

Updated distribution and habitat use by endangered Himalayan red panda (*Ailurus fulgens* Cuvier, 1825) in Bhutan

Pema Dendup^{1*}, Ugyen Ugyen², Rinzin Dorji³ and Choki Lham¹

¹Jigme Dorji National Park, Department of Forests and Park Services, Ministry of Energy and Natural Resources, Royal Government of Bhutan, Bhutan

²Jigme Khesar Strict Nature Reserve, Department of Forests and Park Services, Ministry of Energy and Natural Resources, Royal Government of Bhutan, Bhutan

³Gedu Forest Division, Department of Forests and Park Services, Ministry of Energy and Natural Resources, Royal Government of Bhutan, Bhutan

*Corresponding author ✉: pemadndp@gmail.com

Citation: Dendup, P., Ugyen, U., Dorji, R. and Lham, C. (2023). Updated distribution and habitat use by endangered Himalayan red panda (*Ailurus fulgens* Cuvier, 1825) in Bhutan. *Journal of Animal Diversity*, 5 (1): 55–64. <http://dx.doi.org/10.61186/JAD.5.1.55>

Abstract

The Himalayan red panda *Ailurus fulgens* F. Cuvier (family Ailuridae) is a carnivore that feeds mainly on bamboo leaves and shoots. Habitat loss, fragmentation, degradation, and poaching are some of the major threats to the red panda population. In Bhutan, *Ailurus fulgens* is reported from within and outside protected areas; however, only a few studies (distribution, threats, and habitat correlates) have been carried out, and much remains unknown about this species. Herein, we report information on the updated distribution, habitat use, and activity pattern from by-catch images of *A. fulgens* occurrence from both systematic camera traps set for a country-wide tiger *Panthera tigris* (Linnaeus) survey (2014–2015) and other surveys during 2015–2021 from different parks and forest divisions. *Ailurus fulgens* was found to occur in 19 out of 20 districts in Bhutan. Regarding protected areas, they were found in eight out of eleven protected areas (Wangchuck Centennial, Jigme Dorji, Jigme Singye, Phrumsengla National Park, Bumdeling and Sakteng Wildlife Sanctuary, Jigme Kheser Strict Nature Reserve, and Royal Botanical Park) and five out of eight biological corridors (connecting Phibsoo Wildlife Sanctuary to Jigme Singye National Park, Wangchuck Centennial National Park to Jigme Singye National Park, Phrumsengla National Park to Jigme Singye National Park, Phrumsengla National Park to Bumdeling Wildlife Sanctuary, and Sakteng Wildlife Sanctuary to Jomotsangkha Wildlife Sanctuary). The majority of *A. fulgens* were recorded in broadleaf forest followed by mixed conifer forest and were found to be distributed at elevations between 1,520–4,331 m (mean 3,131 m). Red pandas displayed higher use of habitats including cool broadleaf and mixed conifer forests. The activity pattern of *A. fulgens* showed that they were mostly diurnal, with peak activities taking place between 10:00–11:00 hours.

Received: 29 November 2022

Accepted: 9 March 2023

Published online: 31 March 2023

Key words: Activity pattern, *Ailurus fulgens*, Bhutan, camera trapping, endangered, habitat use

Introduction

Most wildlife species are shy and elusive and inhabit areas far from human settlement. Studying such elusive wildlife species is challenging due to time, cost, and

methodological constraints. The challenge is further aggravated when the species of interest inhabit mountainous terrain within a largely rugged, inaccessible landscape and with low population density.

Camera traps are increasingly used for wildlife investigation and monitoring and are considered the best technique to study elusive species (Karanth and Nichols, 1998; Silver et al., 2004; Galvis et al., 2014; Agha et al., 2018). Camera trap technology was designed for the study of wildlife and has been considered a non-invasive technique since the 20th century (Chapman, 1927; O'Connell et al., 2011). In Bhutan, camera traps have been widely used to study felids from snow leopards *Panthera uncia* (Schreber, 1775) in the mountains to tigers (*Panthera tigris*) in the lowlands (Tempa et al., 2011; DoFPS, 2015; Lham et al., 2021; Dendup et al., 2023). These camera trap studies have detected species that were not recorded before. A recent example demonstrating the use of camera traps is the photo capture of both snow leopard and Royal Bengal tigers in one location (Dendup and Lham, In Press).

The Himalayan red panda (hereafter red panda) (Fig. 1) is distributed across Nepal, Bhutan, northern India, northern Myanmar, Tibet, and the western Yunnan Province of China (Hu et al., 2020). Due to its declining population as a result of habitat loss, fragmentation, degradation, and poaching (Yonzon and Hunter, 1991; Wei et al., 1999; Pradhan et al., 2001; Glatston et al., 2015; Bista et al., 2017; Dendup et al., 2020), the red panda is included in Schedule I of the Forest and Nature Conservation Act (1995) of Bhutan (MoA, 1995) and is designated as Endangered in the IUCN Red List of Threatened Species (Glatston et al., 2015). It is an indicator species for eastern Himalayan broadleaf and conifer forest and to ensure its population survival, special conservation efforts are required (Williams, 2006).

A range-wide ecological modelling study has shown that the red panda occurs in evergreen forests, mixed broadleaf forests, deciduous forests, and conifer forests with bamboo understories (Yonzon et al., 1991; Wei et al., 1999; Thapa et al., 2018). The presence of red pandas in alpine meadows was also reported within the Pangchen Lumpo Muchat Community Conserved Area in the Tawang District of western Arunachal Pradesh, India (Dorjee et al., 2014). In Bhutan, red pandas are reported to occur in fir forests, mixed conifer, and cool broadleaf forests (Dorji et al., 2011, 2012; Dendup et al., 2016, 2018, 2020). Recently, field offices across Bhutan carried out numerous research works and occurrences of red pandas have now been reported from areas where there were no previous records.

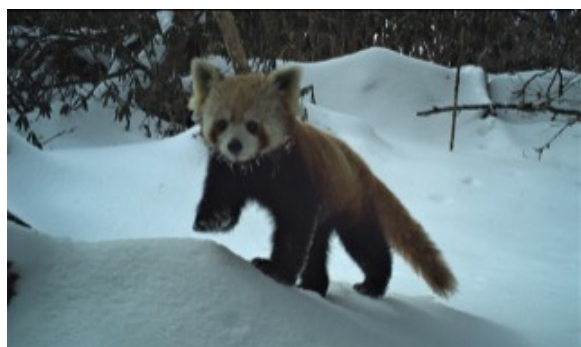


Figure 1: The Himalayan red panda *Ailurus fulgens*. © Jigme Dorji National Park, 2021.

