STATUS OF RED PANDA IN SIKKIM: A CASE STUDY IN EAST SIKKIM

Partha S. Ghose, Basant K. Sharma, Rajarshi Chakraborty and Karma Legshey D.

ABSTRACT

Red panda is the state animal of Sikkim and its population in the wild is highly vulnerable globally. Very little is known about red panda from Sikkim. With this background in mind the present collaborative survey by WWF-India and Forest Environment and Wildlife Management Department, Government of Sikkim was initiated since 2005 to understand red panda's status in the wild and threats they are exposed to. The present work was conducted at three protected areas of East District and the results were subsequently used to assess the extent of red panda habitat in East District. Our results show that bamboo presence and cover emerged as the essential habitat feature to support red panda population. Among forest types mixed conifer was best suited for red pandas, followed by oak forests. However, conifer forest unlike the most beliefs did not emerge as the best possible habitat feature. The threat issues observed during the survey were discussed.

KEYWORDS: *Red panda, Sikkim, mixed conifer, oak forest, feral dogs, threats*

Red Panda photographed at Chowkidara Phedi-Pangolakha Wild Life Sanctuary

Red panda sighted at Pangolakha Ridge Top

INTRODUCTION

Red panda is a unique carnivore that has adapted to the herbivore mode of life and is a resident of Himalayan and Hengduan mountain ranges (Roberts and Gittleman, 1984; Glatston, 1994; Wei et al., 1999; Chowdhury, 2001). Like its phylogenetic position, status of the red panda in wild has also been a matter of great discussion and speculation for over a long period (Glatston, 1994). But recently IUCN has reassessed the global status of red panda and placed it under the vulnerable category and they presume that the global number of red panda across its range - spanning from Nepal to Sichuan province of China through India (Sikkim, West Bengal (Darjeeling district only), Arunachal Pradesh and Meghalaya), Bhutan and Myanmar, could number to c. 10000 individuals (Wang et al., 2008). In India too, though red panda is included under the Schedule - I of Indian Wildlife (Protection) Act 1972, very little is known about its status in the wild.

From the handful of studies undertaken till now it has been established that high altitude bamboo forests with dense tree cover are ideal for red panda (Johnson et al., 1988; Yonzon and Hunter, 1991; Wei et al., 1999; Pradhan et al., 2001). It is a popular belief that red pandas are strictly nocturnal showing polyphasic activities throughout the night (Roberts and Gittleman, 1984; Johnson et al., 1988). Field studies, with radio-collared animals, have shown that they may express diurnal activities too under given circumstances to go with their nocturnal activities (Yonzon and Hunter, 1991). This may be related to the fact that these animals subsists mainly on low nutrient diet of bamboo and needs to feed at constant intervals to overcome the dietary deficiency (Yonzon and Hunter, 1991). Red pandas are known to have high mortality (Roberts and Gittleman, 1984), which probably is one of the main reasons behind their slow population recovery in the wild. Yonzon and Hunter's (1991) study at Langtang validates this presumption and establishes that majority of the causes behind red panda mortality are human-related.

In spite of its vulnerable status, the global population of red panda is showing a progressive decline over time till now (Yonzon and Hunter, 1991; Glatston, 1994; Choudhury, 2001; Pradhan et al., 2001). Primary among the causes is habitat loss to expansion of human habitations and to expanding agricultural practices (Yonzon and Hunter, 1991; Choudhury, 2001; Pradhan et al., 2001). GIS provides us with an ideal tool to understand the changes in the habitat conditions and it is used extensively in wildlife biology (Osborne et al., 2001; Haines et al., 2006; Talukdar et al., 2007; Clark et al., 2008). Though Yonzon et al. (1991) have shown how valuable GIS technique could be in elucidating the status of red panda habitat through their study in Langtang National Park, Nepal, no one has applied this method in the later studies conducted on this carnivore adapted to herbivory. Other than habitat loss, stress to red panda population in past has been inflicted by poaching and procurement of red pandas from the wild to be supplied at zoos as exhibits. However, in recent times this practice has been curbed to controllable limits (Glatston 1994; Choudhury 2001; Pradhan et al. 2001; Adhwes Kumar for Arunachal Pradesh, personal communication). The picture was no different in Sikkim either.

Sikkim houses the second largest red panda habitat in India and red panda is the State animal too. In spite of this hardly anything is known about the habitat status of this animal in the wild and the tentative threats they face. With this background WWF-India in collaboration with Forest Environment and Wildlife Management Department (FEWMD), Government of Sikkim, had initiated a state-wide survey in 2005 to understand the status of this cherub in Sikkim. As part of this study three Protected Areas (PAs) of East District have been surveyed till now, of which Pangolakha Wildlife Sanctuary have been surveyed more intensively compared to Fambonglho Wildlife Sanctuary and Kyongnosla Alpine Sanctuary between 2008 and 2010. Here we compile the findings of surveys at these three PAs - (i) to understand the habitat status of red panda in these three PAs; (ii) based on the assessments evaluate the overall extent of red panda in East District with the help of GIS; and, (iii) assess the existing threats along the red panda habitat.

