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Short Note

Seasonal food habits of the red panda (*Ailurus fulgens*) in Rara National Park, Nepal

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Abstract

We documented the seasonal food habits of the red panda *Ailurus fulgens* based on the analysis of 152 fecal pellet groups 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 pandas in Rara National Park, occurring in 100% of pellet groups in both the pre- and post-monsoon seasons. Similarly, bamboo was also reported as the dominant food item (80–100%) in the diet of red pandas in seven studies conducted throughout their range. These results confirm previous findings and suggest that red pandas may be vulnerable to bamboo loss through anthropogenic impacts, which could influence their survival.

Introduction

Documenting the foraging behavior of wildlife is important for understanding the ecology, evolution, and conservation of animals (Symondson, 2002). The 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 foods consumed by red pandas (*Ailurus fulgens*) might be of importance for conservation planning, especially for protection of critical habitats.

The red panda is globally vulnerable, with a declining wild population of less than 10000 individuals (Wang et al., 2008), and its current range is restricted to the Himalayan Range in Bhutan, China, India, Myanmar and Nepal at 1500-4800 m in elevation (Choudhury, 2001). The red panda inhabits evergreen, deciduous, and mixed forests with dense bamboo understory (Roberts and Gittleman, 1984; Wei et al., 1999a; Choudhury, 2001; Pradhan et al., 2001b). Bamboos (Bambuseae) are an important component of the red panda's diet (Yonzon and Hunter, 1991; Das and Thapa, 1999; Wei et al., 1999b; Pradhan et al., 2001a). However, small population size and restricted range highlight the need for more detailed information about red panda habitat requirements. Documenting the preferred seasonal food of red pandas throughout their range is necessary to improve our knowledge of their year-round habitat requirements.

Few studies have been conducted on the annual diet of red pandas (Reid et al., 1991; Wei et al., 1999a), but the general finding is that bamboo is the most important food item, followed by fruits, mushrooms, and animal matter. The purpose of our study was to describe and compare seasonal food habits and diet overlap in red pandas in the pre- and post-monsoon seasons in Rara National Park, Nepal. In addition, we summarized the available literature regarding the degree of bamboo specialization throughout the species' range.

Methods

Study area

Rara National Park (RNP) comprises 106 km^2 in western Nepal (81°59′54″ to 82°08′27″ E, 29°26′28″ to 29°33′11″ N) 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 wallichiana*) up to 3200 m. Other tree species include rhododendron (*Rhododendron arboreum*), 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 (*Juglans regia*), and Himalayan poplar (*Populus ciliata*). The size of the red panda population in RNP is currently unknown. The Park is surrounded by nine Village Development Committees within Jumla and Mugu districts, which have been declared as a buffer zone of 198 km^2. The buffer zone contains 34.6 km^2 cultivated land, 112.4 km^2 forests, 35.63 km^2 grasslands, and 14.2 km^2 shrub land. Agriculture and livestock are the primary income

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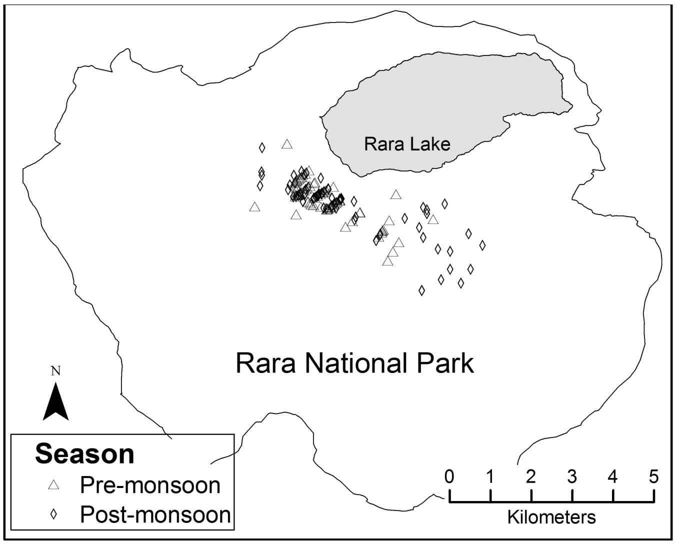