Deployment of extensive camera traps in the field can generate much information on terrestrial mammal species besides capturing the target species (Sangay et al., 2014; Scotson et al., 2017). Though red pandas are primarily arboreal, red pandas are also found on forest floors, especially during the winter months when searching for mates, foraging, and drinking (Pradhan et al., 2001). Photo-capturing red pandas can provide critical information and help conservation managers establish strategic management interventions. This study aimed to enhance our understanding of the updated red panda distribution, habitat use, and activity pattern in Bhutan to help conservationists with informed conservation planning for this endangered species.

Material and Methods

Study area

Bhutan, with an area of 38,394 km², is a small country landlocked between the Tibetan Autonomous Region (China) in the north and India in the south, east, and west (NSB, 2022). The country is mountainous with steep terrain, narrow river valleys, and deep gorges with nearly 95% of its area located >600 m (NSB, 2022). The altitude ranges from 80 m in the south to above 7,500 m in the north (Tempa et al., 2011; Dendup et al., 2021). The country has six distinct forest types including tropical forest (<1,000 m), subtropical forest (1,000–2,000 m), warm temperate forest (2,000–2,500 m), cool temperate forest (2,500–3,000 m), subarctic/cold temperate forest (3,000–4,000 m), and rhododendron scrub (>4,000 m) and the presence of bamboos has been recorded in areas to cold temperate forests (Ohsawa (1987). The country has a forest cover of 70.8% of the total geographic area (FRMD, 2017) with four distinct seasons (summer: June–August, autumn: September–November, winter: December–February, and spring: March–May). The wet season occurs between July–September, with precipitation ranging from <1,400 to 7,665 mm and mean temperature ranging from –20 to 30 °C (Dorji et al., 2015).

Due to Bhutan's location at the juncture of two biogeographical realms, the Oriental and the Sino-Japanese (Holt et al., 2013), Bhutan has a rich biodiversity. More than 5,600 species of vascular plants, >740 species of birds, and 160 mammal species have been recorded (MoA, 2009). Some other mammal species besides the red panda occurring in Bhutan are the tiger (*Panthera tigris*), leopard *Panthera pardus* (Linnaeus, 1758), snow leopard (*Panthera uncia*), takin (*Budorcas taxicolor* Hodgson, 1850), Asian elephant (*Elephas maximus* Linnaeus, 1758), golden langur *Trachypithecus geei* (Khajuria, 1956), Himalayan black bear (*Ursus thibetanus* G. Cuvier, 1823), and Asiatic wild dog *Cuon alpinus* (Pallas, 1811). Bird species such as the white-bellied heron (*Ardea insignis* Hume, 1878), rufous-necked

hombill *Aceros nipalensis* (Hodgson, 1829), black-necked crane (*Grus nigricollis* Prjevalsky, 1876), beautiful nuthatch (*Sitta formosa* Blyth, 1843), and Ward's trogon *Harpactes wardi* (Kinnear, 1927) are recorded. The vegetation type varies from subtropical broadleaf forest in the south to alpine scrubs and meadows in the north (FRMD, 2017). The mean human population density is 19.89 per km² and the country's total population is 763,249 (NSB, 2022).

The country-wide camera trapping exercise for the national tiger survey was conducted in Bhutan between March 2014 to March 2015. The entire country area was divided into 1,522 5 × 5 km² grids which were used to guide the placement of camera traps. At each station, a pair of cameras were placed and mounted on a pole/tree 45 cm above the ground and 2.0–2.5 meters away from the trail. Six camera models were used: Bushnell, Cuddeback, HCO ScoutGuard, Reconyx, U-Way, and Panthera. At an interval of 30 days, camera monitoring was carried out to replace batteries and memory cards, clear bushes, and retrieve data.

Additional information on red panda presence was collected from national parks and forest divisions involved in the camera trap survey that captured red pandas (n= 9). We also used data on red pandas that were reported while rangers were on patrol. Data collected were mainly the location points of red panda presence evidence such as direct sightings and dung (n= 56).

The images of red pandas captured in the camera traps were used to analyze the spatial distribution of red pandas in protected areas (PAs) and districts. Camera trap pictures were managed using Camera Trap File Manager v.2.1.6.

The habitat selection ratio (use/availability) was calculated to understand which habitats were more or less used. The selection ratio (SR) for habitat *i*, is defined as follows:

$$SR_i = (P_i^U / P_i^A)$$

where P_i^U is the proportion of habitat *i* in the set of used locations, and P_i^A is the proportion of habitat *i* in the set of available locations when availability is estimated using random locations. Ratios >1.0 indicate a positive selection (preference) and those <1.0 indicate a negative selection (avoidance) (Manly et al., 2002; Aho and Bowyer, 2015). The red panda location points were used to extract altitude and used habitat type from Land Use and Land Cover (LULC) (2016) data (30 m resolution) of Bhutan (FRMD, 2017) using ArcGIS v.10.3 (ESRI, Redlands, California, USA). The available habitat type was selected using a 200 m buffer from the red panda presence location in LULC (2016) and the LULC (2016) is the only available dataset for the country. We chose 200 m as the buffer because the median daily distance travelled by red pandas was 756 m

(Bista et al., 2021). We concluded that from the point of red panda evidence (dung) a 200 m buffer would be best to be included as an available habitat. The differences in the habitat selection ratio were also tested using a paired *t*-test in R v. 3.5.1 (R Development Core Team, 2018).

The activity time of each independent event per species was classified into three categories based on the classifications made by Dou et al. (2019). The categories were crepuscular (05:01–7:00 and 15:44–17:43 hours), diurnal (07:01–15:43 hours), and nocturnal (17:44–05:00 hours). Species activity patterns were then classified into crepuscular (~50% of detections during the crepuscular phase), diurnal (<10% of detections in the night), nocturnal (>90% of detections in the night), mostly diurnal (10–30% of detections in the night), mostly nocturnal (70–90% of detections in the night) and cathemeral (the rest of the detections) (Gomez et al., 2005; Jimenez et al., 2010; Ross et al., 2013). We used one-way ANOVA (R v.3.5.1) to study whether there was a significant difference between means of activity pattern (crepuscular, diurnal, and nocturnal). The results of one-way ANOVA were further tested using Tukey's HSD post-hoc test.

Results

From the combined data, we obtained 928 images of red pandas in 71 camera locations across Bhutan. A total of 750 images were obtained during the country-wide tiger survey from 62 camera stations and 178 images from other surveys in 9 camera stations.

The red pandas in Bhutan were distributed in 19 out of 20 districts (i.e., all except Pemagatshel district) (Fig. 2).

Within protected areas, red pandas were found in four national parks, Wangchuck Centennial, Jigme Dorji, Jigme Singye, and Phrumsengla National Park; two wildlife sanctuaries, Bumdeling and Sakteng Wildlife Sanctuary; one strict nature reserve, Jigme Kheser Strict Nature Reserve; and one botanical park, Royal Botanical Park. Red pandas were also found in five biological corridors (BCs) including those connecting Phibsoo Wildlife Sanctuary to Jigme Singye National Park, Wangchuck Centennial National Park to Jigme Singye National Park, Phrumsengla National Park to Jigme Singye National Park, Phrumsengla National Park to Bumdeling Wildlife Sanctuary, and Sakteng Wildlife Sanctuary to Jomotsangkha Wildlife Sanctuary (Fig. 3).

