FOOD HABITS AND CONSERVATION THREATS OF THE RED PANDA IN RARA NATIONAL PARK, NEPAL

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Photo by Hari Prasad Sharma

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Summary

This thesis deals with issues of conservation threats to the red panda (*Ailurus fulgens*), specifically regarding foraging resources and anthropogenic activities i.e. livestock grazing.

I studied the diet components of red panda during the pre-monsoon and post-monsoon seasons of this herbivorous carnivore. I evaluated the diet of red panda through micro-histological study of fecal matters to determine the composition of diets. The results indicated that the red panda feeds primarily on bamboo (*Thamnocalamus* sp.) species, which comprised 90.6% and 77.8% of the volume of pre-monsoon and post-monsoon scats respectively, followed by minute consumption of *Abis spectabilis, Rhododendron arboreum, Quercus semecarpifolia, Betula utilis, Tsuga dumosa, Acer acuminatum* and *Texus wallichiana.* Seasonal fruits of *Aconogonum* sp., *Juniperus indica, Sorbus cuspidata* and mushrooms were found only in the post-monsoon season and comprised 13.8% of the volume of scats. This result indicated that the red panda is a bamboo specialist, explaining why it selects forest habitat with bamboo-dominated understory. I conducted a literature review to determine the degree to which bamboo was a part of the species' diet throughout its range. I found that different species of bamboo were always of major importance, which suggests that factors negatively affecting the availability of bamboo can be an important threat for the species. Such factors include livestock grazing and other human-related factors and potentially bamboo die-off after mass flowering, as found with giant panda (*Ailuropoda melanoleuca*) in the mid-1970s.

Based on this, I investigated the effects of illegal grazing inside Rara National Park on the occurrence of red pandas. I found that livestock grazing had a small but significant adverse effect on red panda presence and that bamboo availability within a certain elevational range with water sources determined red panda occurrence.

PART ONE: SYNOPSIS

Introduction

The red panda (*Ailurus fulgens*) is one of the threatened species in the Himalayan region (IUCN 2012), and inhabits mountainous ranges of Bhutan, China, India, Myanmar, and Nepal. Its preferred habitat is bamboo-dominated understory in evergreen, deciduous, and mixed evergreen and deciduous forests (Choudhury 2001; Pradhan et al. 2001; Roberts & Gittleman 1984; Wei et al. 1999; Yonzon 1989). The ecology of this species is little known due to its low population worldwide <10,000 individuals (Wang et al. 2008) and restricted distribution in remote areas.

The red panda has received much interest in the conservation field, due to its specialized habitat and feeding behavior (Glatston 1994; Wei et al. 1996). Taxonomically, it is a carnivore, but the feeding habit is herbivorous. Many wildlife species are threatened by the loss of bamboo (Kratter 2006; Reid et al. 1989; Remsen 1986; Tan 1999). The red panda is among these species and additional threats include human persecution and habitat loss due to fragmentation, deforestation, and resource uses in red panda habitat (Schaller et al. 1985; Sharma & Belant 2010; Wei et al. 1999; Williams 2003).

This study examined the occurrence and diet of red panda in Rara National Park (RNP), Nepal. To achieve this goal, I made a micro-histological analysis of fecal matters from the pre-monsoon and post-monsoon seasons (Manuscript 1). From this study, I found that the red panda is a diet-specialist species and depends only on bamboo in all seasons. Thus, I assumed that it is found only in areas where bamboo is present. Based on this assumption, I studied the possible effect of livestock grazing on the occurrence of red pandas (Manuscript 2).

Study area

RNP comprises 106 km^2 in mid-western Nepal (81° E, 29° N) with elevations ranging from 2754 to 4097 m. The park contains mainly coniferous forest and is dominated by blue pine (*Pinus wallachiana*) up to 3200 m. Other tree species include rhododendron (*Rhododendron arboretum*), black juniper (*Juniperus indica*), west Himalayan spruce (*Picea smithina*), oak (*Quercus semecarpifolia*), and Himalayan cypress (*Cupressus torulosa*). A mixed forest of pine, spruce, and fir occurs from 3200 to 3550 m. At about 3350 m, the forest changes to coniferous-broadleaf forest of fir, oak, and birch. Other deciduous tree species include Indian horse-chestnut (*Aesculus indica*), walnut (*Junglans regia*), and Himalayan poplar (*Populus ciliata*). The Park is surrounded by nine Village Development Committees within Jumla and Mugu districts, which have been declared a Buffer Zone and comprise 198 km^2.

Materials and Methods

I studied red panda's food habits by fecal analysis, in which the plant fragments were compared with reference plants slides prepared during this study (Manuscript 1). I collected leaves of fifteen common plant species and fruits of four plants in RNP that presumably were consumed by red pandas (Wei et al., 1999). I photographed each reference material using a digital camera attached to a stereoscope or compound microscope at 200X and 400X magnifications with an ocular measuring scale to aid in identifying materials in fecal samples. Feces were analyzed following Anthony & Smith (1974) and Holechek *et al*. (1982). Laboratory work was conducted at the Central Department of Zoology, Tribhuvan University, Kathmandu.

To identify the effects of livestock grazing on red panda occurrence, I delineated a total of 25 vertical transects at 500-m intervals in the forest around Rara Lake and established 10 x 10 m plots along each at 100-m increase in elevation (total of 106 plots) (Manuscript 2). Only livestock grazing was found among the anthropogenic activities inside the park, even though it was illegal. The livestock foraged on bamboo, which is a major food of red pandas.

Results and Discussion

To address the seasonal composition of food before and after fruiting, I evaluated the micro-histological analysis of feces. Bamboo consumption was found to be higher than other components in both seasons. In the post-monsoon season, the bamboo consumption was lower (77.8%) than pre-monsoon season (90.6%), due to foraging on seasonal fruits. From the literature on diet of red panda, I predicted that an important conservation threat to the survival of red panda may be the factors that negatively affect the availability of bamboo, such as human-influenced factors, such as livestock grazing and collection from the forest, and natural factors, such as mass die-off of bamboo flowering, which has negatively affected another bamboo-specialist carnivore, the giant pandas (Johnson et al. 1988; Panthi et al. 2012; Pradhan et al. 2001; Reid et al. 1989; Wei et al. 1996; Wei et al. 2000; Yonzon 1989; Zhang et al. 2006) (Manuscript1).