Figure 1 – Present study area and fecal sample collection of red panda in Rara National Park, Nepal.

sources for the 12121 residents of the buffer zone. Livestock grazing and resource extraction from the park is prohibited (Durga Poudel, Chief Warden, *pers. comm.*), but it is allowed in the buffer zone to minimize park-people conflicts (Budhathoki, 2004). There are ten buffer zone user committees that work with park staff to implement rules and regulations involving sustainable use of natural resources. Despite these efforts, livestock still occur within the Park. Residents in the buffer zone claim that these livestock belong to owners outside of the buffer zone, and that they posed a threat to RNP, including threats to wildlife (Sharma et al., 2014).

Sampling

We collected fecal pellet groups in August–November (post-monsoon) 2007 and March–June (pre-monsoon) 2011. The discontinuous sampling was due to lack of financial support during 2008–2010. We delineated 14 transects (Burnham et al., 1980) on the north-facing slope of the forest around Rara Lake with 500 m between transects (Fig. 1). This covered almost all red panda habitat in the park. The beginning point of each transect was within 50 m of the park road and transects continued uphill. The average transect length was 1.53 km ($\pm$0.62 SD) and ranged from 0.6 to 2.5 km. We walked the 14 transects once in each season, from 7h00-18h00, to collect fecal samples. Fecal samples were collected from the ground within 2 m of each transect. Samples were also collected opportunistically from branches of trees and shrubs within 10 m of transects. We also collected samples opportunistically while walking from one transect to another.

We did not use DNA analysis to quantify the number of individuals from which we collected samples, as is the case with most studies of mammalian food habits based on scat analysis. Nevertheless, we are confident that the samples came from many individuals representating a large portion of the red panda population, because the 30 km^2 sampled area covered 8-9 home ranges (ca 3.5 km^2, according to Yonzon 1989) and we observed three pandas together on one transect.

Laboratory Analysis

We analyzed feces following Anthony and Smith (1974) and Holechek et al. (1982). We mixed all pellets in each pellet group thoroughly in the field, placed about one fourth of each sample into a labeled plastic bag, and then transported the samples to a laboratory at the Central Department of Zoology, Tribhuvan University, Kathmandu. We also examined the feces for undigested animal remains (e.g. bone and hair).

We oven-dried fecal 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 a 5% concentration of NaOH solution and boiled each until the samples became transparent. We cooled and rinsed the samples to remove remaining NaOH, 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 prepared two slides from each fecal sample. We used a Distyrene, a plasticizer, and xylene (DPX)-resin mounting medium on each slide. 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 of potential forage plants from the same study area by microscopic examination of whole mounts. We recorded all fragments found along the central line of the slide.

Reference plants

We collected the leaves of 15 common plant species that potentially were consumed by red pandas in RNP (Wei et al., 1999b). We followed Polunin and Stainton (1984) for plant nomenclature. The sampled potential red panda foods were *Thamnocalamus* sp., *Yushania/Chimnobambusa* sp., *Abies spectabilis*, *Juniperus indica*, *Rhododendron arboreum*, *R. campanulatum*, *Quercus semecarpifolia*, *Sorbus cuspidata*, *Betula utilis*, *Tsuga dumosa*, *Texus wallichiana*, *Acer acuminatum*, and mushrooms. 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 each of *Thamnocalamus* and *Yushania/Chimnobambusa* sp. (i.e., newly sprouted shoots and mature leaves). We prepared reference materials following procedures described for fecal samples, except that each reference plant material was treated 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 photographed the reference materials using a digital camera attached to a stereoscope or compound microscope at 200$\times$ and 400$\times$ magnifications with an ocular measuring scale to aid in identifying materials in fecal samples. Bamboo was identified to genus only, due to our inability to identify some bamboo fragments to species, mainly those fragments from the upper side of the leaf where stomata were not distinguishable. Because the anatomical characteristics of the different potential food groups were so different and diagnostic, we did not expect that we misidentified them using this technique.