The 127 location points (62 tiger camera locations, 9 other survey camera locations, and 56 red panda dung locations) indicated red panda use of 10 different types including alpine scrub (0.8%), blue pine (2.4%), cool broadleaf (36.2%), fir (11.8%), meadows (2.4%), mixed conifer (37.8%), and shrubs (6.3%); however, three red panda locations (2.4%) were near built-up areas and therefore removed from the analysis.

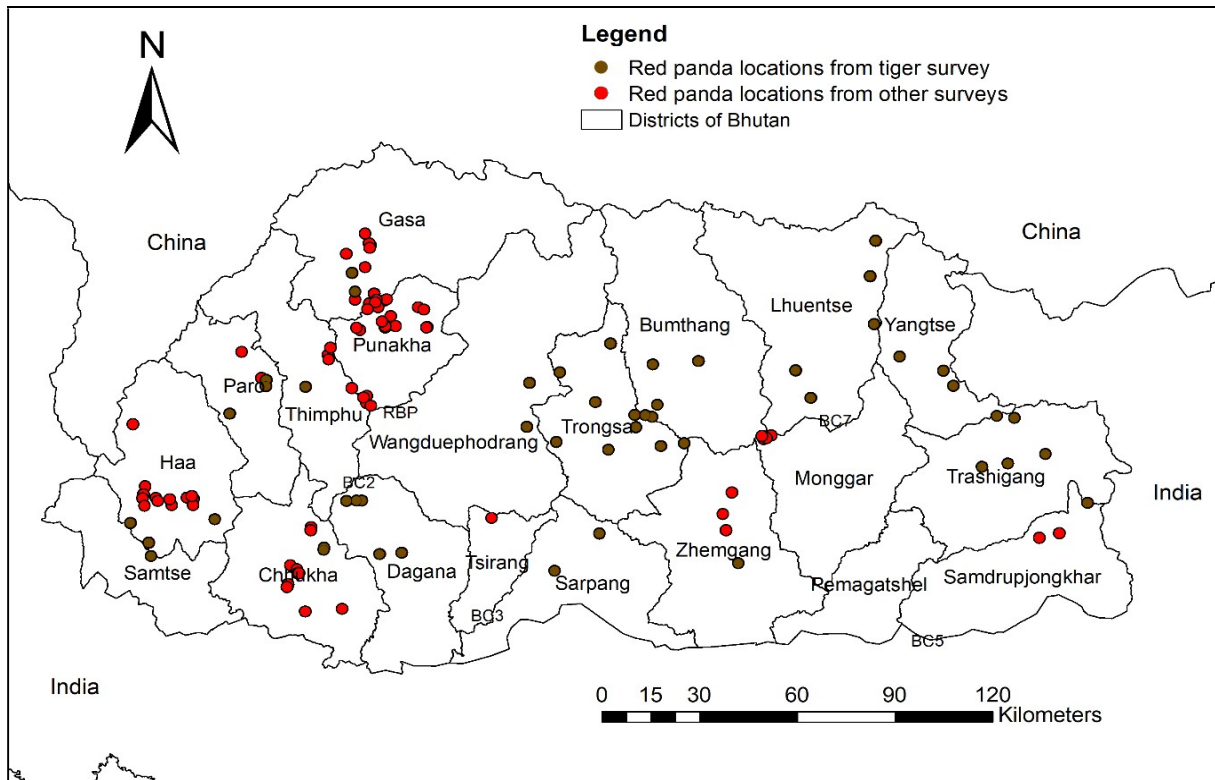


Figure 2: Distribution of red pandas in Bhutan. Brown dots represent red pandas photo captured during the country-wide tiger survey (2014–2015) and red dots represent red pandas reported from other surveys (2015–2021).

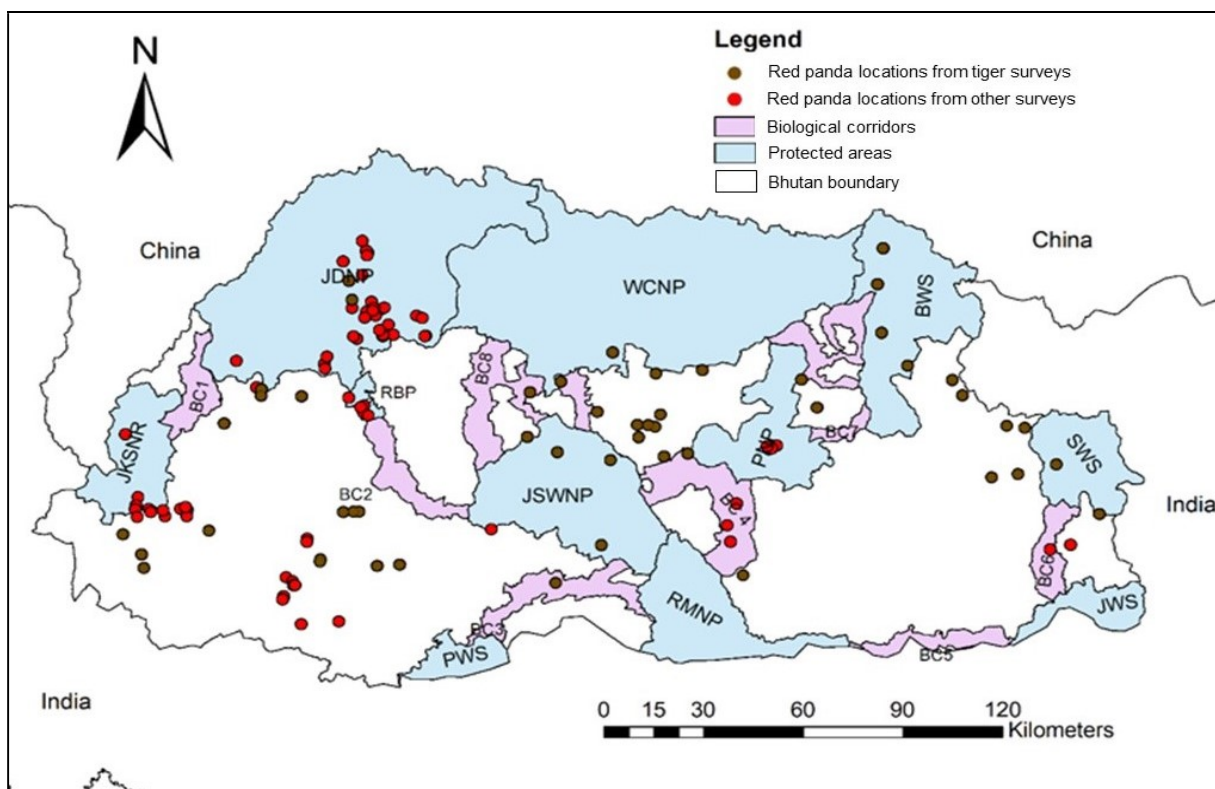


Figure 3: Red panda occurrence in protected areas (blue) and biological corridors (light pink) of Bhutan. JDNP: Jigme Dorji National Park, WCNP: Wangchuck Centennial National Park, JSWNP: Jigme Singye Wangchuck National Park, RMNP: Royal National Park, PNP: Phrumsengla National Park, BWS: Bomdelling Wildlife Sanctuary, SWS: Sakteng Wildlife Sanctuary, JWS: Jomotsangkha Wildlife Sanctuary, PWS: Phibsoo Wildlife Sanctuary, JKSNR: Jigme Khesar Strict Nature Reserve, RBP: Royal Botanical Park.

