Global Ecology and Conservation 15 (2018) e00420

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

Pervasive human disturbance on habitats of endangered red panda *Ailurus fulgens* in the central Himalaya

Krishna Prasad Acharya [a], Saroj Shrestha [b], Prakash Kumar Paudel [c], Ang Phuri Sherpa [b], Shant Raj Jnawali [d], Sakshi Acharya [e], Damber Bista [b, *]

[a] *Department of Forests, Ministry of Forest and Soil Conservation, Government of Nepal, Babarmahal, Kathmandu, Nepal*
[b] *Red Panda Network, PO Box 2785, Baluwatar, Kathmandu, Nepal*
[c] *Center for Conservation Biology, Kathmandu Institute of Applied Sciences, PO Box 23002, Kathmandu, Nepal*
[d] *WWF Nepal, PO Box 7660, Baluwatar, Kathmandu, Nepal*
[e] *ZSL Nepal, PO Box 5867, Bishalnagar Road, Bhatbhateni, Kathmandu, Nepal*

ARTICLE INFO

Article history:
Received 24 April 2018
Received in revised form 25 July 2018
Accepted 26 July 2018

Keywords:
Anthropogenic threats
Disturbance
Habitat degradation
Protected areas
Red panda

ABSTRACT

Red pandas (*Ailurus fulgens*) live in the dense forests of mid-hills of the Himalaya and feed almost exclusively on bamboo. They are vulnerable to extinction due to human induced disturbances. Habitat loss, degradation and fragmentation along with poaching are the most pressing anthropogenic threats to red panda conservation. The extinction risk to red pandas is further compounded by their life history traits. However, there is a paucity of information regarding human impact on red panda habitats. We have used presence and absence data collected from entire red panda range in Nepal, including habitat both inside and outside the Protected Areas (PAs) to examine the impact of human disturbance on their distribution. Our findings indicate that red panda prefer less disturbed habitats but will occupy human disturbed areas. Signs of poaching and cattle trails were significantly associated with red panda presence throughout Nepal while livestock faeces and landslides were negatively associated. Plant disturbance, presence of solid waste and proximity to herders' shed were significantly associated with presence of red panda in PAs whereas landslides and livestock faeces were significant disturbance variables outside the PAs. The findings show that red panda habitats are invariably disturbed and that integrated conservation programs such as awareness, livelihood support that reduces human dependency on forests, and regulations are must.

1. Introduction

The red panda (*Ailurus fulgens* Cuvier, 1825) occurs in subalpine areas of Nepal, India, Bhutan, Myanmar and China within a preferred altitudinal range of 2300–4000 m (Glatston et al., 2015). They inhabit temperate broadleaf forests with a bamboo understory. In Nepal, red pandas are documented in 23 districts with the majority of habitat falling outside the PA networks within the available potential habitat of 23,977 km^2 (MoFSC, 2016). The red panda is listed as endangered in the IUCN Red Data Book and is included on Appendix I in CITES (Glatston et al., 2015). It is protected by law in its all range countries, including in Nepal, by the National Parks and Wildlife Conservation Act (1973).

* Corresponding author.
E-mail address: damber.bista@redpandanetwork.org (D. Bista).

https://doi.org/10.1016/j.gecco.2018.e00420
2351-9894/

Red pandas are reported to prefer areas with dense forest (tree canopy cover over 30%), abundant bamboo cover (>37%) and bamboo height (2.9 m) and in close proximity to water sources (within 100–200 m), (Bista et al., 2017a; Dorji et al., 2012; Pradhan et al., 2001; Yonzon and Hunter, 1991a). Some authors indicate red pandas prefer habitats with gentle while others indicate a preference for steeper slopes all agree preferred area include fallen logs, tree stumps, and snags. They generally seem to prefer to inhabit slopes with north and north-west aspects although in some authors report that they occur on slopes with south-west aspects (Zhang et al., 2008; Yonzon and Hunter, 1991a). Bamboo leaves and shoots constitute 83% of the overall diet of red pandas (Reid et al., 1991; Wei et al., 1999a, 1999b; Yonzon et al., 1991). Even though, red pandas are crepuscular, they enjoy foraging and basking during the day (Yonzon and Hunter, 1991a). Although they are generally assumed to be a solitary species; they are found in small groups, probably mothers with their offspring, during the breeding season (Hu, 1991; Roberts and Kessler, 1979).

Even though red pandas have no negative impact on humans (Glatston, 1994), they still face anthropogenic threats (Bista et al., 2017a; Panthi et al., 2017). These animals have been observed to have preferred habitat with higher bamboo cover avoiding areas disturbed by livestock or close to human settlements (Dendup, 2016). Yonzon et al. (1991) had also reported bamboo loss as one of the key threats to the red panda survival. Like other wildlife species, the red panda is also threatened due to the habitat alteration of the landscape by humans. The impact of habitat loss and degradation for red pandas varies throughout the country (Jnawali et al., 2012). Agriculture and livestock herding remain the principal economic activities (79.85%) in mountain areas where nearly 95% of households depend on wood as energy source for cooking and heating (CBS, 2014). All these activities and the resulting deforestation and habitat loss are considered as the major conservation challenges for red pandas throughout their range (Bista et al., 2017a; Glatston et al., 2015; Choudhury, 2001). Increasing incidents of red panda hide confiscation in recent years have indicated that poaching and illicit trade are an emerging threat (Bista et al., 2017a). The dogs, either feral or reared by the herders, are also harmful for red pandas and other wildlife. Red panda kills due to dog attacks have been reported in Nepal (Yonzon and Hunter, 1991a; Williams et al., 2011; Bista and Paudel, 2014). In addition to unrestricted livestock grazing, excessive harvesting of forest resource and habitat fragmentation due to infrastructure development, have created an unprecedented level of threat to red panda survival (Sharma et al., 2014a; Sharma and Belant, 2010; Williams, 2003; Roder et al., 2002; Gratzer et al., 1999). Mass flowering and die off of bamboo is one of the critical issues that could extirpate a local population of red pandas from a particular habitat (Paudel, 2009; Steffens, 2004). Dying off of bamboo makes forest floor dry which is highly prone to forest fire. Albeit, impact of forest fires on small mammals like red panda has not been documented well, anecdotal evidences suggest that the forest fire has negative effects on red pandas (Williams et al., 2011).