Data analysis

For each season, we calculated the percentage frequency of occurrence of each food item as:

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

Then, we conducted bootstrapping to calculate 95% binomial confidence limits using the Statistical Packages for Social Sciences, Version 20.0 (Reynolds and Aebischer, 1991; Agresti and Coull, 1998).

We then calculated food niche overlap between seasons using Pianka's Index (1973) to identify seasonal overlap of food items:

$$O_{jk} = \frac{\sum_{i=1}^{n} p_{ij} p_{ik}}{\sum p_{ij}^2 p_{ik}^2},$$

where O_{jk} is Pianka's Index of food niche overlap between the premonsoon season j and post-monsoon season k; p_{ij} and p_{ik} are the % occurrence of food item 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 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 when confidence intervals overlapped slightly between seasons to confirm the differences in the occurrence of fecal components and we assumed statistical significance at $\alpha < 0.05$.

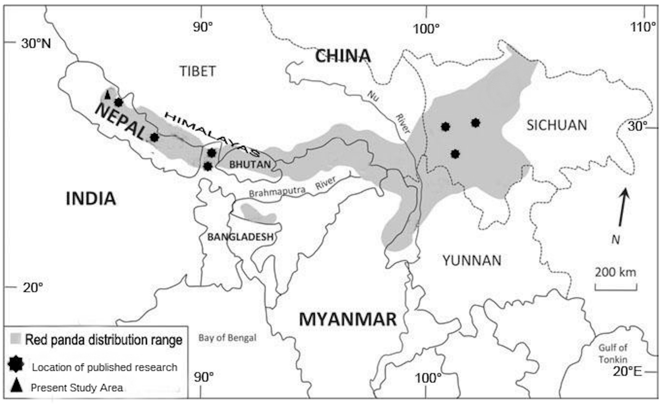

Figure 2 – Red panda distribution; a) Published research on diet of red panda in its range (modified from Choudhury 2001).

Literature Review

We used Google Scholar® to search for articles documenting the diet of red pandas throughout their range (Fig. 2). We used the keywords, "Red panda or *Ailurus fulgens* or diet or food habits 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, and bamboo species found in the study areas.

Results

We analyzed 152 fecal samples, with equal numbers collected in the pre- and post-monsoon seasons. The frequency of occurrence of food types differed within both the pre-monsoon ($\chi^2_{0.05,7}$ = 172.99, $p <$ 0.001) and post-monsoon ($\chi^2_{0.05,10}$ = 183.24, $p < 0.001$) seasons. Bamboo (*Thamnocalamus* sp.) was the primary food item in both seasons and occurred in all pellet groups. The non-overlapping Confidence Intervals (Tab. 1) indicated a seasonal difference in the occurrence on bamboo and non-bamboo items. *Juniperus indica*, *Sorbus cuspidata*, *Aconogonum* sp. and mushrooms were found only during the post-monsoon, whereas *Texus wallichiana* in the pre-monsoon season. The occurrence of other non-bamboo foods were leaves of *R. arboreum*, *A. spectabilis*, *Q. semecarpifolia*, *B. utilis*, *T. dumosa*, and *A. acuminatum* in both seasons and fruits during the post-monsoon season; *Aconogonum* sp. at 55.3%, followed by *S. cuspidata* and *J. indica* (Tab. 1). Percentage occurrence of non-bamboo species combined was greater during the pre- than post-monsoon season, but there were no seasonal differences for specific food items, except *A. spectabilis*, and *Q. semecarpifolia*. The percentage of occurrence of non-bamboo foliage was 58% during the pre-monsoon, 63% in the post-monsoon season, and fruits were 84.2% in the post-monsoon season (Tab. 2). We found no animal matter in the pellet groups we analyzed. Pianka's Index of seasonal food niche overlap was not significant, although there was a tendency towards a difference (O_{jk} = 0.78, p = 0.08).