Red pandas were found to use cooler broadleaf forests followed by mixed conifer forests (Tables 1 and 2, Fig. 4). However, there was no significant difference in the habitat preference over used and available habitats (paired *t*-test, $t = -1.376$, $df = 6$, $p = 0.218$). Red pandas were found distributed between 1,520–4,331 m with the majority between 2,895–3,394 m (Fig. 4).

We used independent detections to evaluate the red panda temporal activity pattern. The activity pattern indicated that red pandas were mostly diurnal, with peak activity between 10:00–11:00 hours (Table 3, Fig. 5).

However, one-way ANOVA results indicated no significant difference in the activity patterns of red pandas ($F_{2,73} = 0.627$, $p = 0.540$) (Fig. 6).

Discussion

The present study revealed the occurrence of red pandas from nineteen of twenty districts, eight PAs, and five BCs. The previous research conducted in Bhutan reported the occurrence of red pandas in thirteen districts, eight PAs, one botanical park, and four BCs (Dorji et al., 2012; Letro et al., 2022). The distribution of red pandas in Bhutan was confined for habitats such as mixed conifer, fir, and cool broadleaf forests (Dorji et al., 2012; Dendup et al., 2016; Dendup et al., 2018; Dendup et al., 2020). In addition to these habitat types, the present study unveiled alpine scrub, meadows, blue pine, and shrubs as

habitats used by red pandas. Red pandas were also recorded near human settlements; however, red pandas were found to use more cool broadleaf followed by mixed conifer forests. The detection of red pandas in more habitat types may be due to the coverage of a more comprehensive survey area across the country. The previous studies were confined to a few PAs or districts. Other studies in Bhutan and the region revealed that red pandas prefer habitats such as mixed conifer and fir with bamboo understory (Dorji, 2012; Chakraborty et al., 2103; Bhatta et al., 2014; Dendup, 2016; Dendup, 2020). The altitude range of the red panda was reported from 2,860–4,389 m (Dorji et al., 2012; Dendup et al., 2016). Our findings report the occurrence of red pandas as low as 1,520–4,331 m. The recording of red pandas >4,000 and <2,000 m may be attributed to the availability of bamboo and intact habitats. Choudhury (2001) reported red panda presence in areas 1,500–4,800 m and almost up to the summer snowline at 5,000 m. In Meghalaya, India, red pandas were recorded at elevations from 700–1,400 m and both recordings were attributed to favorable habitat type and bamboo availability (Choudhury, 1997; 2001). Red panda occurrence was high in the altitude range of 2,895–3,394 m and declined at higher elevations, and this result is similar to the findings of Sharma and Belant (2009). The combined information from Dorji et al. (2012) and the present study now suggest that red pandas in Bhutan can be found in an altitudinal range of 1,520–4,389 m.

Table 1: Himalayan red panda *Ailurus fulgens* occurrence in districts, habitat types, and altitude ranges in Bhutan (source: FRMD, 2017).

Sl. #	District	Habitat types	Altitude range (m)
1	Bumthang	Fr, BP, MC	3,096–3,971
2	Chukha	MC	2,450–3,647
3	Dagana	CBL, Mea, MC	1,816–3,833
4	Gasa	CBL, MC, Shr, Fr	2,411–3,537
5	Haa	CBL, MC, Shr, Fr	2,319–3,682
6	Lhuentse	CBL, Fr	2,072–3,524
7	Monggar	MC, Fr	3,354–3,581
8	Paro	BP, MC, Mea	2,672–4,216
9	Punakha	CBL, MC	2,597–3,453
10	Samdrup Jongkhar	CBL	2,157–2,957
11	Samtse	CBL	1,900–2,504
12	Sarpang	CBL	2,027–2,374
13	Thimphu	MC, BP	3,127–3,640
14	Tashigang	Shr, Fr, CBL, MC	2,900–3,248
15	Trongsa	AS, CBL, Mea, MC, Shr	1,533–4,325
16	Tsirang	CBL	2,000–2,500
17	Wangdue Phodrang	MC, Fr	3,636–3,740
18	Tashi Yangtse	CBL, Fr	2,915–3,840
19	Zhemgang	CBL	1,520–3,700

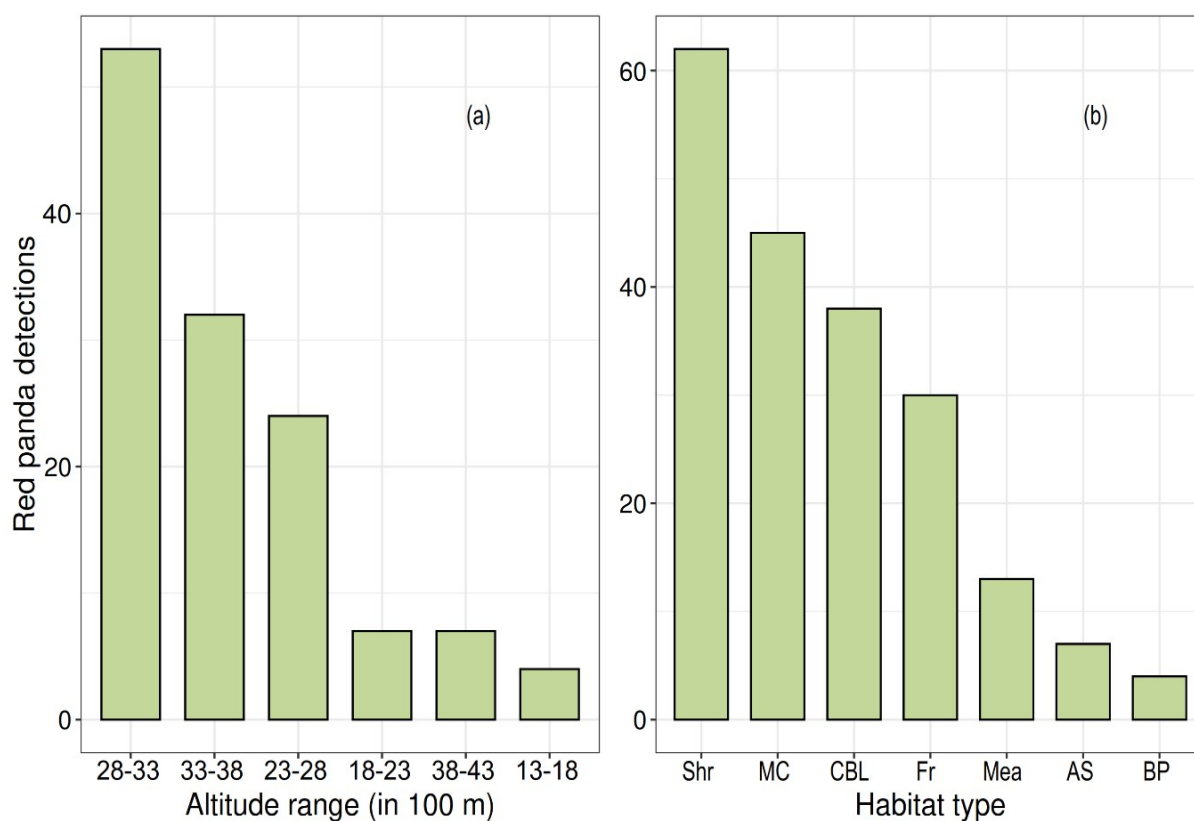
AS: alpine scrub, CBL: cool broadleaf, MC: mixed conifer, Fr: fir, BP: blue pine, Mea: meadow, Shr: shrub.