Similarly, the occurrence of red panda was affected by livestock grazing in RNP, based on the low probability of detecting red panda latrines in areas grazed by livestock. Logistic regression models also indicated that the presence of bamboo and water sources was important to red pandas, but they did not influence their habitat use at the spatial scale I studied (Manuscript 2).

Perspectives for future studies

In this study, I identified critical feeding and habitat components and their possible effects on the survival of red pandas. However, some important questions still have to be addressed, including compiling comprehensive records of past mass flowering of bamboos within red panda habitat, population estimation of red pandas, and determining the carrying capacity of RNP for long-term red panda survival.

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PART TWO: COMPILATION OF MANUSCRIPTS

Manuscript 1 (To be submitted to a peer-reviewed journal)

The diet of red panda in Rara National Park, Nepal: Possible effects of bamboo loss on the species' persistence

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ABSTRACT

The seasonal food habits of red panda *Ailurus fulgens* were estimated based on the analysis of 152 latrines in Rara National Park, Nepal, using micro-histological techniques. We also reviewed previous studies documenting the degree of specialization in red panda diets throughout their range. We found that bamboo was the major food item for red panda in Rara National Park, representing 77.8% and 90.6%, in post- and pre-monsoon seasons, respectively. Similarly, bamboo was also reported as the dominant food item (81–99%) of red pandas in all previous studies conducted throughout their range. We suggest that red pandas may be

vulnerable to bamboo loss through anthropogenic impacts and potentially natural mass bamboo die-offs. Loss of bamboo may pose an important threat to their survival.

Key words: *Ailurus fulgens*, bamboo die-off, diet, mass flowering, conservation.

Introduction

Documenting the foraging behavior of wildlife is important for understanding the ecology, evolution, and conservation of animals (Symondson 2002). Feeding habits of wildlife may vary with season, land use, plant composition, and population status (Korschgen 1962) and be linked to the abundance, phenology, and nutrient quality of plants (Short 1971). Identifying the food of red panda (*Ailurus fulgens*) might be of important for conservation planning, especially habitat protection. There are about <10,000 red pandas in the wild and the population is declining (Wang et al. 2008). This indicates a need for more detailed information about red panda habitat requirements. Documenting the preferred food of red pandas throughout their range is required to improve our knowledge of their habitat requirements.

The red panda is globally vulnerable (IUCN 2012) and has a restricted geographic range of the Himalayan Range in Bhutan, China, India, Myanmar and Nepal, from 1500 to 4800 m in elevation (Choudhury 2001). The red panda inhabits in evergreen, deciduous and mixed evergreen and deciduous forest of dense understory bamboo (Roberts and Gittleman 1984; Wei et al. 1999; Choudhury 2001; Pradhan et al. 2001). Bamboos (Bambuseae) have been found to be an important component of the food for red panda wherever its diet has been studied (Das and Thapa 1999; Pradhan et al. 2001; Yonzon and Hunter 1991; Wei et al. 2000). We documented the red panda’s diet in Rara National Park (RNP), Nepal, and summarized the available literature regarding the degree of bamboo specialization. Based on this, we address the potential effects of loss of bamboo on this species in relation to its conservation.

Methods

Study area

Rara National Park (RNP) comprises 106 km^2 in mid-western Nepal (81° 59'54" to 82° 08'27" E, 29° 26' 28" to 29° 33'11" N) (Figure 1) with elevations ranging from 2754 to 4097 m. It was established and gazetted in 1976 to conserve its biodiversity and Rara Lake (10.8 km^2). The park contains mainly coniferous forest and the area around the lake is dominated by blue pine (*Pinus wallachiana*) up to 3200 m. Other tree species include rhododendron (*Rhododendron arboretum*), black juniper (*Juniperus indica*), west Himalayan spruce (*Picea smithina*), oak (*Quercus semecarpifolia*), and Himalayan cypress (*Cupressus torulosa*). A mixed forest of pine, spruce, and fir occurs from 3200 to 3550 m. At about 3350 m the forest changes to a coniferous-broadleaf forest of fir, oak, and birch. Other deciduous tree species include Indian horse-chestnut (*Aesculus indica*), walnut (*Junglans regia*), and Himalayan poplar (*Populus ciliata*). The Park is surrounded by nine Village Development Committees within Jumla and Mugu districts, which have been declared a Buffer Zone and comprise 198 km^2.

Reference plants

We collected the leaves of 15 common plant species that presumably were consumed by red pandas in RNP (Wei et al. 1999). The sampled potential red panda foods were *Thamnocalamus* sp, *Abies spectabilis, Juniperus indica*, *Rhododendron arboretum, R. campanulatum, Quercus semecarpifolia, Sorbus cuspidata*, *Betula utilis, Tsuga dumosa, Texus wallichiana, Acer acuminatum,* and mushrooms. We followed Polunin and Stainton (1984) for plant nomenclature.

We also collected fruit with seeds of *Sorbus cuspidata*, *Aconogonum* sp., *Juniperus indica,* and *J. squamata* during the post-monsoon season. We prepared reference slides for two basic forms of each *Thamnocalamus* and *Yushania*/*Chimnobambusa* sp. (i.e., newly sprouted shoots and mature leaves).