MATERIALS AND METHODS

Study Localities

During the present phase of the survey we covered three protected areas of East District. Among these Pangolakha Wildlife Sanctuary (PWS) is situated at the south-eastern extreme of Sikkim. The eastern ridge of the sanctuary forms a continuous international boundary between Sikkim and neighboring country Bhutan. At its north-eastern extreme this ridge forms an international tri-junction between India, Bhutan and China. At the south-eastern end the ridge forms another tri-border between Sikkim, neighboring state West Bengal and Bhutan. Pangolakha Wildlife Sanctuary has an area of 128 km^2 and the altitudinal range varies from 1200 m to 4700 m (Centre for Interdisciplinary Studies of Mountain and Hill Environment, unpublished). The main vegetation types of PWS are sub-tropical wet hill forest, east Himalayan wet temperate forest, east Himalayan mixed coniferous forest, east Himalayan dry temperate coniferous forest, birch/rhododendron scrub, and alpine meadows which are home to a great diversity of flora and fauna (Champion and Seth, 1968; Grierson and Long, 1983) (Table 1; Fig. 1).

The Kyongnos La Alpine Sanctuary (KAS) is situated at a distance of c. 38 km from State capital Gangtok, along the J. N. Road. KAS has an area of 31 km^2. The altitudinal range of the KAS ranges from 3200 – 4255 m. In east the boundary extends along the Rongchu ridge up to Natso, towards west the Kyongnosla ridge forms the boundary, the northern boundary runs from Natso Peak to up to the Kyongnosla ridge and the southern boundary runs along J. N. Road between 5^{th} Mile Check Post to up to Rongchu Ridge. There are two major forest types to be found in KAS – the east Himalayan Sub-Alpine Birch/Fir Forest and Birch-Rhododendron Scrub Forest. There are no established villages around the park except for the settlement near Kyongnosla Check Post comprising of c. 60 households (Fig. 1).

Fambonglho Wildlife Sanctuary derives its name from the Lepcha word "Hambomloh", the local term for avocado trees (*Machilus* sp). 51.76 km^2 in size, and situated at a distance of c. 25 km from Gantok the Sanctuary historically shared connectivity with the Rate Chu Reserve Forest and forms the part of Rani Khola's catchment area. Tinjuray, the highest point of the sanctuary is connected to Fambong Lho peak and Ragorathai peak by mountainous ridges. The entire sanctuary has many fringe villages and habitations situated near the sanctuary edge. The major forest types of Fambonglho Wildlife Sanctuary (FWS) are east Himalayan sub-tropical wet hill forest, east Himalayan wet temperate forest and east Himalayan mixed temperate forest (Fig. 1).

Figure 1. Map of Sikkim showing the three protected areas – Pangolakha Wildlife Sanctuary, Fambonglho Wildlife Sanctuay and Kyongnosla Alpine Sanctuary, of East District, Sikkim

Fresh red panda pellets photographed at Pangolakha Wildlife Sanctuary

East District (Fig 1) situated between 27°08´05?– 27°25´24? N and 88°26´27? - 88°55´06? E is the most populated district of Sikkim. It has an overall area of 964 km² and is bound by Tibet Autonomous Region (China) and Bhutan in the east, neighboring State West Bengal in the south and by neighboring districts South and North towards west and north. According to 2001 census East Sikkim houses a population of 2, 44,790 with density of 281persons/km². Average annual maximum and minimum temperatures are 27.2° C and 1.6° C respectively, while the average annual rainfall recorded is about 3894 mm.

Field Surveys

We undertook sign surveys as part of the extensive study at these three protected areas between February 2008 to June 2008 for PWS and FWS and between May to August 2009 at KAS. These surveys gave some initial ideas regarding the habitat status of the sanctuaries and distribution of red panda in these areas. Based on the outcome of these surveys it was understood that PWS house best habitat among the three sanctuaries and was shortlisted for intensive surveys which was initiated since November 2008.

For field surveys we selected pre-existing tracks and trails within the forest at various altitudinal zones and searched for red panda evidences. Among these, other than direct sighting, pellets gave best indication of red panda's occurrence in the study habitat and this was used to estimate the relative abundance of the animal in the area (Pradhan et al., 2001).

After encountering a pellet group in field, we recorded the state of the pellet group, substrate of defecation, number of fresh pellets in the given pile, total number of pellets in a pile, and if we recorded pellets on a tree we also checked the number of levels at which the animal has defecated in that tree. Pellet groups recorded per hour was used as an index of relative abundance of red pandas in the study area (Gese, 2001). When animals were encountered we recorded the number of animals seen together, age class (in terms of young, sub-adult and adult), sex and activity. Plots where animal evidences were located were termed evidence-centered plots.

At each evidence-centered plot we measured the habitat features in details using quadrat method (Bullock, 2006). Physical features like altitude, slope aspect, and slope angle and habitat features like canopy cover, tree species, tree height, girth at breast height (GBH), number of individuals per tree species and their regeneration patterns and details of bamboo thickets like - density, height, number of stems per cluster and cover were measured within 10m ×10m quadrats. Number, cover and height of the shrub species and whether they are flowering or fruiting was measured within 3m × 3m quadrat inside the 100m^2 tree quadrate. Herb species present, herb cover, height, whether they are flowering or fruiting was recorded by demarcating 1 m × 1 m plots within the 9 m^2 shrub quadrate.