Table 2: Habitat preference ratio of red panda *Ailurus fulgens* in Bhutan.

Habitat type	Used	Availability	Ratio
Fir	15	30	0.8
Mixed conifer	48	45	1.7
Alpine scrub	1	7	0.2
Cool broadleaf	46	38	1.9
Meadow	3	13	0.4
Blue pine	3	4	1.2
Shrub	8	62	0.2

Table 3: Activity period of the red panda *Ailurus fulgens* based on the number of detections recorded by camera traps in Bhutan (2014–2021).

Number of detections	Diurnal 07:01–15:43	Nocturnal 17:44–05:00	Crepuscular 05:01–07:00 15:44–17:43	Category
928	62.39%	22.37%	10.23%	Mostly Diurnal

**Figure 4:** The occurrence of red pandas (a) across different altitudinal ranges (in 100 m) and (b) in different habitat types in Bhutan. Shr: shrub, MC: mixed conifer, CBL: cool broadleaf, Fr: fir, Mea: meadow, AS: Alpine scrub, BP: blue pine

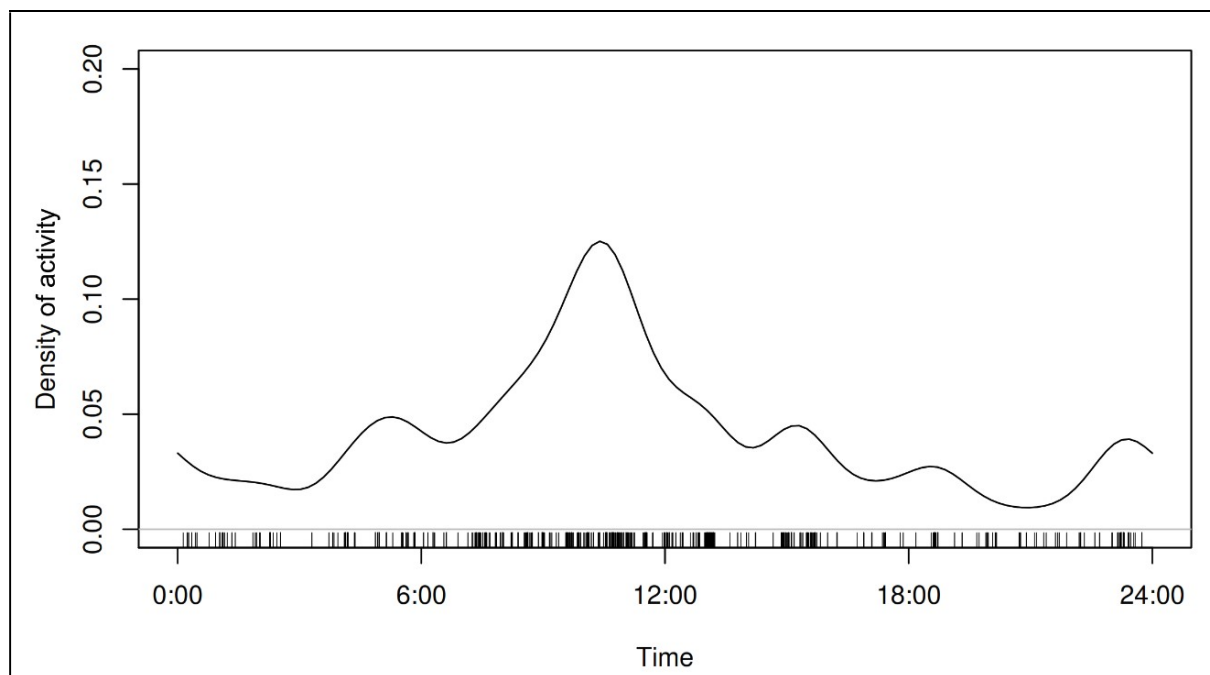


Figure 5: Activity pattern of Himalayan red panda *Ailurus fulgens* in Bhutan, indicating peak activity at around 10:00–11:00 hours.