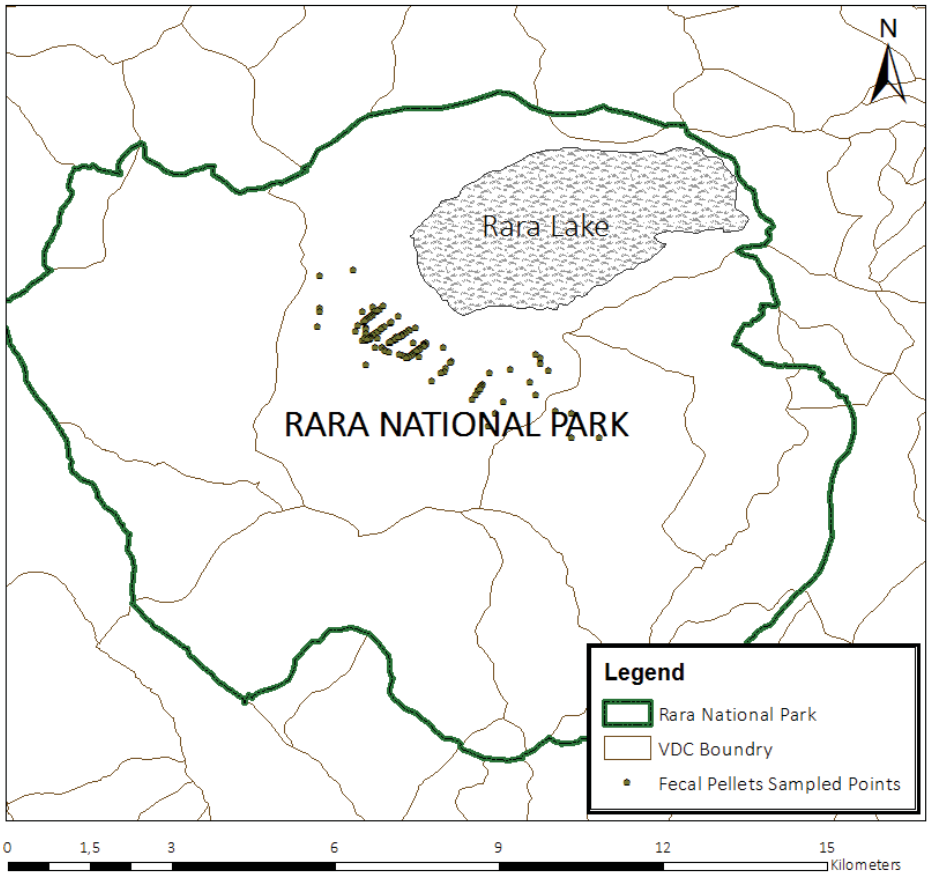

Figure 1: Rara National Park and red panda fecal sampled collection points

We oven-dried plant samples at 60–70˚C, then ground them separately with an electric grinder, and sieved the products using a 1-mm followed by a 0.3-mm mesh. We retrieved contents from the 0.3 mm sieve and treated samples with 10% concentrations of nitric and chromic acid solutions (Dusi 1949) for at least 4 hours in a warming oven at 40 ˚C until samples became transparent. We cooled and washed plant samples to remove the acid, then placed each in an ethyl alcohol bath series (30%, 50%, 70%, 90%, and 100% concentrations) for 15 minutes in each concentration for dehydration. We used a DPX- resin mounting medium on each slide. We photographed reference materials using a digital camera attached to a stereoscope or compound microscope at 200X and 400X magnifications with an ocular measuring scale to aid in identifying materials in fecal samples.

Fecal Samples

We collected fecal pellet groups in August–November (post-monsoon) 2007 and March–June (pre-monsoon) 2011 from established transects in the area (Figure 1). We analyzed the feces following Anthony and Smith (1974) and Holechek et al. (1982). We mixed all pellets in each pellet group thoroughly in the field and placed about one fourth of the sample in a labeled plastic bag, then transported the samples to a laboratory of the Central Department of Zoology, Tribhuvan University, Kathmandu. We also examined the feces for animal parts, e.g. bone and hair.

We prepared fecal material following procedures described for reference plants, except that fecal material was treated with a 5% concentration of NaOH solution and boiled until the samples became transparent. We prepared two slides from each fecal sample. We separated undigested seeds before grinding and used one quarter of them for data analysis. We identified plant fragments based on distinguishing features found in reference slides by microscopic examination of whole mounts. We recorded all fragments found along the central line of the slide.

Data analysis

We calculated percent frequency of occurrence of each food item following:

$$\%\ \text{Occurrence} = \frac{\text{Number of occurrence of food item} \times 100}{\text{Total number of occurrences of all food items}}.$$

We then calculated food niche overlap between seasons using Pianka's Index (1973):

$$Ojk = \frac{\sum_{i=1}^{n} pij\ pik}{\sum pij^2\, pik^2},$$

where O_{jk} is Pianka's Index of food niche overlap between the pre-monsoon season *j* and post-monsoon season *k*; *pij* and *pik* are the % occurrence of food items *i* in relation to the total species of food items in seasons *j* and *k* and n is the total number of food items. Pianka's Index is symmetrical regarding overlap between season *j* and season *k* and ranges from 0 (no overlap) to 1 (complete overlap).

We also used Levin's measure (Krebs 1999) to estimate food niche breadth:

$$\mathrm{B} = \frac{1}{\sum pi^2},$$

where B is Levin's measure of food niche breadth, *pi* is the % occurrence of food item i in the diet, and n is the total number of food items. Then, we calculated Levin's standardized food niche breadth, B_S, as

$$Bs = \frac{B-1}{n-1},$$

where B is Levin's measure of food niche breadth and *n* is the total number of food items in the pellets each season.

We tested whether niche overlap differed between seasons by comparing observed values with values obtained by randomizing the original matrices (1000 iterations) using the default procedure (RA3) of ECOSIM 7 software (Entsminger 2012). We used χ^2 tests to compare occurrence of food items within seasons and a Welch's two sample *t*-test for between season comparisons. We assumed statistical significance at $\alpha < 0.05$.

Literature Review

We used Google Scholar® to search for articles documenting the diet of red pandas throughout their geographic range (Figure 2). We used the keywords, "Red panda or *Ailurus fulgens* or diet or food habits or bamboo die-offs or bamboo-dependent species or food specialist species". From the articles retrieved, we reviewed literature cited sections for additional articles on red panda diet not found during the literature search. We then summarized the seasonal and annual proportional intake of bamboo and other red panda food items based on studies of fecal contents, bamboo species found the study areas where red panda food habits had been studied, and effects of bamboo flowering and subsequent mass die-offs on bamboo-dependent species.