In addition to random evidence-centered plots we also assessed vegetation composition, structure and regeneration and intensity and types of disturbances within study localities, by placing 10m×10 m quadrats at an interval of 200 m at 11 altitudinal zones (1800 – 2000 m, >2000-2200 m, >2200-2400 m, >2400-2600 m, >2600-2800 m, >2800-3000 m, >3000-3200, >3200-3400, >3400-3600 m, >3600-3800 m and >3800-4000 m) starting at 1800 m.

Importance value index (IVI) of each tree species, for each of these altitudinal zones, was determined by summing their relative frequency, relative dominance and relative density (Smith and Smith, 2001).

Pristine oak forests are vital for the long term survival of the Red Panda

Spatial data and image processing

For land cover mapping, multispectral satellite image from Indian Remote Sensing Satellite (IRS-1C) with 23 m spatial resolution, and having an acquisition date of 16th Feb, 2002 was used. Ground control points (GCP), covering all the land use types as well as covering the shadow areas were collected with the help of GPS (Garmin Etrex-summit 12 channel and Garmin GPS 72). The signatures of GCPs thus collected after ground checks were used for supervised classification in Erdas Imagine (version 8.5) software using standard techniques resulting in accurate land-use classes (Roy and Tomar, 2000). We identified dense forests as vegetated areas with > 40% of tree canopy cover, open forests as those with 10–40% tree canopy cover, very open forests as those with 5–10% tree canopy cover, scrub as areas devoid of tree cover with less than 5% cover and blank as barren areas devoid of tree and shrub cover (Forest Survey of India, 2005). Total forest cover refers to the combined areas of dense and non-dense forests in forest and private lands. Image rectification, enhancement, hybrid classification and smoothening with adequate ground truthing were carried out to map the broad land cover classes. For delineation of oak and conifer forests, band 4 in the 1.55 - 1.70 μ meter wavelength range was found to be very useful. The mixing of classes was reduced by masking the forest and non forest areas separately into 4 elevation zones (1500 – 2000m, 2000 – 2500m, 2500 – 3000m and greater than 3000m). Thereafter reclassification was carried out using a subset of the land cover categories which were known to occur in a given elevation zone was then done. This was followed by manual recoding to remove the drop lines, clouds and their shadow. Finally a mosaic of these 12 separately classified images was done to obtain a composite image, and area statistics were calculated after normalization. This hybrid approach combining efforts from supervised classification, reclassification using elevation and visual interpretation resulted in the final 21 broad land cover classes.

Following completion of classification portion of East District was scooped out of the image of Sikkim using the area of interest tool in Erdas 8.5. Data collected from the field were fitted into the GIS domain to determine the extent of potential red panda habitat in the East District. ArcGIS (version 9.2) was used for integration of the various layers on a GIS platform.

Statistical Analysis

During the field survey we worked for c. 180 field days and c. 1620 man hours and sampled 312 plots along 30 tracks and trails within three sanctuaries. Out of these 312 plots 29 were removed due to incomplete data and only 283 were considered for final analyses.

To understand the vegetation structure of the study area we used cluster analysis (Pradhan et al. 2001) using the IVI matrix of the tree species for the eleven altitudinal zones. Subsequently, we segregated the vegetation type for each altitudinal zone into broad forest types encountered in the study area after Champion and Seth (1968) based on their composition.

Red panda sighted at West Dzongchen

We conducted data reduction using Principal Component Analysis (PCA) with the main objective of extracting most influential variables from a set of 23 identified during the study that may have significant impact on red panda distribution at the three PAs, both qualitative and quantitative, summarizing maximum variance of the original set of variables. The analysis was conducted using SPSS 16.0 (SPSS Inc., 2007). The factor matrix was rotated using Varimax method (Shankar Raman et al. 1998) to help interpretation and representation.