Previous studies of red pandas in Nepal have provided important insights into site-specific conservation issues (e.g., community forests, national parks) (Bista et al., 2017a; Sharma et al., 2014b; Panthi et al., 2012; Sharma and Belant, 2010; Yonzon and Hunter, 1991a). However, these findings are not enough to allow the development of a landscape level conservation strategy at national level. Therefore, this study aims to provide a snapshot of impacts of human activities on red panda habitats by answering following questions:

– Does the red panda respond equally or at different level to various human disturbance variables?
– How does the red panda respond to human disturbances within and outside the Protected Areas (PAs)?

2. Methods

2.1. Study area and sampling design

Based on the previously available red panda presence data (Bista et al., 2017a; Kandel et al., 2015; Bhatta et al., 2014) and environmental parameters including 23 environmental variables (19 bioclimatic variables, altitude, slope, aspect, and land cover), Maximum Entropy Modeling –MaxEnt (Phillips et al., 2006) helped us identify potential red panda habitats (MaxEnt version, 3.3.3 k) (Bista et al., 2017a). The predictive distribution model developed in MaxEnt at the Area Under Curve (AUC) value of 0.926 was considered the potential red panda habitat. Thus, identified potential habitat was overlaid with grids of 9.6 km^2, which is equivalent to maximum home range of red panda reported in Langtang National Park (Fox et al., 1996). Grid cells with more than 50% area suitable habitat were considered for random sampling. We randomly selected 50% of the suitable grid cells and overlaid each with 6 sub-grids (area = 1.6 km^2). We selected 3 grids randomly as sampling sites (MoFSC, 2015) and a total of 557 sub-grids were sampled across the entire habitat.

All existing transects, with an average of three to five transects, each ranging from 500 m to 1000 m in length were traversed at an interval of 100 m contour available within a sub-grid. GPS coordinates of start and end points of all available transects within a sampling sub-grid were sorted out and loaded in GPS to ease tracking in field. In each transect, the presence or absence of red pandas was determined in a circular plot with radius of 10 m (hereafter referred to as the sampling plot) at start point and successive intervals of 500 m. Presence was indicated by direct sighting or by observation of indirect signs such as droppings, paw prints, foraging signs, scratch marks or remains of a dead animal. Human disturbance variables were also recorded (Table 1). The first seven of these variables number of tree logs, tree stumps and lopped trees, livestock droppings, human tracks, cattle trails and dumped solid waste were recorded in each plot together with the distance to the nearest

Table 1
Description of the environmental variables included in the analysis.

Variables (code)	Description
Number of logs, stumps, lopped trees (hereafter plant disturbance)	Total number of tree logs and stumps chopped off by human, and lopped trees observed within a circular plot (no. of trees/plot)
Livestock droppings	Total number of cattle, sheep, goat and horse faeces observed within a circular plot
Human tracks	Total number of tracks within or near the sampling plot
Cattle trails	Total number of livestock trails within or near the sampling plots
Distance to livestock herding station	The aerial distance between sampling plot and the nearest herder's shed. Proxy value based on visual estimation was considered. Field assistants involved in the survey were local people, and they were familiar with the local topography and location of herders shed. So, only the sheds being used by the herders during survey time were considered. This was categorized as either: low (<250 m), moderate (250−500 m) and high (>500 m)
Garbage	Total number of garbage dumps within the sampling plot (e.g., plastic, paper, cans, rubber, construction materials and other rubbish)
Poaching signs	Total number of hunting signs: traps, snares, feathers, fur, body parts of hunted animals, remains of campfires and killed animals observed between two consecutive sampling plots along the transect (no. of observations per 500 m).
Landslides	Recent landslide sites (i.e. those with no vegetation observed along the transect (no. of observations per 500 m)).

livestock herding station and settlement. It would be unrealistic to expect some variables such as poaching signs and landslides to be observed within the sampling plot so we recorded these variables while walking the transects and visually inspecting 25 m either side. We argue that both of poaching signs and landslides are attributable to the landscape activity, and therefore indices of poaching and landslides along 500 m of transect walk were considered as representative of corresponding sampling plot.

We surveyed a total of 2935 sampling plots in the entire study area these included 1006 plots within 10 different PAs and 1929 plots outside the PAs (Fig. 1).

We walked a total of a 1451 km along transects. It took a total of 6730 h and involved 40 field biologists, each accompanied by two assistants to complete the work. This field work was carried out in June, July and October 2016.

2.2. Data analysis

We tested multicollinearity problems among predictors in model with the variance inflation factor (VIF) of each predictor using the usdm package (Naimi, 2015) in R (R Core Team, 2015). A VIF value greater than 10 was regarded as strong