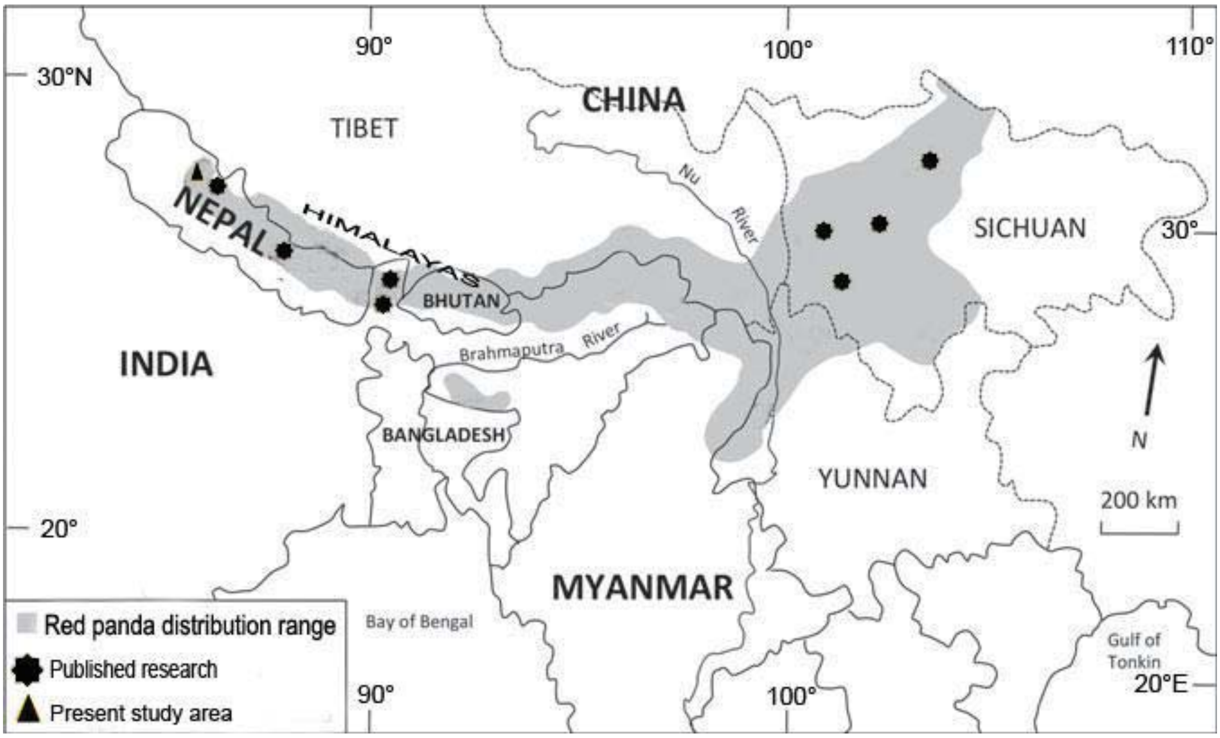

Figure 2. Red panda distribution range (modified from Choudhury 2001 and Dorji et al. 2012), showing present research and published researches focusing on the diet on the red panda.

Results

We analyzed 152 fecal samples with equal numbers from the pre- and post-monsoon seasons. The frequency of occurrence of food types differed within both the pre-monsoon ($\chi^2_{0.05,7}$ = 304.0, $P < 0.001$) and post-monsoon ($\chi^2_{0.05,10}$ = 368.0, $P < 0.001$) seasons. Bamboo (*Thamnocalamus* sp.) was the primary food item during both the pre-monsoon (90.6%) and post-monsoon (77.8%) seasons (Table 1). *Juniperus indica*, S*orbus cuspidata*, *Aconogonum* sp. and mushrooms were found only during the post-monsoon and *Texus wallichiana* only during the pre-monsoon season. The occurrence of non-bamboo foods was comparatively similar and all foods had an occurrence <3% during the pre-monsoon. However, during the post-monsoon season, the occurrence of *Aconogonum* sp. was greater (13.8%) than other non-bamboo foods, which were < 3% each. Percentages of *A. spectabilis, R. arboreum,* and *Q. semecarpifolia* were greater during the pre-monsoon season, but there were no seasonal differences for percentages consumed for *Thamnocalamus* sp., *B. utilis*, *T. dumosa,* and *A. acuminatum* (Table 1). We found no remnants of animal matter in the feces we analyzed.

Pianka's Index of food niche overlap was not significant between seasons, although there was a tendency towards a difference (*Ojk* = 0.67, *p* = 0.71), perhaps a consequence of the high occurrence of bamboo in both seasons. Levin’s food niche breadth was slightly less (1.2) in the pre-monsoon than the post-monsoon season (1.6). Levin’s standardized food niche breadth was also less in pre-monsoon season (0.02) than in the post-monsoon (0.06) season.

Table 1. Mean (+ standard error [*SE*]) percentage occurrence of plant fragments in fecal pellets of red panda, Rara National Park, Nepal, during pre- and post-monsoon seasons 2012. Welch's two sample *t*-test was used to test differences in food items consumed by red panda between pre- and post-monsoon seasons.

	Within season comparisons				Between season comparisons	
	Pre-monsoon		Post-monsoon			
Plant species	Mean	SE	Mean	SE	*T*	*P*
Thamnocalamus sp.	90.6	1.6	77.8	1.7	1.74	0.083
Aconogonum sp.	0	0	13.8	0.2	-	-
Juniperus indica	0	0	2.8	0.5	-	-
Sorbus cuspidate	0	0	1.5	0.2	-	-
Abies spectabilis	2.7	0.6	1.0	0.2	2.12	0.036
Mushroom	0	0	0.8	0.2	-	-
Rhododendron Arboretum	2.4	0.5	0.7	0.2	2.7	0.008
Quercus semecarpifolia	1.7	0.4	0.6	0.4	0.99	0.049
Betula utilis	1.0	0.2	0.6	0.2	0.69	0.491
Tsuga dumosa	0.7	0.2	0.5	0.1	0.25	0.805
Acer acuminatum	0.6	0.2	0.2	1.6	1.67	0.098
Texus wallichiana	0.3	0.1	0	0	-	-

Table 2. Food items consumed by red panda throughout its geographic range. a = annual, p = pre-monsoon, q = post-monsoon, and s = summer; - = no indication.