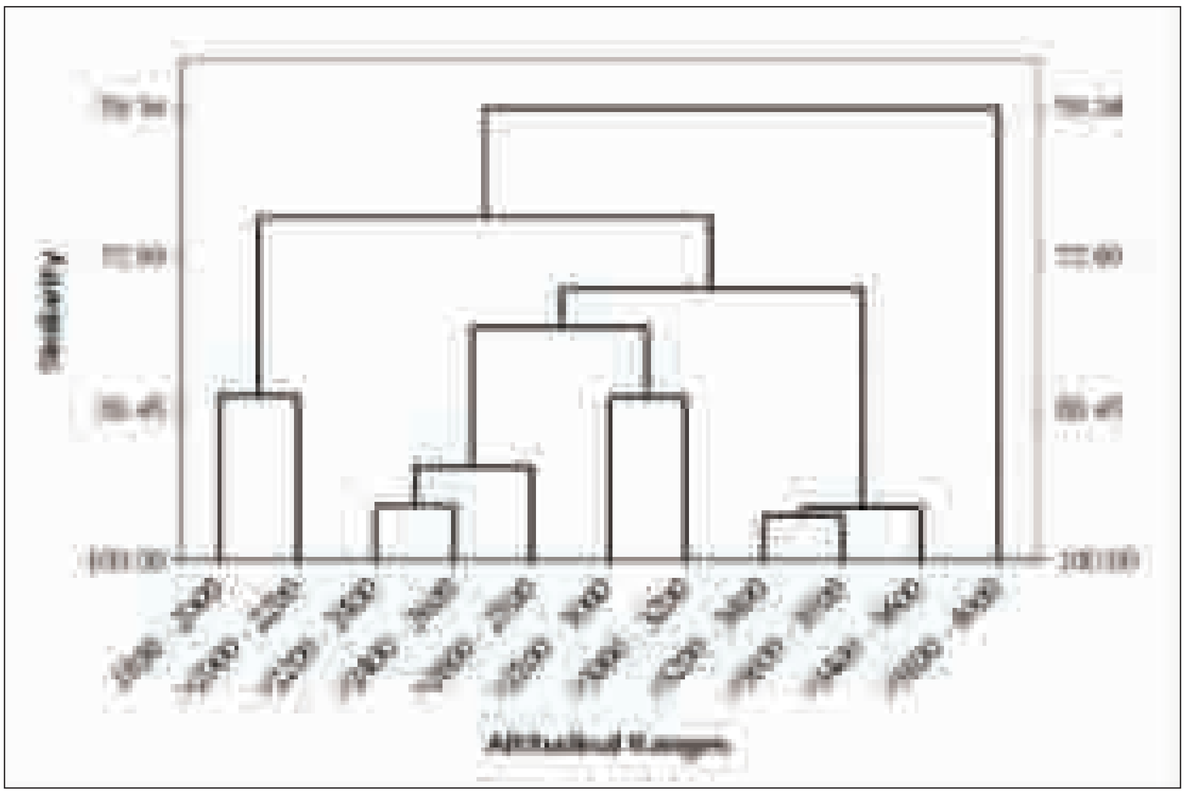
Variables showing high correlation with the major principal axes were used as predictor variables (independent) against red panda occurrence (dependent) to test which habitat variables play significant roles in regulating distribution of the target species in a given area. To test this we used binary logistic regression analysis and significance of the model was tested with Omnibus Model Fit test (SPSS Inc., 2007). The results for the statistical tests were considered significant if $P < 0.05$.

RESULTS

Vegetation zonation

Cluster analysis for the vegetation of 11 altitudinal zones show that vegetation for altitudes >3200 – 3400 m and >3600 – 3800 m link with each other with 96.17% vegetation similarity and this cluster subsequently joins with vegetation composition of altitudinal range >3400 – 3600 m with 95.25 % of similarity. This forms the cluster 1. Cluster 2, comprises of two linkages. Here altitudinal range >2200 – 2400 m first links with that of altitudinal range >2400 – 2600 m with 95.15% similarity and then it links to altitudinal range >2600 – 2800 m with 91.71% similarity. In the next stage altitudinal zones >2800 – 3000 m and >3000 – 3200 m pair with each other to form cluster 3 with a vegetation similarity of 85.41% in vegetation. Cluster 4 comprises of the altitudinal zones 1800 – 2000 m and >2000 – 2200 m that pair with each other having a vegetation similarity of 85.29% among them. In the subsequent stages clusters 2 and 3 link to each other, having 79.11% of vegetation common among them and thereon this whole group links to cluster 1 with similarity of 75.61%. Finally this major cluster links to cluster 4 and altitudinal range >3800 – 4000 m in subsequent stages to complete the overall cluster. This whole structure comprises of three major vegetation types – oak forest (1800 – 2800 m), mixed conifer forest (>2800 – 3100 m), conifer forest (> 3100-3600 m) and alpine scrub and meadow (>3600 m) (Fig 2, Table 1).

Figure 2. Cluster analysis between the IVI matrices of vegetation at different altitudinal zones.



Distribution and habitat use

Though we conducted our surveys between altitudes 1876 m to 3940 we recorded red panda evidences between altitudes 2210 m and 3570 m. The highest pellet encounter rate per hour was recorded at PWS – 0.456 pellet groups/hour, while at KAS we recorded a pellet encounter rate of 0.0315 pellet groups/hour. 80% of the evidences were recorded at oak forest, followed by mixed conifer forest (15%) and conifer forest (5%) respectively. Red panda pellets were recorded in c.. 67% of the plots surveyed in the oak forest; in c. 83% of plots surveyed in the mixed conifer zone and in c. 27% of plots surveyed in the conifer zone.

To test which habitat variables impact the red panda distribution most, we first extracted highly important habitat variables using PCA from a set of 23 qualitative and quantitative variables measured during the field surveys. PCA generated 8 principal components (PC1 through PC8) having eigenvalues >1 among which first four components accounted for c. 53% of variance among the data (Table 2). PC1 highlighted the predominance of the bamboo forest and showed very high correlation with bamboo detection and total bamboo cover. PC2 represented the topology of the terrain showing very high correlation with moderate and gentle slope of the survey areas. PC3 emphasizes the heterogeneous habitat nature showing high correlation with three different habitat variables – herb cover, scrub forest types and status of water body. PC4 show high correlations with the open and dense forest types indicating at the predominance of these forest types in the survey areas (Table 2).