We examined seven additional studies in the literature that collectively documented six genera of bamboo consumed by red pandas (Tab. 2). Bamboo species comprised > 78% dry volume in fecal pellets both in the post- and pre-monsoon seasons, whereas occurrence of bamboo was > 91% in all annual studies. Percentage of fruits in the diet was comparatively low (i.e., < 20%; Tab. 2). Fruits consumed included the genera *Aconogonum*, *Actinidia*, *Berberis*, *Clematoclethera*, *Cotoneaster*, *Juniperus*, *Maddenia*, *Prunus*, *Rubus*, *Ribes*, *Rosa*, *Sorbus* and *Sabina*.

Discussion

We identified twelve plant species and no animal matter in the diet of red pandas at RNP. The leaves and shoots of *Thamnocalamus* sp. were the major food components and comprised 100% occurrence in the diet in both pre- and post-monsoon seasons. Thus, the red panda is a bamboo specialist, explaining why it selects habitats with bamboo-dominated understory (Yonzon, 1989).

Other plant species were used more infrequently, except fruits in the post-monsoon season. The percentage occurrence of *Thamnocalamus* sp. in the diet was equal in both seasons, thus there was no effect of feeding on fruits on the occurrence of bamboo, perhaps due to limited access to fruit during the post-monsoon season. The occurrence of individual food items did not differ between seasons, except for *A. spectabilis* and *Q. semecarpifolia*, which may be due to feeding of leaves of these species during sheltering on branches. Of course, our conclusions about seasonal comparisons assume that there was no annual difference in food availability or diet composition by red pandas between 2007 and 2011. We have no indications of important differences between these years.

The low seasonal food niche overlap was a consequence of high bamboo consumption during both seasons and comparatively few supplementary foods. However, we found more non-bamboo plant species in RNP than in other red panda diet studies. *R. arboreum*, *B. utilis*, *Q. semecarpifolia*, *A. spectabilis*, and *Acer* spp. were consumed in two areas in western Nepal, in RNP (this study), and in Dhorpatan Hunting Reserve (Panthi et al., 2012). The percentage occurrence of bamboo consumed by red pandas in RNP was greater than reported in Fengtongzhai Nature Reserve, China, Dhorpatan Hunting Reserve, Nepal, and Langtang National Park, Nepal, in the post-monsoon season (Yonzon, 1989; Zhang et al., 2009; Panthi et al., 2012) (Tab. 2). In addition to bamboo, we found berries and mushrooms in the post-monsoon season (autumn), whereas other authors have found small mammals, birds, eggs, blossoms, and acorns in the diet of red pandas (Johnson et al., 1988). These are nutritional and protein-rich foods (Pradhan et al., 2001a) and may be beneficial for red pandas after parturition (generally late July) and while rearing their cubs (Roberts and Gittleman, 1984). However, non-bamboo food items seem to supplement bamboo, the staple food (Roberts and Gittleman, 1984). No other parts

Table 1 – Percentage occurrence and 95% confidence limits of foods consumed by red pandas based on fecal pellet group analyses during pre-monsoon (n = 76; 2007) and post-monsoon seasons (n = 76; 2011), Rara National Park, Nepal, *n.s.* indicates a non-significant result.