		% Food item consumed			
Location	Bamboo species	Bamboo	Foliage other than bamboo	Fruit	Source
Rara National Park, mid-western Nepal	*Thamnocalamus* sp	90.6^{p} 77.8^{q}	9.4^{p} 4.1^{q}	 18.1^{q}	Present study
Dhorpatan Hunting Reserve, western Nepal	*Arundinaria* spp.	81.7^{s}	16.2^{s}	2.1^{s}	Panthi et al. (2012)
Langtang National Park, central Nepal	*Himalayacalamus aristata*	83^{q}	-	15.4^{q}	Yonzon (1989)
Singhila National Park, north-western India	*Arundinaria maling* and *A.aristata*	95^{q}	-	5^{q}	Pradhan et al. (2001)
Neora Valley National Park, west Bengal, India	*Yushania maling, A. hookeriana, A. aristata*	Not quantified	-	-	Mallick (2010)

Wolong National Park, Sichusan, China	*Sinarundinaria fangiana* *Fargesia spathacea*	99.1[a]	-	<1	Reid et al.(1989) and Johnson et al. (1988)
Fengtongzhai Nature Reserve, Sichusan Province, China	*Bashania faberi*	99[p] 85[q]	-	14[q]	Zhang et al. (2006)
Mabian Nature Reserve, Sichusan Province, China	*Qiongzhuea macrophylla, Yushania glauca* and *Q.macrophylla*	87[a]	-	-	Wei et al. (1996)
Yale Nature Reserve, Sichusan Province, China	*Bashania spanostachya, Fargesia dulcicula, Fargesia exposita*	89.9[a]	-	<1[a]	Wei et al. (2000)

We located nine studies in the literature that collectively documented nine genera of bamboo consumed by red pandas (Table 2). The reported occurrence of bamboo species in fecal pellets was >78% in the post-monsoon season and in the pre-monsoon season, occurrence of bamboo was >91% in all studies. Consumption of fruits was comparatively low and seemed to represent local opportunistic feeding. Fruits consumed included the genera *Prunus, Rubus, Ribes, Sorbus, Sabina, Aconogonum, Juniperus, Berberis,* and *Actinidia.*

Discussion

We identified twelve plant species and no animal matter in the diet of red panda at RNP. The dominant food item was bamboo, *Thamnocalamus* sp., which comprised 77.8% and 90.6% of the diet in post- and pre-monsoon seasons, respectively. Thus, the red panda is a bamboo specialist, explaining why it selects habitats with bamboo-dominated understory (Yonzon 1989). The leaves and shoots of *Thamnocalamus* sp. were the major food components for red pandas at RNP, with other plant species used comparatively infrequently, except fruits in the post-monsoon season. The percentage of *Thamnocalamus* sp. in the diet was slightly greater in pre-monsoon than post-monsoon, perhaps due to limited access to fruit during this season.

Levin's standardized food niche breadth was relatively higher in the post-monsoon season than pre-monsoon due to more food items available for feeding during this period. The food niche overlap of red panda diet between seasons indicated overall diet similarities, a consequence of high bamboo consumption during both seasons and comparatively few supplementary foods. However, the consumption of different plant species was greater in RNP than other red panda diet studies. We are unsure of the reason, but *R. arboreum, B. utilis, Q. semecarpifolia, A. spectabilis,* and *Acer* spp, were consumed in minor amounts in this study, as also was documented in Dhorpatan Hunting Reserve, Nepal (Panthi et al. 2012). This shows the major dependency of red panda on bamboo in both seasons, but that red pandas do show flexibility in their diet.

The percentage occurrence of bamboo consumed by red pandas in RNP was less than reported in Fengtongzhai Nature Reserve, China, Singhila National Park, India, and Dhorpatan Hunting Reserve, Nepal in the post-monsoon season (Table 2). During the pre-monsoon season, we found high use of bamboo (91–99%) in all red panda diet studies (Johnson et al. 1988;

Pradhan et al. 2001; Reid et al. 1989; Zhang et al. 2006). In addition to bamboo, berries in the post-monsoon (autumn) and small mammals, birds, eggs, blossoms, acorn, and mushrooms were found in the diet of red pandas (Jonson et al. 1988). These seem to be supplementary foods, with bamboo as the staple food (Roberts and Gittleman 1984). No other parts (e.g., leaves or twigs) of fruiting species were observed in red panda pellets, indicating that fruit consumption represents opportunistic foraging of seasonally available resources.

Red pandas consume only a few species of the Bambuseae available throughout their range. For example, 6 of 15 bamboo species were reported consumed in China and 1 of 4 species in Langtang National Park, Nepal (Qi et al. 2009; Yonzon 1989). In our study area, *Thamnocalamus* sp. and *Yushania*/*Chimnobambusa* sp. were available, but only *Thamnocalamus* sp. was eaten by red pandas. However, *Yushania*/*Chimnobambusa* sp was uncommon and found in lowlands ≤3000 m in elevation. Red pandas may shift to other bamboo species if a preferred species is scarce, as shown by Schaller et al. (1985) for *Fargesia spathacea* and *Sinarundinaria fangiana* in Wolong National Park and for *Arundinaria maling* and *A. aristata* in Singhilia National Park (Pradhan et al. 2001).

Bamboos flower synchronously at 40–100 year intervals, depending on the species (Janzen 1976), and the plants die after flowering. Thus, synchronous bamboo flowering and subsequent mortality can have a strong effect on bamboo-dependent species (Reid et al. 1989). For example, in the mid-1970s, periodic synchronous flowering and mass die-off of bamboo in the Min Mountains of Sichuan and Gansu provinces, China, resulted in the starvation of 138 giant pandas, whose diet consist of 99% bamboo (Johnson et al. 1988; Schaller et al. 1985). Both the red panda and giant panda inhabit similar habitats containing bamboo (Wei et al. 2000). Might a mass die off of bamboo after mass flowering have a similar effect on red panda populations, as it has had on giant pandas? Perhaps a more general and immediate danger is the numerous factors that can reduce the distribution and abundance of bamboos, such as land use change, livestock grazing, collection for livestock fodder, and human needs including house construction, ornamentals, and furniture (Das and Thapa 1999; Janzen 1976; Reid and Jinchu 1991; Remsen 1986; Schaller et al. 1985; Seeland 1980; Sharma and Belant 2010; Tan 1999).

The results of our study and literature review suggest that red pandas may be vulnerable to bamboo loss, either from anthropogenic activities or mass bamboo die-off following mass flowering. The virtual extinction of Bachman's Warbler (*Vermivora bachmanii*), also a bamboo specialist (Remsen 1986), and increased mortality of giant panda in China (Johnson et al. 1988), were both due to mass die-offs of bamboo species. Thus, this phenomenon also may pose a threat to red pandas, although this is difficult to quantify, because we are unaware of a comprehensive record of past mass flowering of bamboos within the geographic distribution of red panda. Nevertheless, many questions remain regarding the ability of red pandas to shift food preferences, or the importance of habitat variables other than food. Therefore, we call for raised awareness of the need to conduct research on red pandas that includes estimating and mapping suitable habitat and emphasizing the potential impact of factors that affect the availability of high quality bamboo of preferred species and that of mass die-offs of bamboo.