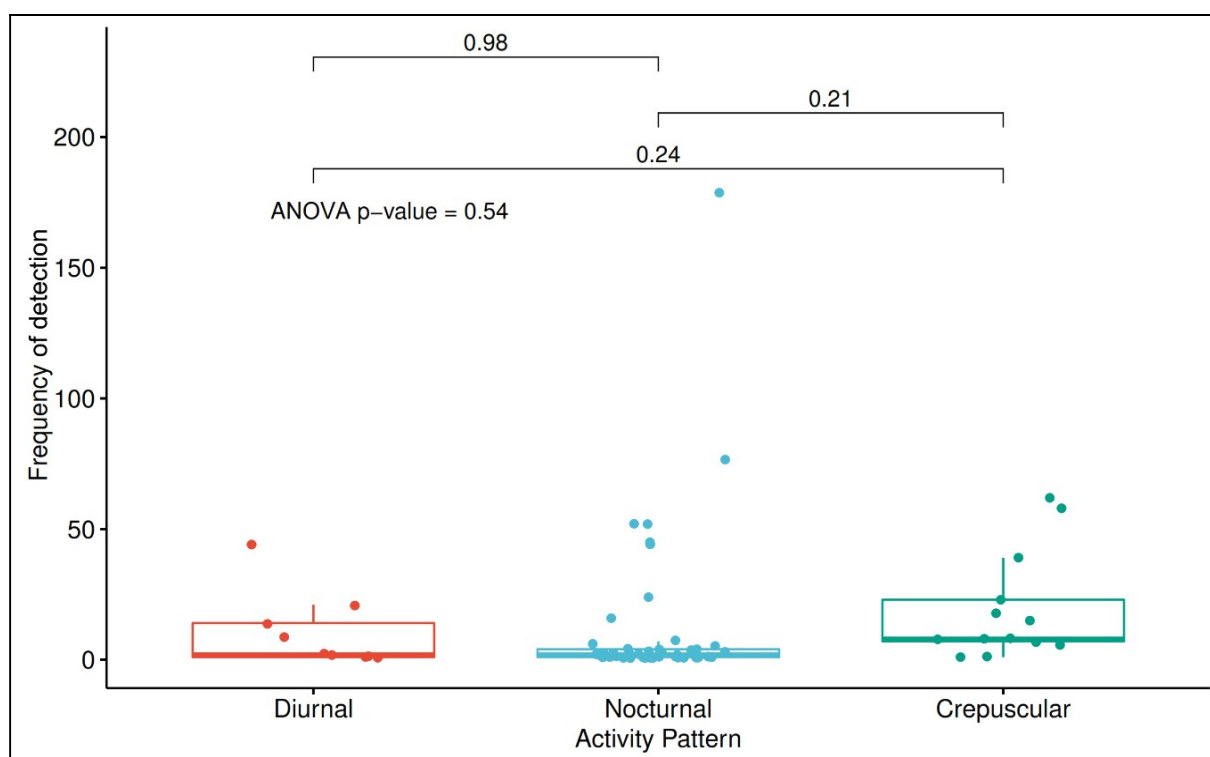


Figure 6: One-way ANOVA and Tukey's HSD results indicate a non-significant difference in the activity pattern of the red panda *Ailurus fulgens*.

The activity pattern of the red panda in our study differed from Roberts and Gittleman (1984) and Johnson et al. (1988), which suggested that the red panda has crepuscular and nocturnal behavior. Our findings indicated that red pandas are mostly diurnal. The depicted diurnal activity patterns may be

attributed to the time of the study as majority (62%) of camera traps were conducted in winter. Winter is the mating season and so red pandas may move around more actively during the day to find a mate, forage, drink, and search for a new home range. Other possibilities are that they may be in search of

high-quality habitat and or engaging in predator avoidance (Dendup et al., 2016; Bista et al., 2022). Alternatively, the red panda displaying mostly diurnal activity patterns could be due to the duration allocated to conclude such a pattern. While the diurnal activity pattern is calculated over 8.75 hours, nocturnal is allocated 11.25 hours, and crepuscular only 4.00 hours (Gomez et al., 2005; Jimenez et al., 2010; Ross et al., 2013).

This study reveals a broad understanding of spatial distribution (with altitude in protected areas and districts), habitat use, and activity pattern of the endangered Himalayan red panda in Bhutan. Our results, such as spatial distribution, habitat use, and activity pattern, are largely novel to red panda conservation in Bhutan and the region. On a global level, the activity pattern shown by our study is different from other studies (Bista et al., 2021). The results of such a study may vary according to the region or location; nevertheless, such aspects could be best studied using radio-telemetry techniques in combination with extensive camera traps. The use of extensive camera traps has the further potential to record red pandas from Pemagatshel district, BC1, and BC2 because the elevation range and habitat types are the same as other districts and BCs with red pandas.

Acknowledgements

We would like to thank Sonam Wangdi (Nature Conservation Division) and Tandin (WWF Bhutan) for permitting us to use the red panda data obtained from the country-wide tiger survey. The following individuals of the Department of Forests and Park Services (DoFPS) and other agencies are especially thanked for sharing red panda occurrence information from the field: Jigme Dorji (Department of Tourism), Sherab Jamtsho (Jigme Khesar Strict Nature Reserve), Shacha Dorji (Tsirang Forest Division), Sangay Wangchuk (Ugyen Wangchuck Institute for Forestry Research and Training), Phub Dorji (Zhemgang Forest Division), Kesang Dorjee (Sakteng Wildlife Sanctuary), Damber Kumar Ghemirey (Jomotsangkha Wildlife Sanctuary), Sonam Wangchuk (Pemagatshel Forest Division), Thiney Wangchuk (Samdrup Jongkhar Forest Division), and Sonam Dorji (Paro Forest Division). We would also like to thank our colleagues at JDNF for sharing red panda occurrence points collected through Spatial Monitoring and Reporting Tool patrolling activity, particularly Bep Tshering, Kinley Tshering, Pema Kuenzang, Tashi, Bishnu Kumar Ghalley, and Yeshey Jamtsho. We express our heartfelt gratitude to Ugyen Thinley (College of Natural Resources) and Chimi Dema (Gyalpozhing College of Information Technology) for reviewing our manuscript. We would also like to thank the anonymous reviewers and editors for their critical comments and suggestions in improving this manuscript with special thanks to Dr. Erica DeMilio (Associate English Editor, Journal of Animal

Diversity) for English edits. Finally, we would like to thank all the staff of DoFPS who were involved during the country-wide tiger survey (2014–2015).

Author contributions

P.D. and C.L. conceived and designed the research. P.D., C.L., U.U., and R.D. performed the survey. P.D. analyzed the data. P.D., C.L., U.U., and R.D. wrote the draft and reviewed the article and P.D. wrote the final article.

Conflict of interest

All the authors declare that there are no conflicting issues related to this research article.

References

- Agha, M., Batter, T., Bolas, E. C., Collins, A. C., da Rocha, D. G., Monteza-Moreno, C. M., Preckler-Quisquater, S. and Sollmann, R. (2018). A review of wildlife camera trapping trends across Africa. *African Journal of Ecology*, 56 (4): 694–701. <https://doi.org/10.1111/aje.12565>
- Aho, K. and Bowyer, R. T. (2015). Confidence intervals for ratios of proportions; implications for selection ratios. *Methods in Ecology and Evolution*, 6: 121–132. <https://doi.org/10.1111/2041-210X.12304>
- Bhatta, M., Shah, K. B., Devkota, B., Paudel, R. and Panthi, S. (2014). Distribution and habitat preferences of red panda (*Ailurus fulgens fulgens*) in Jumla district, Nepal. *Open Journal of Ecology*, 4: 989–1001. <https://doi.org/10.4236/oje.2014.415082>
- Bista, D., Baxter G. S., Hudson, N. J., Lama, S. T., Weerman, J. and Murray, P. J. (2022). Space use, interaction and recursion in a solitary specialized herbivore: a red panda case study. *Endang Species Research*, 47: 131–143. <https://doi.org/10.3354/esr01171>
- Bista, D., Baxter, G. S., Hudson, N. J., Lama, S. T., Weerman, J. and Murray, P. J. (2021). Movement and dispersal of a habitat specialist in a human-dominated landscape: a case study of the red panda. *Movement Ecology*, 9 (62): 1–15. <https://doi.org/10.1186/s40462-021-00297-z>
- Bista, D., Shrestha, S., Sherpa, P., Thapa, G. J., Kokh, M., Lama, S. T., Khanal, K., Thapa, A. and Jnawali S. R. (2017). Distribution and habitat use of red panda in the Chutwan-Annapurna landscape of Nepal. *PLoS ONE*, 12 (10): 1–16. <https://doi.org/10.1371/journal.pone.0178797>
- Chakraborty, R., Nahmo, L. T., Dutta, P. K., Srivastava, T., Mazumdar, K. and Dorji, D. (2013). Status, abundance and habitat associations of red panda (*Ailurus fulgens*) in Pangchen valley, Arunachal Pradesh, India. *Mammalia*, 79 (1): 25–32. <https://doi.org/10.1515/mammalia-2013-0105>