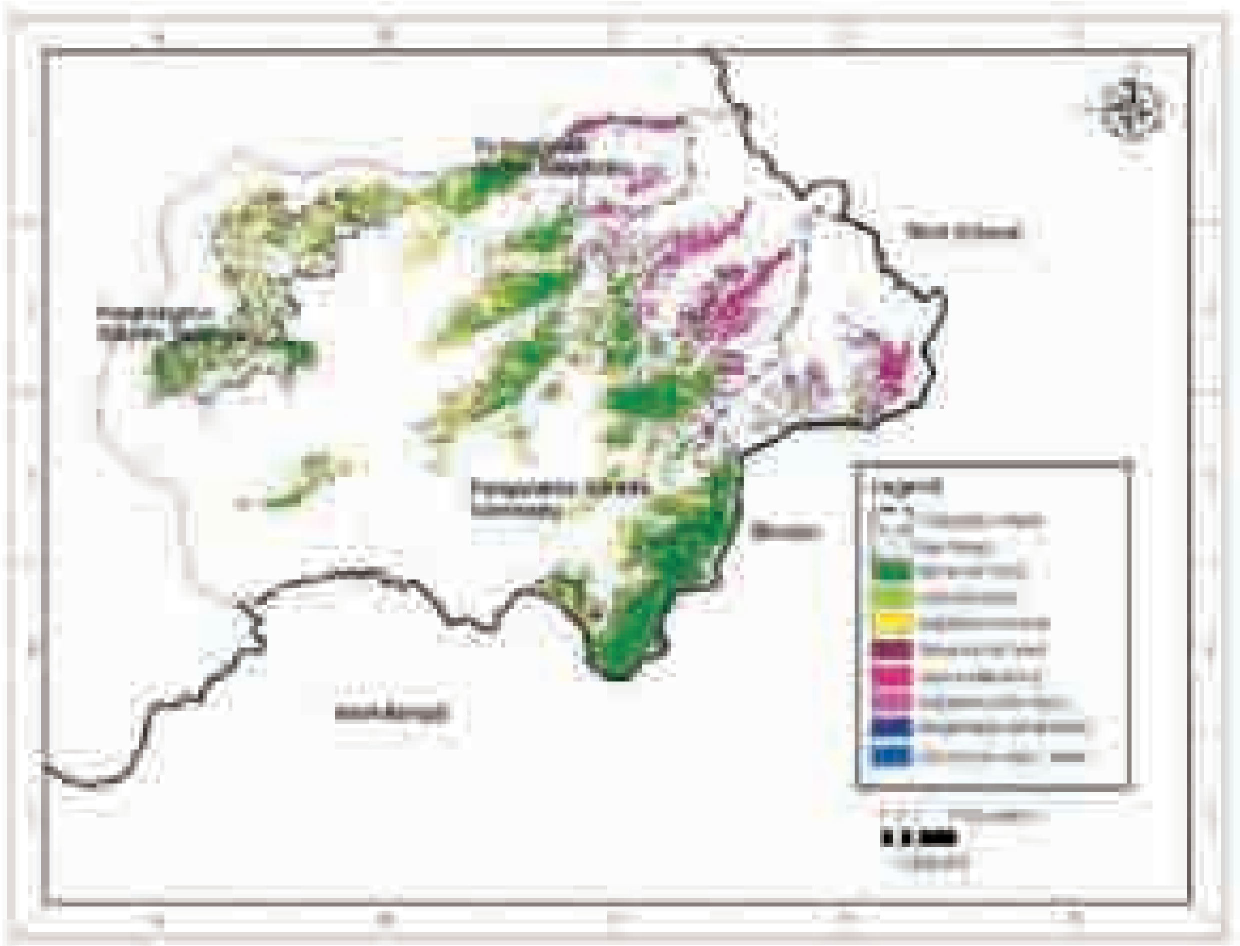
Based on the outcome of PCA analysis our assumption is that habitat features showing very high correlation (> 0.8) with first four axes (PC1 – PC4) would have significant impact on the red panda occurrence in the study locality. With this assumption we selected the six variables showing very high correlation with PC1-PC4 and performed logistic regression analysis hypothesizing that habitat features does not affect red panda occurrence. Significance of the model ($?^2 = 91.313$; df = 6; $P < 0.002$) established the fact that habitat condition does play an important role on occurrence of red panda. Among the variables loaded presence of bamboo, bamboo cover and moderate slope types emerged as significant predictors (Table 3), suggesting their role as important habitat features ideally suited to the red pandas.

Ideal red panda habitat comprising of a mixture of trees and bamboo brakes within oak forest

Extent of red panda habitat in East Sikkim

Incorporating the outcome of the habitat analyses, for the three Protected Areas (PAs), into a GIS platform we propose that potential red panda habitat may extend between the altitudinal zones 2000 to 3600 m in East Sikkim. This altitudinal range supports three major vegetation types – oak, mixed conifer and conifer, that covers c. 28.36% (273.41 km2 approximately) of the total geographical area of the district (Fig 3). Of this oak forms 24.01% (c. 231.46 km²) of the potential red panda habitat within the district, followed by conifer (c 4.08%; 39.34 km² approximately) and mixed conifer (c. 0.55%; 5.30 km² approximately). Past researches suggest that red panda usually prefer dense bamboo forests (Yonzon and Hunter 1991; Pradhan et al. 2001). Considering this it has been estimated that dense red panda habitat within East District is about 156 km² (approximately 16% of the geographical area) (oak – 122.5 km², conifer – c. 28 km² and mixed conifer – c. 5.5 km²) (Figure 3).