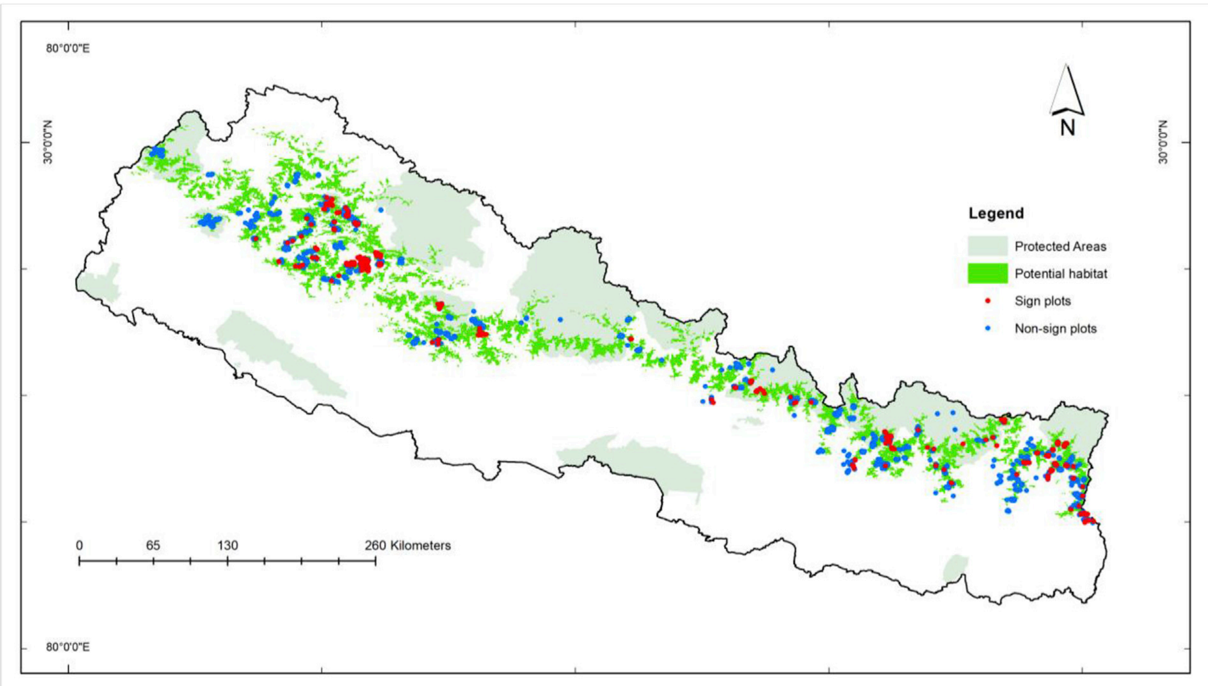

Fig. 1. Location of sampling sites with presence and absence plots within and outside the protected areas.

multicollinearity (Montgomery et al., 2012). Our analysis suggested that no pairs of the seven input variables were problematically correlated. The input variable 'distance to livestock herding station' was excluded in the VIF test as it was ordinal variable. We computed mean and standard error of each disturbance variables in presence and absence plots and in PAs and non PAs. We used a one-way ANOVA to test whether there was a significance difference between means of disturbance variables in red panda presence and absence locations. To explore whether human disturbance variables had an influence on red panda presence locations, we fitted a Generalized Linear Model (GLM) with binomial family.

To test the response of red panda to human disturbance variables, we fitted GLM with a binomial error distribution and used the binary response (red panda presence and absence) as response variable and human disturbance variables as predictors. We ran three separate GLMs for (a) protected area network, (b) non-protected areas and (c) combining both protected area and non-protected areas. The PAs are considered as a cornerstone for effective wildlife conservation (Shrestha, 1996). However, Nepal's protected areas are under threat from encroachment, poaching, grazing, recreation and other human activities. Therefore, it is essential to evaluate their effectiveness (Nepali, 2006). We simultaneously used ANOVA to compare means of disturbance variables between red panda presence and absence locations, and logistic regression to examine whether independent disturbance variables have any effect on probability of red panda presence. We argue that such analyses can help examine whether red pandas are better secured in protected areas and determine if national average differ from both protected areas and non-protected areas. We carried out all analyses using R statistical analysis software (R Development Team, 2015).

3. Results

We found a total of 601 (155 plots in PAs and 446 plots outside the PAs) plots with signs of red panda presence. We found at least one sign out of eight human disturbance signs in 88% of plots. There were variations in categories of disturbance in the sampled locations; plant disturbance (72%), cattle trail (54%), human tracks (39%), livestock droppings (27%), landslide (22%), solid waste (17%) and poaching signs (13%) (Fig. 2).

Our initial comparisons of disturbance variables between protected areas and outside and between red panda presence and absence locations using one-way ANOVA showed that there were significant differences between the occurrence of human disturbance within the PA network and outside those areas with the exception of cattle trails ($P = 0.09$), proximity to settlements ($P = 0.07$) and solid waste ($P = 0.17$) (Fig. 3a).

Average plant disturbance was significantly higher outside PAs ($n = 4.770$) than inside them ($n = 2.918$) ($F = 131.34$, $P < 0.001$). Red panda presence locations were also significantly lower in plots with plant disturbance than those without ($F = 72.96$, $P < 0.001$, and Fig. 3b). Livestock droppings were significantly higher in plots where red pandas were recorded than in plots where they were absent ($F = 4.679$, $P = 0.03$) even though PAs had significantly less livestock droppings than the habitat outside PAs ($F = 37.38$, $P < 0.0001$). Poaching signs were also significantly higher outside the PAs ($F = 12.43$, $p = 0.004$) and in plots where red pandas were absent ($F = 10.86$, $P = 0.001$). Human tracks were more common in areas where red pandas were present ($F = 5.58$, $P = 0.01$) and in PAs ($F = 5.08$, $P = 0.08$). Areas affected by landslides also demonstrated a similar pattern with higher occurrence inside the PAs ($F = 46.11$, $p < 0.001$) and in locations where red pandas were present ($F = 46.48$, $p < 0.001$). Interestingly, the red panda presence locations were found in proximity to the settlement ($F = 13.51$, $p < 0.0001$) where the quantity of solid waste was recorded to be comparatively higher than in the absence locations ($F = 20.206$, $p < 0.001$).

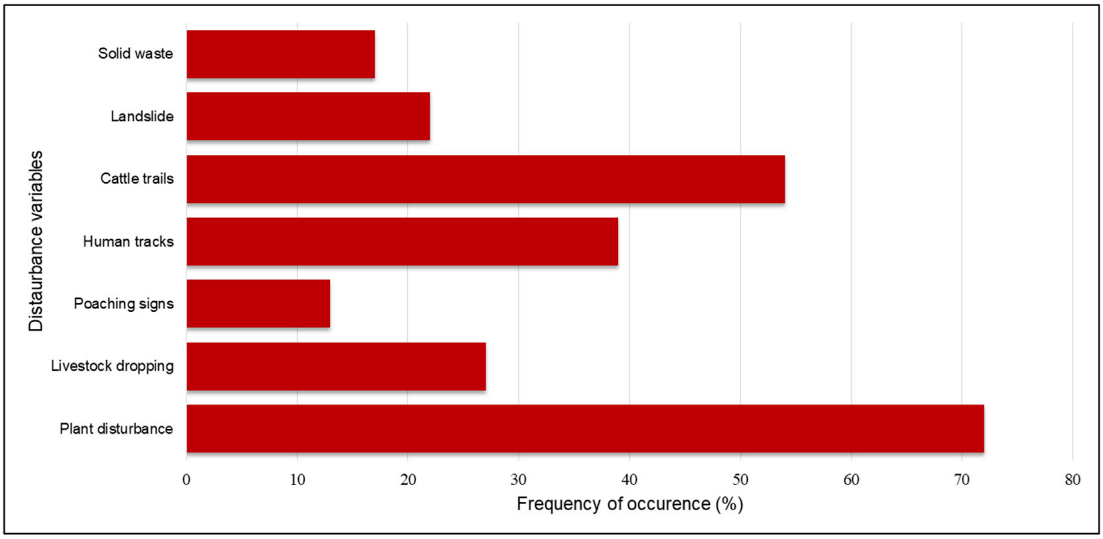

Fig. 2. Bar graph showing the frequency of occurrence of disturbance variables in sampled plots.

