. Peoples living nearby the JKSNR had better knowledge compared to people living in other three divisions, which can be mainly attributed to increased awareness programmes in the protected areas (Dorji *et al.* 2011; Katel and Schmidt-Vogt 2011; Millar and Tenzing 2021). Male respondents and elderly people had a higher awareness on red panda, a perception similar to one observed in northern Bhutan towards tiger conservation (Letro and Fischer 2020). That female respondents have less knowledge than men could be due to the fact that females are mainly busy with household work, whereas males spend more time to interact socially (Katel and Schmidt-Vogt 2011). On the other hand, increased knowledge on 'wildlife killing being an offence under conservation rules' by majority of the respondents can be mainly attributed to increased awareness about conservation rules by the Department of Forests and Park

Services as Bhutan's nature conservation policy aims to integrate nature conservation and economic development (Rinzin *et al.* 2009).

Despite having limited knowledge on red panda, people's perception towards red panda conservation is positive with close to 70% of the respondent's feeling conservation of red panda being important. Logistic regression results revealed that increased awareness programmes, knowledge on red panda and people practicing farming are three top covariates influencing positively towards their perception. People valued conservation knowing that the species is rare, wildlife being part of natural asset of the country, and cultural values associated to conservation as inspired by Buddhist ethos. The fact the animal is also harmless to them is being attributed as one of the reasons for valuing its conservation, unlike for conflicting carnivores and herbivores (Letro and Fischer 2020). Thus, awareness education programs by conservation practitioners and education through Buddhist religious discourses on conservation by spiritual leaders are expected to further enhance their conservation values (Letro and Fischer 2020). Farming community, as compared to people depending on other livelihood sources such as day labour and local businesses had positive perception towards red panda conservation which can be indirectly linked to people valuing natural resources for their livelihood sustenance and being better informed through conservation awareness programmes about the value of conservation. Ultimately, conservation awareness programmes and conservation incentives such as pasture management (Millar and Tenzing 2021), livestock intensification and alternatives to natural resources are expected to further reduce the negative attitudes towards conservation in the landscape. Several studies have demonstrated links between developmental programs and positive attitudes towards conservation (Studsrod and Wegge 1995; Dorji 2009; Letro and Fischer 2020).

4.4 Recommendations

Taking into account the findings, the following actions are recommended to strengthen red panda conservation in the landscape:

1. Carry out periodic monitoring of red panda at the sites where red panda or their evidences are recorded during the current study and at the potential sites and prime habitats identified through modelling.

2. Strengthen partnerships and collaborations with the local communities residing in the red panda habitats to involve them as conservation stewards.

3. Develop/implement site-specific conservation strategies for different jurisdictions in line with the red panda conservation action plan.

4. Include red panda presence sites/potential habitats under protection zone of the FMU and LFMA during forest function mapping of the two management regimes.

5. Install conservation signage and passageways along the national highways and PA roads where red panda habitats are present to prevent road kill.

6. Initiate GPS/satellite telemetry of the red panda from the prime habitats to understand their behaviour and movement in the landscape to evaluate the functionality of the predicted habitat and least-cost corridors.

7. Explore the feasibility of a transboundary conservation initiative with adjacent Indian state of Sikkim and West Bengal to facilitate genetic dispersal of the species in a larger landscape.

8. In replicating the study to other landscapes, revise the approach of field survey to enhance detection of red panda and its signs. Camera traps can be set up in arboreal habitats to increase detection.

9. Explore other ecological and behavioural study such as breeding, dietary, and movement pattern of red panda.

10. Explore non-invasive genetic study to ascertain genetic diversity and population status of red panda in Bhutan.

Conservation landscape

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06 APPENDIX

Images of carnivores captured on camera traps

Tiger, Samtse

Clouded lepard, Dagana

Marbled cat, Samtse

Asiatic golden cat, Gedu

Common leopard, Dagana

Dhole, JKSNR

Masked palm civet, Samtse

Leopard cat, Gedu

Yellow threated marten, Gedu

Himalayan black bear, Gedu

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