Conclusions

The red panda, a bamboo-dependent species, is globally vulnerable to extinction due to natural and anthropogenic activities. Because it is a year-round dietary specialist of bamboo, factors affecting the availability of preferred bamboo could seriously threaten the red panda populations.

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Manuscript 2 (Submitted to Peer Reviewed Journal)

Effects of livestock grazing on red panda habitat use

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Abstract

The red panda (*Ailurus fulgens*) is a globally-threatened carnivore inhabiting the Himalayan Range. Anthropogenic activities, including deforestation, adversely affect red panda habitat use; however, the effects of livestock on red panda habitat use have not been addressed. We assessed the effects of illegal livestock activity on red panda habitat use in Rara National Park (RNP), Nepal, using logistic regression. We found that the probability of detecting red panda pellets was negatively associated with livestock occurrence and positively associated with increasing elevation. Presence of bamboo and proximity to water are important to red pandas, but did not influence their habitat use at the spatial resolution used in this study. We suggest that the current intensity of livestock use in RNP adversely affects red panda habitat use and encourage increased education and enforcement of park regulations to reduce livestock use of RNP.

Keywords *Ailurus fulgens*, Threatened species, Habitat, Grazing, Conservation

Introduction

The red panda (*Ailurus fulgens*) is endemic to the Himalayan Range of Bhutan, China, India, Myanmar, and Nepal (Roberts & Gittleman, 1984) at elevations from 1500 to 4800 m (Yonzon & Hunter, 1991; Choudhury, 2001; Pradhan et al., 2001, Sharma & Belant, 2009). Red pandas occur in evergreen, deciduous, and mixed evergreen and deciduous forests with dense understory (Roberts & Gittleman, 1984; Wei et al., 1999; Choudhury, 2001; Pradhan et al., 2001). Within these forests, red pandas have microhabitat requirements including fallen logs for resting and feeding, bamboo or fruiting vegetation for forage, and open water (Yonzon, 1989; Wei et al., 2000; Pradhan et al., 2001; Zhang et al., 2004; Dorji et al., 2011).

The red panda is classified as vulnerable to extinction across its geographic range by the IUCN Red List of Threatened Species (IUCN, 2012). Major threats to red pandas throughout their range include human persecution and habitat loss due to fragmentation and deforestation (Schaller et al., 1985; Wei et al., 1999; Choudhury, 2001; Williams, 2003). In addition, other resources use, including livestock grazing and collection of plants for livestock feed (Schaller et al., 1985; Wei et al., 1999; Sharma & Belant, 2010), may further alter the structure and quality of red panda habitats. Understanding red panda habitat use and factors that influence their selection, especially anthropogenic activities, are important for the species' conservation. Livestock grazing is one of the major conservation threats in protected areas of developing countries (Berkmueller et al., 1990), and livestock, particularly cattle and buffalo, can destroy wildlife habitat, compete for food with native species, and introduce diseases (Jolles et al., 2005; Schmidt et al., 2005), which has lead to population declines of some species (Muchiru et al., 2008). Consequently, we investigated red panda habitat use in relation to a dominant anthropogenic pressure, livestock grazing. Specifically, we assessed the effects of livestock use on red panda habitat selection.

Methods

We collected data during May–July 2011–2012 in Rara National Park, Nepal (29°25′48″N, 81°00′00″E; Fig. 1). The study area elevation ranged from 2800 to 4090 m. Dominant trees and shrubs include blue pine (*Pinus wallachiana),* rhododendron (*Rhododendron arboreum*), black juniper (*Juniperus indica*), west Himalayan spruce (*Picea smithina*), oak (*Quercus semecarpefolia*), Himalayan cypress (*Cupressus torulosa*), Indian horse-chestnut (*Aesculus indica*), walnut (*Junglans regia*), and Himalayan poplar (*Populus ciliata*). Fauna in the park includes Himalayan black bear (*Ursus thibetanus*), common leopard (*Panthera pardus*), musk deer (*Moschus moschiferous*), goral (*Nemorhaedus goral*), Himalayan tahr (*Hemitragus jemlahicus*), and wild dog (*Cuon alpinus*). The park is surrounded by nine Village Development Committees within Jumla and Mugu districts, which have been declared a Buffer Zone with the goal of increasing the people's participation in conservation for long-term sustainability and minimizing park-people conflicts (Budhathoki, 2004). The Buffer Zone and park together comprise 304 km^2. Livestock grazing has occurred in RNP and the adjacent buffer zone since before its establishment in 1976. There are no defined grazing units or fencing inside the park, nor is the park boundary fenced.