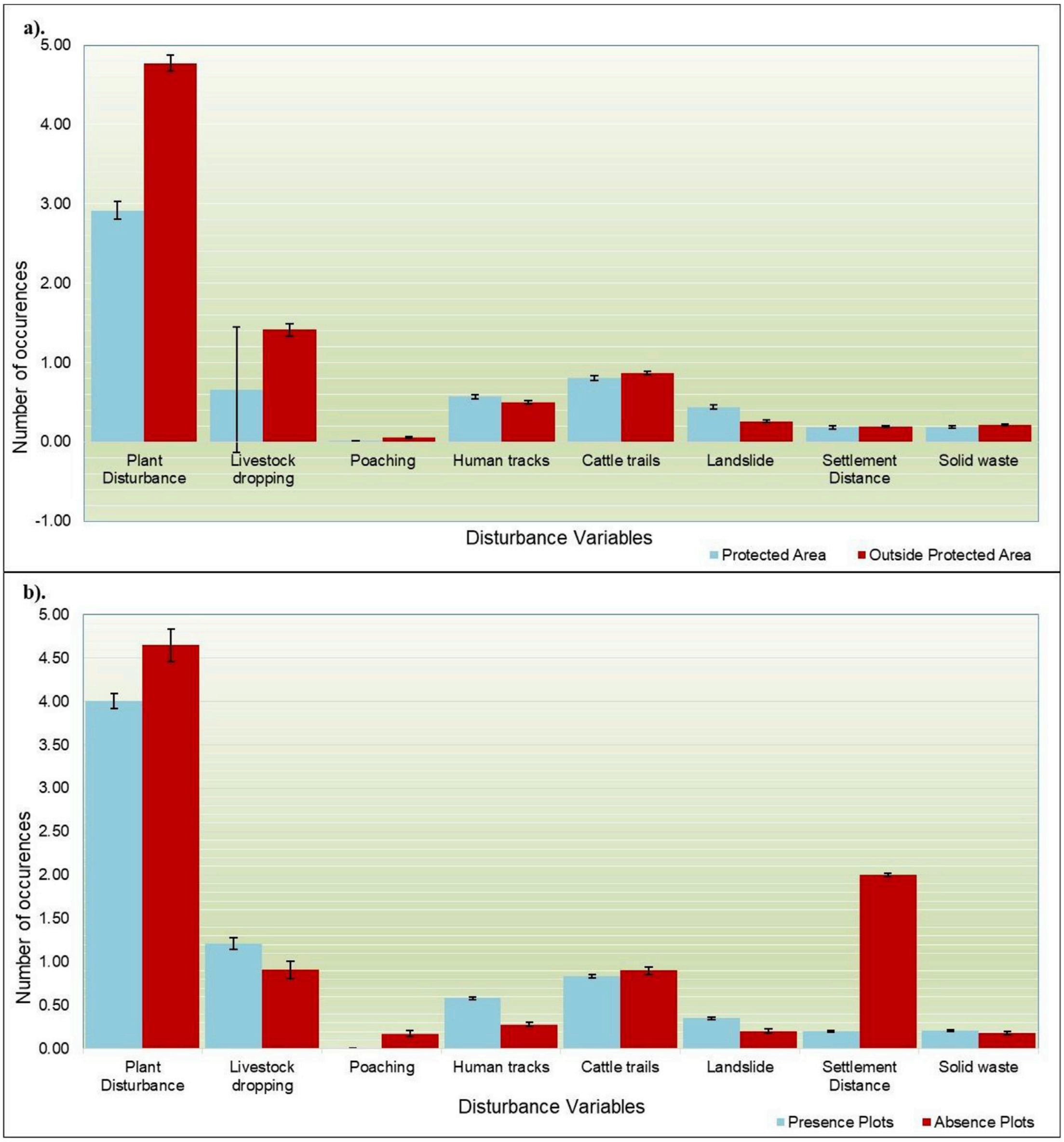

Fig. 3. Error bar graph showing mean and standard error of the status of disturbance variables (a) within and outside the protected areas, and (b) presence and absence locations.

Results of the binary logistic regression showed that wildlife poaching signs and cattle trails were positively, and livestock droppings and human tracks were negatively associated with red panda presence in the entire red panda range in Nepal. Odd Ratio (OR) further indicated livestock droppings had the strongest negative impact (OR = 0.903) followed by landslides (OR = 0.738) and human trails (OR = 418) in red panda distribution (Table 2). Interestingly, areas which had hunting incidents were positively associated with presence of red panda. However, poaching and livestock droppings were not significantly associated with the red panda presence in the PA network (Table 3). The model suggested that the red panda avoided disturbed forest (OR = 0.915), and areas with solid waste (OR = 0.231), and areas near human tracks (OR = 0.557) and livestock herding stations (OR = 0.52). Cattle trails and landslides were positively associated with red panda occurrence. Observation outside the PAs was slightly different as the red panda showed positive association with disturbed vegetation, wildlife poaching location, cattle trails and solid waste whereas livestock droppings, human tracks and landslides were negatively associated. The level of impact of these last three disturbances followed the trend that was observed in the entire red panda range in Nepal (Table 4).

Table 2
Summary from binary logistic regression analysis of the distribution of red panda by disturbance variables in Nepal.

Variables	Estimate	SE	z value	p	Odd Ratio
Intercept	−1.470	0.127	−11.582	<0.001	0.230
Number of logs, stumped, lopped trees	0.052	0.012	4.225	2.39	1.053
Livestock droppings	−0.102	0.024	−4.286	0.00	0.903
Poaching	1.603	0.272	5.898	0.00	4.969
Human tracks	−0.872	0.096	−9.114	<0.0001	0.418
Cattle trails	0.405	0.063	6.422	<0.0001	1.499
Landslide	−0.304	0.092	−3.311	<0.01	0.738
Solid waste	0.199	0.126	1.580	0.11	1.220
Distance to livestock herding station (Moderate)	0.011	0.180	0.061	0.95	1.011
Distance to livestock herding station (Low)	−0.123	0.221	−0.556	0.57	0.885
Distance to livestock herding station (High)	−0.065	0.128	−0.509	0.61	0.937

Table 3
Summary from logistic regression analysis of the distribution of red panda by disturbance variables in protected areas.