Figure 3. Maps showing the extent of oak, mixed conifer and conifer forest within potential red panda habitat of East District, Sikkim



DISCUSSION

In the light of infrequent red panda sighting pellet groups provided us with suitable tool to judge the probable abundance of the target species at the three protected areas covered during the present survey (Table 3). Similar reports on infrequent sighting of red pandas have been reported by past researchers too (Johnson et al., 1988; Yonzon and Hunter, 1991a; Wei et al., 1999; Pradhan et al. 2001). Our results show that PWS harbored comparatively congenial habitat conditions for red panda compared to that of KAS and FWS. This was further validated by a preliminary assessment made by Ghose et al. (2009) which shows that the probable extent of ideal red panda habitat at PWS was about 43.53 km², which rounds up to c. 34% of the Sanctuary. In comparison the tentative extent of red panda habitat for KAS and FWS were c. 0.72 km² and 5.73 km² respectively, and unlike PWS these forest patches are situated disjunctly interspersed by areas unsuitable for red pandas. Though we did not record single red panda evidence at FWS it would not suggest that red panda has gone extinct from here. During our survey we sampled FWS partially and to make a final comment on probable absence of red panda from this Sanctuary can only be made after a thorough survey is conducted to validate its existence here.

During our survey we recorded very high percentage of plots with red panda pellet groups between altitudinal levels >2800 m and 3100 m, which is represented by the mixed conifer forest type. High density of evidences at this altitudinal range has also been reported by Pradhan et al. (2001) and Williams (2004). The major tree species of this altitudinal range include *Rhododendron* sp., *Sorbus* sp., *Machilus* sp., *Magnolia* sp., *Abies* sp. among others.

Yonzon and Hunter (1991) and Pradhan et al. (2001) identified conifer forest as second major forest type preferred by the red pandas, next to mixed conifer forest. Our GIS assessments suggest that though this forest type is the second largest to be found in East District, our survey habitats did not support conifer forest too extensively. This hinders us from making exact assessments about how these habitat suites the red panda in comparison to mixed conifer and oak forest types. Our results, on contrary to the past studies (Yonzon et al. 1991; Pradhan et al. 2001), suggest that the oak forest is the second best habitat type suited for the red pandas, after mixed conifer forests. This difference in the outcome, to a great extent, must have been an influence of the fact that over 65% of the potential red panda habitat comprises of oak forest. Even the GIS analysis reveals the predominance of this forest type in the district too, suggesting that the oak forest is highly essential for housing a sizeable red panda population. The major plant species to be found in the oak forest included *Quercus* sp., *Castanopsis* sp., *Machilus* sp., *Michelia* sp., *Acer* sp., *Symplocos* sp. and *Rhododendron* sp.. During the survey we sighted red panda on six occasions out of which it has been photographed only four occasions.

Red pandas occupy dense bamboo forests (Yonzon and Hunter 1991; Pradhan et al. 2001). The importance of bamboo, being the essential component of an ideal red panda habitat, has also been reiterated in our study. Based on the assumption that the dense forests, with an understory of bamboo, are quintessential for red panda, Ghose et al. (2009) assessed the extent of dense red panda habitat for Sikkim. Following their finding it has been seen that about 50 km² of dense red panda habitat in East Sikkim fall within the three protected areas (see above for detail break up), which is only c. 32% of overall potential red panda habitat in East Sikkim. The extent of potential red panda habitat in East Sikkim thus falling outside the PA network is approximately 68%.

Conservation of red panda and its habitat in East Sikkim should involve implementation of management plans that would ensure – firstly, proper preservation of the habitats as red panda is a keystone species occurring a very narrow range of habitat conditions and therefore proper management approach devised to conserve the red panda habitat can not only help protect this iconic species but also would ensure protection for other wildlife sharing the same habitat; and, secondly it should also look into well being of the local community too. As a matter of fact to make conservation efforts more effective, village communities should be trained properly so that they can be involved in the efforts of conservation of red panda and its habitat.

Recommendations

Based on our observations in the field we forward the following recommendations for suitable conservation and management of red panda populations and its habitat in East District

1. **Habitat improvement -** In potential red panda habitat, where red panda presence has not been recorded in recent times, assisted regeneration of indigenous species that are suitable for red panda habitat might be carried out. In order to achieve that the vulnerable areas should be identified and subsequently ecoregion-wise plant species should be planted to improve the habitat conditions. Impetus has to be given to revive the dried water sources inside the forest as water is a critical habitat component for the red pandas and other critically endangered species like mainland serow (*Naemorhedus sumatraensis*), goral (*Naemorhedus goral*), musk deer (*Moschus chrysogaster*), Asiatic black bear (*Ursus thibetanus*) and others, that share the same habitat with the red panda.

2. **Feral dogs -** Have a MoU or agreement with Indian Army at the HQ or Command level to ensure that all new units comply to the regulations required for controlling feral dog populations. Obtaining baseline data on status and population

of feral dogs around red panda habitat is necessary followed by sensitisation of army personnel, as well as the community in forest fringes for controlling the population of these feral dogs.

3. **Sustainable livelihood for local communities -** Local communities may be encouraged to take up tourism measures in red panda habitat outside the PAs, where they could take small groups to show red panda habitats. However, this needs to be a high value, strictly controlled endeavor to ensure that this does not adversely affect red panda survival. People who, are dependent on red panda habitat for livelihood, may be assisted through available government schemes for alternative livelihood that does not adversely impact survival of red panda

4. **Re-introduction -** Potential red panda habitat where red panda has not been encountered recently may be taken up for re-populating through a combination of habitat improvement and wild to wild translocation. Captive to wild translocation could also be taken up with utmost care, and after complying with all relevant national and international guidelines about *ex-situ* conservation, re-population and related matters.