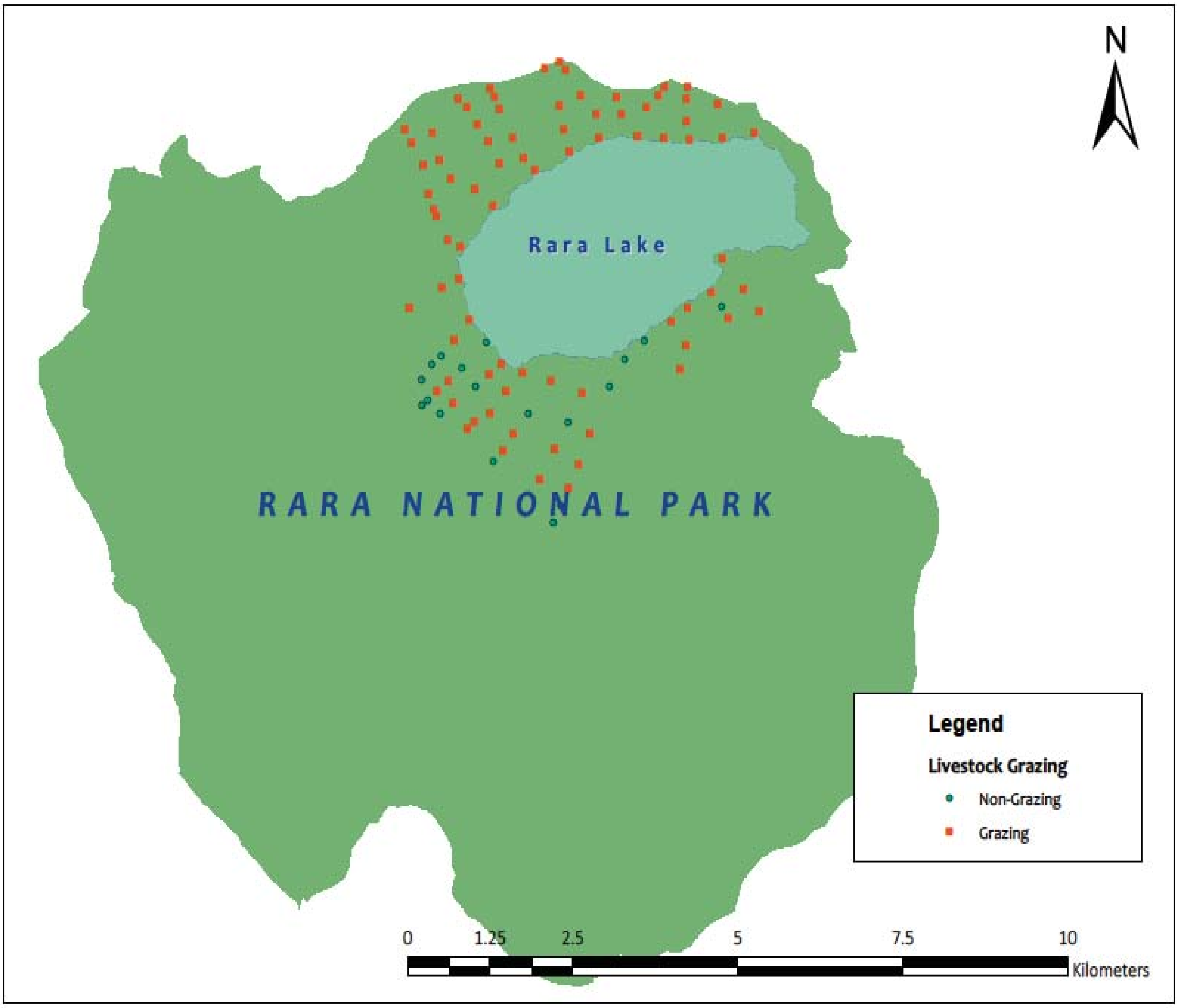

Fig.1 Rara National Park, Nepal, and sampling plots for red panda fecal pellet groups, showing where illegal grazing was documented.

We delineated 25 vertical transects in the forest around Rara Lake at 500-m intervals and established 10 x 10 m plots along each at 100-m increases in elevation (total of 106 plots). The lowest elevation plots in each transect were within 50 m of the park road. At each plot, we recorded aspect and elevation using a handheld GPS. We measured distance from the plot center to the nearest open water using a measuring tape. We documented the presence of livestock grazing as evidenced by sign (e.g. livestock dung, tracks, trampling of vegetation, and areas eroded from livestock movement), bamboo, and red panda fecal pellet groups in each plot.

We calculated means and standard deviations (SD) of continuous variables for plots with and without red panda pellets. We used logistic regression in program R (function glmer; Comprehensive R Archive Network 2011) to estimate the effects of bamboo presence, elevation, livestock grazing presence, aspect, and distance to water on the presence of red panda fecal pellet groups. Because red pandas are bamboo specialists (Roberts & Gittlemans, 1984; Gittleman, 1994; Glatston, 1994), we included bamboo presence in all models and ran all combinations of variables without interactions. Before conducting the logistic regressions, we ran a correlation matrix on all explanatory variables and did not include those with $r > 0.7$ in the same model. We calculated pseudo R^2 for each model and accepted statistical significance at alpha < 0.05.

We ranked models using Akaike Information Criterion adjusted for small samples (AIC_c; Burnham & Anderson, 2002) and selected the best models based on the lowest AIC_c value ($\Delta AIC_c<2$; Arnold (2010)). We used Akaike model weights to estimate the relative strength of evidence for each model. We conducted model averaging using all models to estimate 85% confidence intervals for each variable and assumed that variables influenced red panda presence if the confidence intervals did not encompass 0.

Results

We surveyed 53 plots on 14 transects on north-facing slopes in 2011 and 53 plots on 11 transects on south-facing slopes in 2012. We detected red panda pellet groups in 23 plots (21.7%) on north-facing slopes at elevations from 3185 to 3516 m. The mean ± SD elevation of plots with and without red panda pellet groups was 3166 ± 144 m and 3205 ± 167 m, respectively. Bamboo (*Thamnocalamus* spp.) occurred only in plots on the north-facing slopes at elevations from 2985 to 3516 m. The mean distance to nearest open water for plots with and without red panda pellet groups was 60.6 ± 41.3 m and 99.6 ± 82.0 m, respectively. Livestock grazing occurred in 75.5% of the plots and was observed from 2985 to 3600 m elevation.

Table 1 Logistic regression models describing red panda occurrence in Rara National Park, Nepal, 2011–2012, ranked according to Akaike Information Criterion adjusted for small sample size (AIC_c). Model parameters include Bamboo (bamboo presence), Elevation (m), Aspect (north or south), Water (distance to water nearest open water), and Grazing (presence of cattle grazing). K is the number of parameters, AIC_c is Akaike's Information Criterion adjusted for small sample size, ΔAIC_c is the difference between the AIC_c value of the best-supported model and successive models, and w_i is the Akaike model weight.