Variables	Estimate	SE	z value	p	Odd Ratio
Intercept	−0.930	0.208	−4.470	<0.0001	0.395
Number of logs, stumped, looped trees	−0.088	0.034	−2.636	0.008	0.915
Livestock droppings	0.011	0.045	0.250	0.80	1.011
Poaching	−0.426	1.164	−0.366	0.71	0.653
Human tracks	−0.585	0.173	−3.376	0.001	0.557
Cattle trails	0.341	0.117	2.910	0.004	1.407
Landslide	0.285	0.120	2.373	0.018	1.330
Solid waste	−1.466	0.427	−3.431	0.001	0.231
Distance to livestock herding station (Moderate)	−1.040	0.445	−2.335	0.020	0.353
Distance to livestock herding station (High)	−0.706	0.407	−1.733	0.083	0.494
Distance to livestock herding station (Low)	−0.653	0.217	−3.015	0.003	0.520

Table 4
Summary from logistic regression analysis of the distribution of red panda by disturbance variables outside the protected areas.

Variables	Estimate	SE	z value	p	Odd Ratio
Intercept	−1.756	0.167	−10.538	<0.0001	0.173
Number of logs, stumped, looped trees	0.080	0.015	5.364	<0.0001	1.084
Livestock droppings	−0.154	0.031	−4.944	<0.0001	0.857
Poaching	1.813	0.343	5.285	<0.0001	6.130
Human tracks	−1.025	0.124	−8.287	0.0001	0.359
Cattle trails	0.473	0.078	6.075	<0.0001	1.605
Landslide	−0.757	0.158	−4.790	<0.0001	0.469
Solid waste	0.629	0.149	4.233	<0.0001	1.875
Distance to livestock herding station (Moderate)	0.337	0.215	1.571	0.11	1.401
Distance to livestock herding station (High)	0.207	0.274	0.756	0.44	1.230
Distance to livestock herding station (Low)	0.202	0.167	1.213	0.22	1.224

4. Discussion

In general, our results indicate that the red panda prefers less disturbed habitats. There are, however, considerable variations in response to disturbance variables in the red panda presence locations. The means of disturbance variables in sampling plots outside PA (e.g., plant disturbance, livestock dropping, poaching) were significantly higher than those of inside PA. At the same time, number of landslides was significantly high in PA. All disturbance variables except of plant disturbance and poaching signs, were significantly higher in the presence locations. However, distribution variables responded differently in predicting presence of red panda in PA, outside PA and throughout country. Since disturbance variables were observed in nearly 88% sampled plots, association of disturbance variables in predicting red panda presence in the logistic models needs a careful and cautious interpretation.

Red panda presence was positively associated with disturbed forests outside the PAs with negative association inside the PAs. The attraction of red pandas and humans towards similar environments, e.g., moderately sloped areas with an abundance of bamboo, could be a reason for this positive association of red pandas' presence outside the PAs in the comparatively disturbed forest. It may be the result of controlled access to forests for firewood and fodder collection in the PA system. However, there is a need for further research to shed light on the effectiveness of PAs in conserving red pandas.

Livestock droppings were negatively associated with the presence of red pandas throughout their range and in non-protected areas, whereas it was a positive predictor of red panda presence in PAs. This is a very unusual result, but we offer strong support of such a pattern. Much of red pandas' habitats fall outside PAs, but they are limited to small forest patches far from human settlements due to the double impact of wildlife hunting and unsustainable forest harvesting (Dendup, 2016). This finding is comparable to the results of Panthi et al. (2017), who concluded that habitat with anthropogenic disturbances were less likely to be occupied with red pandas. However, mountain PAs are better protected, but subsistence agriculture with livestock herding is a major source of livelihood of people living here. An average of the closest distance between the red panda presence sites and human settlements has been found to be 0.197 ± 0.010 km which is no distance at all for the local inhabitants and their livestock. Bista et al. (2017b), had also reported that areas of human settlements with livestock herding practices were unsuitable habitats for red pandas. Beyschlag et al. (2008) reiterated that small-scale disturbances due to trampling at an intermediate frequency benefit plant regeneration, which accentuates our findings for red panda association with livestock droppings inside the PAs. Positive association of red panda presence with cattle trails was observed in the entire red panda habitat and PAs, which could be attributed to the preference for similar micro-habitat conditions, with different layers of vegetation for foraging. Livestock forage primarily on bamboo leaves at <1 m level and red pandas above 1 m (Yonzon and Hunter, 1991b), which minimizes the competition for resources.

Interestingly, poaching signs were positively significant in both the entire habitat and outside the PAs. It was non-significant with negative association in PAs. Out of the total 23,977 km^2 of available potential habitat, nearly 70% of the total habitat lies outside the PA network (Bista et al., 2017a; MoFSC, 2016; Bista and Paudel, 2014) with easy access to locals who are highly dependent on forest resources for their subsistence livelihood. Record of red panda presence from disturbed sites in terms of increasing poaching activities, presence of livestock droppings and solid wastes also reflect easy human access to those sites. Dorji et al. (2011) had also reported similar observations in Bhutan. Hunting activities are frequent in the high-mountain regions of Nepal, which may be why poaching signs are recorded frequently outside the PAs (Paudel, 2012). Hunting is uncommon inside the PAs because of the strict regulations that are in place here. The red panda is rarely targeted by the poachers but is accidentally caught in traps set for other species, such as barking deer, musk deer, wild boar, serow, Himalayan black bear and various pheasants (Choudhury, 2001). This might be another reason why red pandas' presence has been observed to be positively associated with poaching throughout its entire habitat range in Nepal and the habitat outside the PAs. This observation is consistent with the findings of Panthi et al. (2017). However, most of the studies (Bista et al., 2017a; Zhang et al., 2017; Dendup, 2016; Sharma et al., 2014a; Dorji et al., 2011) have reported poaching, along with disturbed forest and cattle trails as the major disturbance factors for red panda presence.