- Chapman, F. M. (1927). *With a camera in tiger land*. Chatto and Windus, London, England.
- Choudhury, A. U. (1997). Red panda *Ailurus fulgens* F. Cuvier in the north-east with an important record from Garo hills. *Journal of the Bombay Natural History Society*, 94: 145–147.
- Choudhury, A. U. (2001). An overview of the status and conservation of red panda *Ailurus fulgens* in India, with reference to its global status. *Oryx*, 35 (3): 250–259. <https://doi.org/10.1046/j.1365-3008.2001.00181.x>
- Dendup, P. and Lham, C. (In Press). The photographic evidence suggests habitat overlap and co-occurrence of tigers and snow leopards in Jigme Dorji National Park, Bhutan. *Oryx*, (In Press).
- Dendup, P., Cheng, E., Lham, C. and Tenzin, U. (2016). Response of red panda *Ailurus fulgens fulgens* (Cuvier, 1825) to anthropogenic disturbances and its distribution in Phrumsengla National Park, Bhutan. *Oryx*, 51 (4): 1–8. <https://doi.org/10.1017/S0030605316000399>
- Dendup, P., Humle, T., Bista, D., Penjor, U., Lham, C. and Gyeltshen, J. (2020). Habitat requirements of the Himalayan red panda (*Ailurus fulgens*) and threat analysis in Jigme Dorji National Park, Bhutan. *Ecology and Evolution*, 10: 9444–9453. <https://doi.org/10.1002/ece3.6632>
- Dendup, P., Lham, C., Wangchuk, J. and Tshering, K. (2018). Winter habitat preferences of endangered red panda (*Ailurus fulgens*) in the forest research preserve of Ugyen Wangchuck Institute for Conservation and Environmental Research, Bumthang, Bhutan. *Journal of Bhutan Ecological Society*, 3: 1–13.
- Dendup, P., Lham, C., Wangchuk, W. and Jamtsho, Y. (2023). Tiger abundance and ecology in Jigme Dorji National Park. *Global Ecology and Conservation*, 42 (2): e02378. <https://doi.org/10.1016/j.gecco.2023.e02378>
- Dendup, P., Wangdi, L., Jamtsho, Y., Kunzang, P., Gyeltshen, D., Tashi, T., Rigzin, U., Jamtsho, Y., Dorji, R., Dorji, R., Lham, C. and Tshering, B. (2021). Bird diversity and conservation threats in Jigme Dorji National Park, Bhutan. *Global Ecology and Conservation*, 30: e01771. <https://doi.org/10.1016/j.gecco.2021.e01771>
- Dorjee, D., Chakraborty, R. and Dutta, P. K. (2014). A note on the high elevation distribution record of red panda *Ailurus fulgens* (Mammalia: Carnivora: Ailuridae) in Tawang District, Arunachal Pradesh, India. *Journal of Threatened Taxa*, 6 (9): 6290–6292. <https://doi.org/10.11609/JoTT.o3492.6290-2>
- Dorji, S., Rajaratnam, R. and Vernes, K. (2012). The vulnerable red panda *Ailurus fulgens* in Bhutan: distribution, conservation status and management recommendations. *Oryx*, 46 (4): 536–543. <https://doi.org/10.1017/S0030605311000780>
- Dorji, S., Vernes, K. and Rajaratnam, R. (2011). Habitat correlates of the red panda in the temperate forests of Bhutan. *PLoS ONE*, 6 (10): 1–11. <https://doi.org/10.1371/journal.pone.0026483>
- Dorji, U., Olesen, J. E., Bocher, P. K. and Seidenkrantz, M. S. (2015). Spatial variation of temperature and precipitation in Bhutan and links to vegetation and land cover. *Mountain Research and Development*, 36 (1): 66–79. <https://doi.org/10.1659/MRD-JOURNAL-D-15-00020.1>
- Dou, H., Yang, H., Smith, J. L. D., Feng, L., Wang, T. and Ge, J. (2019). Prey selection of Amur tigers in relation to the spatiotemporal overlap with prey across the Sino-Russian border. *Wildlife Biology*, 1: 1–11. <https://doi.org/10.2981/wlb.00508>
- FRMD (2017). Land use and land cover assessment of Bhutan 2016. Technical Report. Department of Forests and Park Services, Thimphu, Bhutan. 28 pp.
- Galvis, N., Link, A. and Fiore, A. (2014). A novel use of camera traps to study demography and life history in wild animals: A case study of Spider Monkeys (*Ateles belzebuth*). *International Journal of Primatology*, 35: 908–918. <https://doi.org/10.1007/s10764-014-9791-3>
- Glatston, A., Wei, F., Than, Z. and Sherpa, A. (2015). *Ailurus fulgens*. The IUCN Red List of Threatened Species 2015. www.iucnredlist.org (Accessed 17 June 2019)
- Gómez, H., Wallace, R. B., Ayala, G. and Tejada, R. (2005). Dry season activity periods of some Amazonian mammals. *Studies Neotropical Fauna Environmental*, 40: 91–95. <https://doi.org/10.1080/01650520500129638>
- Holt, B. G., Lessard, L-P., Borregaard, M. K., Fritz, S. A., Araujo, M. B., Dimitrov, D., Fabre, P-H., Graham, C. H., Graves, G. R., Jonsson, K. A., Nogues-Bravo, D., Wang, Z., Whittaker, R. J., Ejeldsa, J. and Rahbek, C. (2013). An update of Wallace's zoogeographic regions of the world. *Science*, 339: 74–78. <https://doi.org/10.1126/science.1228282>
- Hu, Y., Thapa, A., Fan, H., Ma, T., Wu, Q., Ma, S., Zhang, D., Wang, B., Li, M., Yan, L. and Wei, F. (2020). Genomic evidence for two phylogenetic species and long-term population bottlenecks in red pandas. *Science Advances*, 6: 1–10. <https://doi.org/10.1126/sciadv.aax5751>
- Jimenez, C. F., Quintana, H., Pacheco, V., Melton, D., Torrealva, J. and Tello, G. (2010). Camera trap survey of medium and large mammals in a montane rainforest of northern Peru. *Revista Peruana de Biología*, 17: 191–196. <https://doi.org/10.15381/rpb.v17i2.27>
- Johnson, K. G., Schaller, G. B. and Jinchu, H. (1988). Comparative behaviour of red panda and giant pandas in the Wolong reserve, China. *Journal of Mammalogy*, 6: 552–564. <https://doi.org/10.2307/1381347>
- Katranth, K. U. and Nichols, J. D. (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, 79: 2852–2862. [https://doi.org/10.1890/0012-9658\(1998\)079\[2852:EOTDII\]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2)