Model	K	loglink	AICc	ΔAICc	w_i	R^2
Bamboo + Elevation	4	-8.89	26.18	0.00	0.45	0.78
Bamboo + Elevation + Aspect	5	-8.58	26.47	1.58	0.21	0.79
Bamboo + Elevation + Water	5	-8.82	28.23	2.05	0.16	0.78
Bamboo + Elevation + Aspect + Water	6	-7.95	28.74	2.56	0.13	0.80
Bamboo + Elevation + Grazing	5	-10.54	31.67	5.49	0.03	0.74
Bamboo + Elevation + Aspect + Grazing	6	-10.36	33.57	7.39	0.01	0.74
Bamboo + Elevation + Aspect + Water + Grazing	7	-9.47	34.09	7.91	0.01	0.76

Bamboo + Grazing	4	-26.19	60.78	34.59	0.00	0.35
Bamboo + Water + Grazing	5	-25.88	62.35	36.17	0.00	0.36
Bamboo + Aspect + Grazing	5	-26.19	62.98	36.79	0.00	0.35
Bamboo + Aspect + Water + Grazing	6	-25.87	64.59	38.41	0.00	0.36
Bamboo	3	-29.79	65.81	39.62	0.00	0.26
Bamboo + Water	4	-29.69	67.79	41.60	0.00	0.26
Bamboo + Aspect	4	-29.74	67.87	41.68	0.00	0.26
Bamboo + Aspect + Water	5	-29.67	69.93	43.75	0.00	0.26
Null	2	-40.18	84.48	58.30	0.00	0.00

No pairwise combinations of variables were highly correlated ($r < 0.7$). The best supported model included bamboo and elevation, with a R^2 of 0.78, followed by the model containing bamboo, elevation, and aspect (Table 1). The probability of red panda presence increased with increasing elevation and was less in plots with evidence of livestock grazing (Table 2). The presence of bamboo, distance to nearest water, and aspect were not significantly associated with red panda presence.

Table 2 Model-averaged parameter estimates and 85% confidence limits (CL) describing red panda occurrence in Rara National Park, Nepal, 2011-2012. Model parameters include Bamboo (bamboo presence), Elevation (m), Aspect (north or south), Water (distance to nearest open water), and Grazing (presence of cattle grazing). Estimates were averaged from all models; SE = standard error.

Parameter	Estimate	SE	Lower CL	Upper CL	*z*	*P*
Bamboo	9.20	8.80	-3.46	21.87	1.047	0.295
Elevation	0.06	0.03	0.01	0.11	1.752	0.080
Aspect	2.24	2.78	-1.77	6.24	0.803	0.422
Water	0.02	0.03	-0.02	0.06	0.620	0.535
Grazing	-5.30	2.33	-8.65	-1.95	2.279	0.023

Discussion

Livestock presence within RNP appeared to adversely affect red panda habitat use, as evidenced by lower probability of finding fecal pellets in areas with livestock use. Himalayan National Park Regulations (HMG, 1979) stipulate that park authorities can provide grazing facility zones for livestock grazing if it is considered important for management (Heinen & Kattel, 1992). However, livestock grazing is presently illegal in RNP (Durga Poudel, Chief Warden, personal communication). Nevertheless, we recorded recent evidence of livestock in our study plots and observed several groups of buffalo, cattle, horses, goats, and sheep in RNP while conducting field work. Due to the low profitability of livestock production, especially for cattle and buffalo, many herders in the study area leave livestock in RNP from spring through autumn, then attempt to collect them during winter (Bir Bahadur Buda, Park Staff, personal communication). Park officials gather livestock in RNP and confine them within fenced areas to punish their owners; however, the owners often do not claim their livestock and park officials release them outside the park boundary within a few weeks. These animals often return to RNP shortly after release by park officials.

Livestock grazing and associated soil erosion, in addition to trampling of bamboo, likely reduces bamboo abundance and availability (Williams, 2003). Livestock grazing occurred on almost on our study plots in RNP and may have reduced bamboo abundance, causing red pandas to forage in areas livestock cannot reach (e.g., steeper slopes, Wei et al., 2000). Jotikapukkana et al. (2010) also demonstrated a negative association between wildlife presence and livestock activity in Thailand.

There are also indirect threats associated with livestock grazing, including herders and dogs used to guard livestock. These indirect threats may have a greater effect on red pandas than grazing itself (Yonzon, 1989). For example, at least 6 red pandas were killed by hunters and herders in Jajarkot District near RNP (Nagarik News, 2012-07-09). Further, the herders' dogs may kill red pandas, introduce disease, and cause red pandas to reduce their activities when present (Daszak et al., 2000; Williams, 2003; Banks & Bryant, 2007; Lenth et al., 2008; Patterson-Kane et al., 2009). Finally, we observed bamboo collection in RNP by people for livestock fodder and construction of homes and sheds, which is illegal. Bamboo collection has been documented in other protected areas of Nepal (Mahato 2004; Sharma & Belant 2010; Yonzon & Hunter 1991) and Bhutan (Dorji et al., 2012) and may further reduce bamboo availability for red pandas.

The presence of bamboo was included in all models, as it is a major factor influencing red panda distribution (Roberts & Gittleman, 1984; Gittleman, 1994; Glatston, 1994). Red pandas are a bamboo-obligate species (Roberts & Gittleman, 1984) and bamboo can represent >90 % of their diet (Schaller et al., 1985; Johnson et al., 1988; Reid & Jinchu, 1991 & Pradhan et al., 2001). The confidence limits of the model-averaged parameter estimate for bamboo suggested that it did not influence presence of red pandas. However, we contend that bamboo was important to red pandas overall, but did not influence their habitat use at the fine spatial resolution (i.e., 10 x 10 m plots) used in this study.

Red panda habitat use in RNP was influenced by elevation, with greatest use at 3000–3500 m. Previous studies (Yonzon, 1989; Choudhury, 2001; Pradhan et al., 2001; Sharma & Belant, 2009) also documented red panda presence within a defined elevational range, usually from 1700 to 4800 m, with greater use at 3000-4000 m. This may be due to the influence of elevation on plant distributions. The climate in RNP at this elevational range on the north-facing slope provided suitable conditions for bamboo (Numata, 1979; Roberts & Wuest, 2009), which supported red pandas. The absence of bamboo and red pandas on the south-facing slopes at a similar elevational range suggests that elevation without bamboo will not support red panda occurrence.

Red pandas eat large amount of poorly nutritional bamboo leaves (Wei et al., 1999), which requires them to drink water soon after eating (Yonzon, 1989). However, distance to water was not important in explaining red panda presence in RNP. Red pandas likely had adequate access to water throughout the study area, because 79% of sampling plots were ≤100 m of water.

Livestock grazing had a small but significant adverse effect on red panda habitat use in RNP. Therefore, livestock grazing should be discouraged within RNP, particularly in areas of known red panda occurrence. Conservation of red pandas in RNP will likely require public education to increase awareness of the species' conservation value and improved enforcement of existing regulations for livestock grazing. Similarly, we encourage the development of education programs for local communities to modify livestock husbandry practices and reduce grazing within RNP.

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