The distribution of the red panda was negatively associated with landslides outside the PAs but was positively associated inside the PAs. The positive association between the red panda and landslides within PAs may be related to the massive earthquake and aftershocks that jolted Nepal on 25 April 2015 and triggered at least 25,000 landslides throughout the steep Himalayan Mountains in central Nepal. Out of seven PAs with confirmed red panda presence, Langtang National Park and Gaurishankar Conservation Area were reported to have extensive landslides (Kargel et al., 2016). Negative association of red panda presence with landslides outside of the PAs could be due to the fact that suitable red pandas' habitats outside of PAs were not hit by earthquakes, as the majority of habitat in earthquake impact zones falls within the protected area system in Central Nepal. However, landslides are likely to be major problems in the future due to infrastructure development, deforestation and other natural disasters. The red panda range area is likely to be affected by developmental activities in the future as their preferred habitat with gentle to steep slopes is more susceptible to landslides (Dorji et al., 2012; Zhang et al., 2008).

Landslides are reported to be threatening the survival in China of a sympatric species, the giant panda, due to loss of habitat, food and fragmentation. Zheng et al. (2012) reported similar results in the Wolong Nature Reserve in Sichuan, China where an earthquake (May 2008) triggered a landslide that destroyed 354 km^2 of giant panda habitat. Wang and Li (2008) reported that the earthquake damaged 32.15% of giant panda habitat due to fragmentation in the Longxi- Hongkou National Nature Reserve.

Our study indicated moderate littering appearing to be negatively associated with red pandas' presence within the PAs. The mountain areas where the red panda resides are predominantly PAs which are entry points for high altitude trekking in Nepal. Trekking routes and roads passing across the red panda habitat are also prevalent outside the PAs. Hiking, camping, wildlife tracking, and other forms of non-consumptive recreation are on the rise, particularly in those PAs in the mountains (Nepal, 2002). As stated by Manfredi et al. (2010) in Sagarmatha National Park and Buffer Zone (Nepal) litter provides a great hazard to environmental and human health and deters animals. Garbage deriving from tourist activities is likely to be disastrous to red pandas and other associated wildlife as this rubbish could not only be the source of disease but also may lead to fatal choking on plastics and the like (Bista et al., 2017a).

This study indicates, red pandas may respond in different ways to increased disturbances which is likely associated with their biological traits (e.g., life history strategy and diet). Red pandas' preference was observed to be positively associated with moderately disturbed forests in general as well as non-protected forests. An average distance of the red panda presence location with the human settlement was recorded at 0.183 ± 0.016 km in the PAs while the presence signs were recorded a bit farther 0.189 ± 0.011 km outside the PAs. This could be attributed to the smaller number of human settlements and comparatively more organized herding activities, resulting in less disturbance within the PA systems than outside.

Human tracks were the only variables that displayed a negative association with red panda presence in all three scenarios. The tracks act as barrier to animal movement, and the area is likely to remain disturbed with a frequent flow of people. In addition, the habitat around the trail is of comparatively poorer quality than an ideal habitat. Ciuti et al. (2012) have also reported similar effects of human disturbance (e.g., hiking) on elk behavior exceeding those of habitat and natural predators in Canada. These might be the reasons why red pandas have avoided human tracks. This finding reinforces the need for specific trails to be used by local people and visitors rather than allowing them to haphazardly walk inside the forest.

This study shows that PAs are less disturbed than Non-PA, but presence locations are no less disturbed than absence zones. This may be the result of inadequate protection of red panda habitat in the PA network. This observation is equivalent to the findings of Pradhan et al. (2001). Unspoiled forest provides better shelter, food and safety from predators with sheltered movement (Dorji et al., 2011; Pradhan et al., 2001; Wei et al., 1999a). Additionally, Bista et al. (2017a); Panthi et al. (2017; 2012) have indicated that undisturbed natural forest, is the ideal habitat for red pandas.

5. Conclusion

In general, our findings indicate that red panda prefers a less-disturbed habitat, albeit the impact of the variables mentioned above is different in different habitats. However, some variables manifested noticeable effects within and outside the PAs. Based on this revelation, a red panda-focused conservation program seems to be imperative on a national scale, though an area-specific conservation plan would be more efficacious, as the influence level of the recorded disturbance variables varies among sites, both within and outside the PAs. Similarly, we also recommend that pertinent conservation measures targeting these disturbance factors (with an emphasis on conservation awareness) be initiated as soon as possible in the entire habitat range. This step should be followed by a sustainable livelihood program focused on ending exploitation of forest resources, unregulated livestock herding and poaching. Designating walking trails and managing garbage within the panda habitat are equally important. In addition, restoration and re-planting at landslide sites should also be carried out, as such areas act as natural barriers to the movement for small mammals like red pandas. Linking isolated habitat patches through bio-bridges with the PAs and larger habitats would also be significant. Existing and new community forests could serve as the potential bio-bridges for maintaining habitat contiguity. This finding further underpins the need for community-based conservation programs outside the PAs. Endorsement of the red panda-focused conservation measures in the operation plan of the Community Forest User Groups may be effective at the community level and could be further extended on larger scale through the creation of a special red panda conservation zone that ensures the conservation of a genetically viable population in the long run. As most of these disturbance factors are observed to be of an anthropogenic nature, an integrated conservation program comprising education, sustainable livelihood, and habitat management seems to be an exigency at this stage.

Acknowledgements

We are very thankful to the WWF/USAID/Hariyo Ban Program and Red Panda Network for the financial support, and the Department of National Parks and Wildlife Conservation, and Department of Forests for granting permission to carry out this work. We would also like to acknowledge the support from the Ministry of Forest and Soil Conservation, government of Nepal and Himali Conservation Forum Taplejung. Likewise, we are very grateful to Dr. Angela Glatston for her thorough review and critical feedback on this paper. We are equally thankful to Terrance Fleming, Danielle Lippe and Dawn Peterson for editing this paper. Our gratitude also goes to all the field biologists and assistants for their support in creating this work.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.gecco.2018.e00420.

References

Beyschlag, W., Wittland, M., Jentsch, A., Steinlein, T., 2008. Soil crusts and disturbance benefit plant germination, establishment and growth on nutrient deficient sand. Basic Appl. Ecol. 9 (3), 243–252. https://doi.org/10.1016/j.baae.2007.03.002.