	Pre-monsoon			Post-monsoon			
		95% CI			95% CI		
Food items	**Estimate**	**Lower**	**Upper**	**Estimate**	**Lower**	**Upper**	***p***
Thamnocalamus sp.	100	100	100	100	100	100	0.08
Aconogonum sp.	-	-	-	55.3	43.4	65.8	-
Juniperus indica	-	-	-	40.8	30.3	52.6	-
Sorbus cuspidata	-	-	-	47.4	36.8	57.9	-
Abies spectabilis	35.5	25	46.1	27.6	17.1	38.2	0.02
Mushrooms	-	-	-	19.7	10.5	28.9	-
Rhododendron arboreum	39.5	28.9	50	22.4	11.8	31.6	*n.s.*
Quercus semecarpifolia	27.6	17.1	38.2	23.7	14.5	32.9	< 0.001
Betula utilis	22.4	13.2	31.6	15.5	7.9	25	n.s.
Tsuga dumosa	15.8	7.9	23.7	19.7	10.5	28.9	n.s.
Acer acuminatum	15.8	7.9	25	6.6	1.3	13.2	n.s.
Texus wallichiana	10.5	3.9	18.4	-	-	-	-

Table 2 – Food items consumed by red panda throughout its geographic range, based on fecal pellet analyses and according to 8 different studies. [a] = annual, [p] = pre-monsoon, [q] = post-monsoon, [s] = summer, 0 = absence, - = no indication, N = sample size. Quantification methods used: [1] = % occurrence, [2] = Relative Frequency, [3] = Frequency of occurrence by percent volume, [4] = % of dry matter by weight.

Location	Bamboo species	N feces	% of food items consumed			Source
			Bamboo	Non-bamboo foliage	Fruits	
Rara National Park, mid-western Nepal	*Thamnocalamus sp.*	76[1] 76[1]	100[p] 100[q]	58[p] 63.2[q]	0 84.2[q]	Present study
Dhorpatan Hunting Reserve, western Nepal	*Arundinaria* spp.	61[2]	81.7[s]	16.2[s]	2.1[s]	Panthi et al. (2012)
Langtang National Park, central Nepal	*Himalayacalamus aristata*	446[3]	85[q]	-	14.4[q]	Yonzon (1989)
Singhila National Park, north-western India	*Arundinaria maling* and *A. aristata*	1250[3]	100[p] 80[q]	-	- 20[q]	Pradhan et al. (2001a)
Neora Valley National Park, west Bengal, India	*Yushania maling*, *A. hookeriana*, *A. aristata*	-	Not quantified	-	-	Mallick (2010)
Wolong National Park, Sichuan, China	*Bashania fangiana*, *Fargesia robusta*	791[1]	100[a]		9.7[a]	Reid et al. (1991)
Fengtongzhai Nature Reserve, Sichuan Province, China	*Bashania faberi*	95[4] 125[4]	99[p] 85[q]	-	- 14.3[q]	Zhang et al. (2009)
Yale Nature Reserve, Sichuan Province, China	*Bashania spanostachya*	720[4]	98.8[a]	-	1.2[a]	Wei et al. (1999a)

(e.g., leaves or twigs) of fruiting species were observed in red panda pellets, indicating that fruit and mushrooms consumption represented opportunistic foraging of a seasonally available resource.

Red pandas consume only a few species of available Bambuseae throughout their range. For example, 6 of 15 bamboo species were reported to be consumed in China and 1 of 4 species in Langtang National Park, Nepal (Yonzon, 1989; Qi et al., 2009). In our study area, both *Thamnocalamus* sp. and *Yushania/Chimnobambusa* sp. were available, but only *Thamnocalamus* sp. was found in the feces. 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 *A. maling* and *A. aristata* in Singhilia National Park, perhaps due to greater protein content and availability (Pradhan et al., 2001a).

Numerous factors may 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 (Seeland, 1980; Schaller et al., 1985; Reid and Jinchu, 1991; Das and Thapa, 1999; Sharma and Belant, 2010). Conservation actions that consider both the amount and spatial distribution of bamboo within red panda habitat will likely have greatest benefit to the species.

The results of our study suggest that red pandas may be vulnerable to bamboo loss, because of their strong dependency on it. Because the red panda is a year-round dietary specialist of bamboo, factors affecting the availability of preferred bamboo could potentially threaten red panda populations. Accordingly, more research is needed on red pandas to estimate and map suitable habitat, identify preferred bamboo species, and address anthropogenic factors potentially affecting the availability of high quality bamboo used by red pandas.

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