- Letro, L. Tandin, T. Wangdi, S. Wangdi, T. Dendup, P. and Millar, J. (2022). Status, distribution and conservation of red panda *Ailurus fulgens* in Bhutan, *In: Glatston, A. R. (Ed.), Red panda biology and conservation of the first panda*. Second Edition. Academic Press. pp. 463–474.
<https://doi.org/10.1016/B978-0-12-823753-3.00004-1>
- Lham, D., Cozzi, G., Sommer, S., Thinley, P., Wangchuk, N., Wangchuk, S. and Ozigul, A. (2021). Modelling distribution and habitat suitability for the snow leopard in Bhutan. *Frontiers in Conservation Science*, 2: 781085
<https://doi.org/10.3389/fcosc.2021.781085>
- Manly, B. F. J., McDonald, L. L., Thomas, D. L., McDonald, T. L. and Erickson, W. P. (2002). *Resource selection by animals: Statistical design and analysis for field studies*. Second Edition. Dordrecht, Kluwer Academic, Netherland. 220 pp.
- MoA (1995). Forest and Nature Conservation Act (1995) of Bhutan. Thimphu. 19 pp.
- MoA (2009). Biodiversity Action Plan 2009. Ministry of Agriculture, Royal Government of Bhutan, Thimphu. 95 pp.
- Northrop, L. E. and Czekala, N. (2010). Reproduction of red panda, *In: Glatston, A. R. (Ed.), Biology and conservation of the first panda*. Academic Press, London, UK. pp. 140–160.
- Nowak, R. (1999). *Walker's mammals of the world*. 2 Sixth Edition. Baltimore, Johns Hopkins University Press, USA. pp. 695–696.
<https://doi.org/10.56021/9780801857898>
- NSB (2022). *Statistical Yearbook of Bhutan 2022*. National Statistical Bureau, Thimphu, Bhutan. 371 pp.
- O'Connell, A. F., Nichols, J. D., and Karanth, K. U. (2011). *Camera traps in animal ecology: Methods and analyses*. New York, NY: Springer. 96 pp.
<https://doi.org/10.1007/978-4-431-99495-4>
- Ohsawa, M. (Ed). (1987). *Life zone ecology of Bhutan Himalaya*. Chiba University, Yayoicho, Chiba, Japan. 71 pp.
- Pradhan, S., Saha, G. K. and Khan, J. A. (2001). Ecology of the red panda *Ailurus fulgens* in the Singhalila National Park, Darjeeling, India. *Biological Conservation*, 98: 11–18.
[https://doi.org/10.1016/S0006-3207\(00\)00079-3](https://doi.org/10.1016/S0006-3207(00)00079-3)
- R Core Team (2018). R: A language and environment for statistical computing. Vienna, Austria. R foundation for statistical computing. <https://www.R-project.org>
- Roberts, M. and Gittleman, J. (1984). *Ailurus fulgens*. *Mammalian Species*, 222: 1–8.
<https://doi.org/10.2307/3503840>
- Roberts, M. S. and Kessler, D. S. (1979). Reproduction in red pandas, *Ailurus fulgens* (Carnivora: Ailuropodidae). *Journal of Zoology*, 188: 233–249.
<https://doi.org/10.1111/j.1469-7998.1979.tb03402.x>
- Ross, J., Hearn, A. J., Johnson, P. J. and Macdonald, D. W. (2013). Activity patterns and temporal avoidance by prey in response to Sunda clouded leopard predation risk. *Journal of Zoology*, 290: 96–106.
<https://doi.org/10.1111/jzo.12018>
- Sangay, T., Rajaratnam, R. and Vernes, K. (2014). Wildlife camera trapping in the Himalayan kingdom of Bhutan with recommendations for the future, *In: Meek, P. and Fleming P. (Eds.), Camera trapping wildlife management and research*. Chapter 10. CSIRO, Australia. pp. 87–96.
- Scotson, L., Fredriksson, G., Ngoprasert, D., Wong, W. and Fieberg, J. (2017). Projecting range-wide sun bear population trends using tree cover and camera-trap bycatch data. *PLoS ONE*, 12 (9): e0185336.
<https://doi.org/10.1371/journal.pone.0185336>
- Sharma, H. P. and Belant, J. L. (2009). Distribution and observation of Red panda *Ailurus fulgens fulgens* in Dhorpatan Hunting Reserve, Nepal. *Small Carnivore Conservation*, 40: 33–35.
- Silver, S. C., Ostro, L. E. T., Marsh, L. K., Maffei, L., Noss, A. J., Kelly, M. J., Wallace, R. B., Gomez, H. and Ayala, G. (2004). The use of camera traps for estimating jaguar *Panthera onca* abundance and density using capture/recapture analysis. *Oryx*, 38: 148–154.
<https://doi.org/10.1017/S0030605304000286>
- Tempa, T., Norbu, N., Dendup, P. and Nidup, T. (2011). Results from a camera trapping exercise for estimating tiger population size in the lower foothills of Royal Manas National Park. Ugyen Wangchuck Institute for Conservation and Environment and Royal Manas National Park, Royal Government of Bhutan, Lamai Gonpa. 50 pp.
- Thapa, A., Hu, Y. and Wei, F. (2018). The endangered red panda (*Ailurus fulgens*): Ecology and conservation approach across the entire range. *Biological Conservation*, 220: 112–121.
<https://doi.org/10.1016/j.biocon.2018.02.014>
- Wei, F., Feng, Z., Wang, Z. and Hu, J. (1999). Current distribution, status and conservation of wild red pandas *Ailurus fulgens* in China. *Biological Conservation*, 89: 285–291.
[https://doi.org/10.1016/S0006-3207\(98\)00156-6](https://doi.org/10.1016/S0006-3207(98)00156-6)
- Williams, B. H. (2006). Red panda in eastern Nepal: how do they fit into ecoregional conservation of the eastern Himalayas? *Conservation Biology in Asia*, 16: 236–250.
- Yonzon, P. B. and Hunter, M. L. (1991). Conservation of red panda *Ailurus fulgens*. *Biological Conservation*, 57: 1–11.
[https://doi.org/10.1016/0006-3207\(91\)90104-H](https://doi.org/10.1016/0006-3207(91)90104-H)
- Yonzon, P. B., Jones, R. and Fox, J. (1991). Geographic information system assessing habitat and estimating the population of red panda in Langtang National Park, Nepal. *Ambio*, 20: 285–288.