Bhatta, M., Shah, K.B., Devkota, B., Paudel, R., Panthi, S., 2014. Distribution and habitat preference of red panda (*Ailurus fulgens fulgens*) in Jumla district, Nepal. Open J. Ecol. 4 (15), 989. https://doi.org/10.4236/oje.2014.415082.

Bista, D., Paudel, R., 2014. An overview of the status and conservation initiatives of red panda *Ailurus fulgens* (Cuvier, 1825) in Nepal. Initiation 5, 171–181. https://doi.org/10.3126/init.v5i0.10268.

Bista, D., Shrestha, S., Sherpa, P., Thapa, G.J., Kokh, M., Lama, S.T., Khanal, K., Thapa, A., Jnawali, S.R., 2017a. Distribution and habitat use of red panda in the Chitwan-Annapurna Landscape of Nepal. PLoS One 12 (10), e0178797. https://doi.org/10.1371/journal.pone.0178797.

Bista, D., Shrestha, S., Kunwar, A.J., Acharya, S., Jnawali, S.R., Acharya, K.P., 2017b. Status of gastrointestinal parasites in red panda of Nepal. PeerJ 5, e3767. https://doi.org/10.7717/peerj.3767.

Central Bureau of Statistics, 2014. Population Monograph of Nepal. (Accessed 24 July 2018).

Choudhury, A., 2001. An overview of the status and conservation of the 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.

Ciuti, S., Northrup, J.M., Muhly, T.B., Simi, S., Musiani, M., Pitt, J.A., Boyce, M.S., 2012. Effects of humans on behaviour of wildlife exceed those of natural predators in a landscape of fear. PLoS One 7 (11), e50611. https://doi.org/10.1371/journal.pone.0050611.

Cuvier, F., 1825. Desinees d' Apris des Animaux Vicants. Histoire naturelle Des Mamniferes avec.des Figures Originales.calories, 2, pp. 1–3. Peris.

Dendup, S., 2016. Fire Impact on white-bellied Heron Habitats along the Bertichu, Zhemgang Dzongkhag.

Dorji, S., Vernes, K., Rajaratnam, R., 2011. Habitat correlates of the red panda in the temperate forests of Bhutan. PLoS One 6 (10), e26483. https://doi.org/10.1371/journal.pone.0026483.

Dorji, S., Rajaratnam, R., 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.

Fox, J., Yonzon, P., Podger, N., 1996. Mapping conflicts between biodiversity and human needs in Langtang National Park, Nepal. Conserv. Biol. 10 (2), 562–569. https://doi.org/10.1046/j.1523-1739.1996.10020562.x.