Himalayan Musk Deer at Chowkidara Phedi, Pangolakha Wildlife Sanctuary

5. **Targeted management -** Red panda shares its habitat with a host of highly endangered mammals and bird species such as - mainland serow (*Naemorhedus sumatraensis*), goral (*Naemorhedus goral*), musk deer (*Moschus chrysogaster*), Asiatic black bear (*Ursus thibetanus*), blood pheasant (*Ithaginis cruentus*), Himalayan monal (*Lophophorus impejanus*), satyr tragopan (*Tragopan satyra*), kalij pheasant (*Lophura leucomelanos*), etc. Hence a targeted management plan for red panda needs to be taken up at least for the PAs where this can serve as an umbrella species and enable us to provide protection to species sharing the same habitat.

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Table 1. List of tree species with altitudinal range recorded during the survey at three protected areas in East District, Sikkim

Species name		**Altitudinal Range (m)**										
Scientific name	**Local name**	**1800 - 2000**	**>2000 - 2200**	**>2200 - 2400**	**>2400 - 2600**	**>2600 - 2800**	**>2800 - 3000**	**>3000 - 3200**	**>3200 - 3400**	**>3400 - 3600**	**>3600 - 3800**	**>3800 - 4000**
Machilus edulis		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Acer laevigatum		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Neonauclea griffithii		0.0000	0.0258	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Symplocos spicata		0.0000	0.0000	0.0000	0.0000	0.0523	0.0286	0.0000	0.0000	0.0000	0.0000	0.0000
Nyssa javanica		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Symplocos sp.		0.1300	0.1574	0.2352	0.1229	0.2729	0.0646	0.0000	0.0000	0.0000	0.0000	0.4242
Ilex sp.		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rhododendron fulgens		0.0000	0.0263	0.1297	0.5401	0.9442	0.5174	1.6651	0.1410	0.0725	0.0000	0.0000
Maesa sp.		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Lati-Kath	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Amoora wallichii		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Myrsine semiserrata		0.0000	0.0000	0.0000	0.0000	0.0000	0.0577	0.0000	0.0000	0.0000	0.0000	0.0000
Quercus lamellosa		0.4899	0.3986	0.0455	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1028	0.8642
Machilus sp.		0.3462	0.9011	0.2429	0.0758	0.0192	0.0308	0.0000	0.0000	0.0000	0.0000	0.0000
Eurya sp.		0.0000	0.0000	0.1215	0.0213	0.0113	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Lekh Chipleypat	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Acer sp.		0.1412	0.0274	0.0407	0.0000	0.0768	0.0136	0.0000	0.0000	0.0484	0.0000	0.4504
Castanopsis hystrix		0.2450	0.1451	1.2521	1.0132	0.5639	0.0335	0.0000	0.0000	0.0000	0.0000	0.0000
	Lekha	0.0000	0.0000	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Evodia meliaefolia		0.2450	0.0797	0.0123	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Abies sp.		0.0000	0.0000	0.0116	0.0000	0.0000	0.0666	1.3698	0.9575	0.7309	0.9762	0.0000
Michelia sp.		0.0000	0.0000	0.0430	0.0274	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Brassaiopsis sp.		0.0000	0.0000	0.0061	0.0504	0.0938	0.1146	0.0000	0.0000	0.0000	0.0000	0.0000
Cinnamomum zelynicum		0.0000	0.0000	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Acer pectinatum		0.0000	0.0000	0.0000	0.0274	0.0000	0.0987	0.0000	0.0000	0.0000	0.0000	0.0000
Pentapanax sp.		0.0000	0.0000	0.0061	0.0622	0.0220	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rhododendron arboreum		0.0000	0.0000	0.0017	0.0211	0.0248	0.0140	0.0764	0.0000	0.0000	0.0000	0.0000
Betula sp.		0.0000	0.0000	0.0000	0.0311	0.0618	0.7286	0.8262	0.0000	0.0721	0.1187	0.0000
Rhododendron sp.		0.0000	0.0249	0.0122	0.0798	0.1622	0.1145	0.0000	0.3671	0.5731	0.4403	0.0000
Juniperus sp.		0.0000	0.0000	0.0000	0.0000	0.0000	0.0555	0.0000	0.1490	0.2090	0.2869	0.0000
Quercus pachyphylla		0.0000	0.0000	0.0000	0.0800	0.0374	0.0136	0.0000	0.0000	0.2324	0.0000	0.0000
Quercus thomsonian		0.0000	0.0000	0.0000	0.0214	0.0000	0.0335	0.0000	0.0000	0.0000	0.0000	0.0000
	Paasi	0.0000	0.0000	0.0067	0.0000	0.0000	0.0152	0.0000	0.0000	0.0200	0.0723	0.0000
	Seti Kaath	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2344	0.0000	0.0000
Prunus sp.		0.0000	0.0000	0.0000	0.0000	0.0000	0.0278	0.0000	0.0000	0.0000	0.0000	0.0000
*Magnolia*sp.		0.0000	0.0000	0.0000	0.0000	0.0000	0.0248	0.0000	0.0000	0.0000	0.0000	0.0000
Andromeda sp.		0.0000	0.0784	0.0185	0.0000	0.0000	0.0587	0.0000	0.6654	0.2474	0.3043	0.0000
Lithocarpus sp.		0.0000	0.0573	0.0128	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0891	0.0000
Cryptomeria japonica		0.0000	0.0803	0.0310	0.0214	0.0123	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Garuga sp.		0.0000	0.0322	0.0247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5111
Alnus sp.		0.0898	0.0094	0.0247	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rhus grifithii		0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Edospermum sp.		0.0000	0.0027	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cupressus sp.		0.0000	0.0816	0.0063	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Eleocarpus sp.		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Quercus lineata		0.1939	0.0800	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Echinocarpus sp.		0.2753	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ficus nemoralis		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Xanthoxylum sp.		0.0000	0.0000	0.0061	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2. Habitat variables summarized by principal component analysis results and correlation between original variables and extracted components

	Principal components							
	1	2	3	4	5	6	7	8
Eigenvalues	3.864	3.267	1.804	1.687	1.417	1.262	1.126	1.023
Habitat Variables	**Correlations**							
Bamboo detection	0.8375	0.1022	-0.1361	0.1110	-0.0621	0.0056	0.0407	-0.0775
Total bamboo cover	0.8310	0.0361	-0.1146	0.1396	-0.1020	0.0445	0.1103	-0.0604
Birch/Fir forest	-0.6559	0.1460	0.5846	0.0380	0.1450	-0.0285	0.1286	-0.2204
Shrub cover	-0.6318	-0.1675	-0.2273	-0.1110	-0.3325	-0.0242	0.0139	0.1403
Moderate slope	0.0748	0.9284	0.0776	0.0121	0.0199	0.0895	-0.1852	-0.0058
Gentle slope	-0.0944	-0.9237	-0.0447	-0.0366	-0.0397	-0.1096	-0.1758	0.0235
Herb cover	-0.2062	0.0073	0.7485	-0.0270	-0.0817	0.0004	-0.1485	-0.0136
Scrub forest	-0.1281	-0.1118	0.6151	0.0575	-0.0383	0.0623	-0.0083	0.3409
State of water body	0.2517	0.3090	0.5533	-0.0895	0.2234	0.0396	0.0747	0.0238
Open forest	0.2189	-0.0362	-0.0688	0.8862	0.0331	-0.2471	0.0744	-0.0590
Dense forest	-0.1345	-0.0140	-0.1342	-0.8248	-0.0191	-0.4558	-0.0662	-0.0596
Conifer forest	-0.1882	0.3193	-0.2300	0.4249	0.1220	0.0019	-0.3370	0.0183
Mixed conifer forest	0.1647	-0.0805	-0.1727	-0.0501	0.8951	-0.0049	0.0418	0.0392
Oak forest	0.4662	-0.1772	-0.2487	-0.1652	-0.7886	-0.0019	0.0302	-0.0243
Elevation	-0.4640	0.3129	0.4437	0.2369	0.5237	0.1368	0.0452	0.0498
Degraded forest	-0.1128	0.2671	-0.1209	-0.0753	-0.0345	0.7983	0.1294	0.1815
Tree cover	-0.2327	-0.1245	-0.3867	-0.4642	-0.0662	-0.6841	-0.0160	-0.0826
Thicket forest	0.1374	-0.2485	0.0948	-0.0876	0.0775	0.4963	-0.2808	-0.4423
Steep slope	0.0501	0.0042	-0.0803	0.0610	0.0493	0.0514	0.8918	-0.0439
Birch/rhododendron forest	-0.0681	-0.0432	0.1429	-0.0221	0.0713	0.1376	-0.0834	0.8219

Table 3. Logistic regression result showing predictor variables having significant effect on red panda distribution across three protected areas

Variables	**B**	**Wald**	**df**	***P***	**Odds ratio**
Bamboo detection	1.386	6.352	1	0.012	3.999
Total bamboo cover	0.024	12.410	1	0.000	1.024
Gentle slope	1.162	3.328	1	0.068	3.195
Moderate slope	1.554	5.803	1	0.016	4.730
Dense forest	-0.242	0.337	1	0.561	0.785
Open forest	0.006	0.000	1	0.989	1.006
Intercept	-2.962	14.871	1	0.0001	0.0517

AUTHORS:

Partha S. Ghose
WWF-India, Khangchendzonga Landscape Programme,
Deorali, Near Forest Secretariat,
Gangtok – 737102. Sikkim, India.
Email : ghose.ps1@gmail.com
Mobile: +919775873293
(Corresponding author)

Basant K. Sharma
WWF-India, Khangchendzonga Landscape Programme,
Deorali, Near Forest Secretariat,
Gangtok – 737102. Sikkim, India.

Rajarshi Chakraborty
WWF-India, Khangchendzonga Landscape Programme,
Deorali, Near Forest Secretariat,
Gangtok – 737102. Sikkim, India.

Karma Legshey D.
Wildlife (East Division), Forest Environment and
Wildlife Management Department,
Government of Sikkim,
Forest Secretariat,
Deorali, Gangtok 737102, Sikkim, India


Bamboo presence and cover are an essential habitat feature to support Red Panda population

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