Glatston, A.R., 1994. Status Survey and Conservation Action Plan for Procyonids and Ailurids: the Red Panda, Olingos, Coatis, Raccoons and Their Relatives. IUCN, Gland, Switzerland.
Glatston, A., Wei, F., THAN, Z., Sherpa, A., 2015. *Ailurus fulgens*. The IUCN Red List of Threatened Species: e. T714A45195924.
Gratzer, G., Rai, P.B., Glatzel, G., 1999. The influence of the bamboo Yushania microphylla on regeneration of Abies densa in central Bhutan. Can. J. For. Res. 29 (10), 1518–1527. https://doi.org/10.1139/X07-101.
Hu, J.C., 1991. Reproductive biology of the red panda. J. Sich. Norm. Coll 12 (1991).
Jnawali, S., Leus, K., Molur, S., Glatston, A., Walker, S., 2012. Red panda (*Ailurus fulgens*). In: Population and Habitat Viability Assessment (PHVA) and Species Conservation Strategy (SCS) Workshop Report. National Trust for Nature Conservation, Kathmandu, Nepal. Conservation Breeding Specialist Group and Zoo Outreach Organization, Coimbatore, India.
Kandel, K., Huettmann, F., Suwal, M.K., Regmi, G.R., Nijman, V., Nekaris, K.A.I., Lama, S.T., Thapa, A., Sharma, H.P., Subedi, T.R., 2015. Rapid multi-nation distribution assessment of a charismatic conservation species using open access ensemble model GIS predictions: red panda (Ailurus fulgens) in the Hindu-Kush Himalaya region. Biol. Conserv. 181, 150–161. https://doi.org/10.1016/j.biocon.2014.10.007.
Kargel, J.S., Leonard, G.J., Shugar, D.H., Haritashya, U.K., Bevington, A., Fielding, E.J., Fujita, K., Geertsema, M., Miles, E.S., Steiner, J., Anderson, E., 2016. Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake. Science 351 (6269), aac8353. https://DOI: 10.1126/science.aac8353.
Manfredi, E.C., Flury, B., Viviano, G., Thakuri, S., Khanal, S.N., Jha, P.K., Maskey, R.K., Kayastha, R.B., Kafle, K.R., Bhochhibhoya, S., Ghimire, N.P., 2010. Solid waste and water quality management models for Sagarmatha National Park and Buffer Zone, Nepal: implementation of a participatory modeling framework. Mt. Res. Dev. 30 (2), 127–142. https://doi.org/10.1659/MRD-JOURNAL-D-10-00028.1.
Ministry of Forests and Soil Conservation, 2015. Red Panda Field Survey and Protocol for Community Based Monitoring. Ministry of Forests and Soil Conservation, Singha Durbar, Kathmandu, Nepal.
Ministry of Forests and Soil Conservation, 2016. National Survey of Red Panda to Assess its Status, Habitat and Distribution in Nepal. Draft report submitted to Ministry of Forest & Soil Conservation.
Montgomery, D.C., Peck, E.A., Vining, G.G., 2012. Introduction to Linear Regression Analysis, vol. 821. John Wiley & Sons.
Naimi, B., 2015. Usdm: Uncertainty Analysis for Species Distribution Models. R package version pp.1-1.
Nepal, S.K., 2002. Mountain ecotourism and sustainable development: ecology, economics, and ethics. Mt. Res. Dev. 22 (2), 104–109. https://doi.org/10.1659/0276-4741(2002)022[0104:MEASD]2.0.CO;2.
Nepali, S.C., 2006. Nepal: Management Effectiveness Assessment of Protected Areas Using WWF's RAPPAM Methodology. WWF Nepal Program, Kathmandu, p. 33.
Panthi, S., Aryal, A., Raubenheimer, D., Lord, J., Adhikari, B., 2012. Summer diet and distribution of the red panda (*Ailurus fulgens fulgens*) in Dhorpatan hunting Reserve, Nepal. Zool. Stud. 51 (5), 701–709.
Panthi, S., Khanal, G., Acharya, K.P., Aryal, A., Srivathsa, A., 2017. Large anthropogenic impacts on a charismatic small carnivore: insights from distribution surveys of red panda Ailurus fulgens in Nepal. PLoS One 12 (7), e0180978. https://doi.org/10.1371/journal.pone.0180978.
Paudel, K., 2009. Status and distribution of red panda (*Ailurus fulgens*) in Manang district, Nepal. In: A Project Paper Submitted in the Partial Fulfillment of the Requirement for the Degree of Bachelor of Science in Forestry. Tribhuvan University, Institute of Forestry, Pokhara Campus, Nepal.
Paudel, P.K., 2012. Challenges to wildlife conservation posed by hunting in non-protected areas north of the Bardia National Park. In: Himalayan Biodiversity in the Changing World. Springer, Dordrecht, pp. 177–195.
Phillips, S.J., Anderson, R.P., Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. Ecol. Model. 190 (3–4), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026.
Pradhan, S., Saha, G.K., Khan, J.A., 2001. Ecology of the red panda *Ailurus fulgens* in the Singhalila national park, Darjeeling, India. Biol. Conserv. 98 (1), 11–18. https://doi.org/10.1016/S0006-3207(00)00079-3.
Reid, D.G., Jinchu, H., Yan, H., 1991. Ecology of the red panda *Ailurus fulgens* in the Wolong Reserve, China. J. Zool. 225 (3), 347–364. https://doi.org/10.1111/j.1469-7998.1991.tb03821.x.
Roberts, M.S., Kessler, D.S., 1979. Reproduction in red pandas, *Ailurus fulgens* (Carnivora: *Ailuropodidae*). J. Zool. 188 (2), 235–249. https://doi.org/10.1111/j.1469-7998.1979.tb03402.x.
Roder, W., Gratzer, G., Wangdi, K., 2002. Cattle grazing in the conifer forests of Bhutan. Mt. Res. Dev. 22 (4), 368–374. https://doi.org/10.1659/0276-4741(2002)022[0368:CGITCF]2.0.CO2.
Sharma, H.P., Belant, J.L., 2010. Threats and conservation of red pandas in Dhorpatan hunting Reserve, Nepal. Hum. Dimens. Wildl. 15 (4), 299–300. https://doi.org/10.1080/10871200903582634.
Sharma, H.P., Belant, J.L., Swenson, J.E., 2014a. Effects of livestock on occurrence of the vulnerable red panda *Ailurus fulgens* in Rara national park, Nepal. Oryx 48 (2), 228–231. https://doi.org/10.1017/S0030605313001403.
Sharma, H.P., Swenson, J., Belant, J.L., 2014b. Seasonal Food Habits of the Red Panda (*Ailurus Fulgens*) in Rara National Park, Nepal. https://doi:10.4404/hystrix-25.1-9033.
Shrestha, B., 1996. Park people conflict around the Royal Chitwan national park. In: Journal of Natural History Museum, vol. 15. Natural History Museum, Kathmandu.
Steffens, E., 2004. Red Pandas and Conservation: Political Ecology, Tenure, Livestock, and Hunting in High Altitude Forests of Nepal. University of Wisconsin-Madison.
Team, R., 2015a. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA. http://www.rstudio.com.
Team, R.C., 2015b. Foreign: Read Data Stored by Minitab, S, SAS, SPSS, Stata, Systat, Weka, DBase. R Package Version 0.8-66.
Wang, M.J., Li, J.Q., 2008. Research on habitat restoration of giant panda after a grave disturbance of earthquake in Wanglang Nature Reserve, Sichuan Province. Acta Ecol. Sin. 28, 5848–5855.
Wei, F., Feng, Z., Wang, Z., Hu, J., 1999a. Current distribution, status and conservation of wild red pandas Ailurus fulgens in China. Biol. Conserv. 89 (3), 285–291. https://doi.org/10.1016/S0006-3207(98)00156-6.
Wei, F., Feng, Z., Wang, Z., Zhou, A., Hu, J., 1999b. Use of the nutrients in bamboo by the red panda (*Ailurus fulgens*). J. Zool. 248 (4), 535–541.
Williams, B.H., 2003. Red panda in eastern Nepal: how do they fit into ecoregional conservation of the eastern Himalaya. Conserv. Biol. Asia 16, 236–250.
Williams, B.H., Dahal, B.R., Subedi, T.R., 2011. Project Punde Kundo: community-based monitoring of a red panda population in eastern Nepal. In: Red Panda, pp. 393–408. https://doi.org/10.1016/B978-1-4377-7813-7.00022-7.
Yonzon, P.B., Hunter Jr., M.L., 1991a. Conservation of the red panda *Ailurus fulgens*. Biol. Conserv. 57 (1), 1–11. https://doi.org/10.1016/0006-3207(91)90104-H.
Yonzon, P.B., Hunter, M.L., 1991b. Cheese, tourists, and red pandas in the Nepal Himalayas. Conserv. Biol. 5 (2), 196–202. https://doi.org/10.1111/j.1523-1739.1991.tb00124.x.
Yonzon, P., Jones, R., Fox, J., 1991. Geographic Information Systems for Assessing Habitat and Estimating Population of Red Pandas in Langtang National Park, Nepal. Ambio, pp. 285–288.
Zhang, J.S., Daszak, P., Huang, H.L., Yang, G.Y., Kilpatrick, A.M., Zhang, S., 2008. Parasite threat to panda conservation. EcoHealth 5 (1), 6–9. https://doi.org/10.1007/s10393-007-0139-8.
Zhang, J., Hull, V., Ouyang, Z., Li, R., Connor, T., Yang, H., Zhang, Z., Silet, B., Zhang, H., Liu, J., 2017. Divergent responses of sympatric species to livestock encroachment at fine spatiotemporal scales. Biol. Conserv. 209, 119–129. https://doi.org/10.1016/j.biocon.2017.02.014.
Zheng, W., Xu, Y., Liao, L., Yang, X., Gu, X., Shang, T., Ran, J., 2012. Effect of the Wenchuan earthquake on habitat use patterns of the giant panda in the Minshan Mountains, southwestern China. Biol. Conserv. 145 (1), 241–245. https://doi.org/10.1016/j.biocon.2011.11.016.