Acta Theriologica 54 (3): 225–234, 2009.
PL ISSN 0001–7051 DOI: 10.4098/j.at.0001–7051.017.2008

Food habits and space-use of red pandas *Ailurus fulgens* in the Fengtongzhai Nature Reserve, China: food effects and behavioural responses

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Zhang Z., Hu J., Yang J., Li M. and Wei F. 2009. Food habits and space-use of red pandas *Ailurus fulgens* in the Fengtongzhai Nature Reserve, China: food effects and behavioural responses. Acta Theriologica 54: 225–234.

The red panda *Ailurus fulgens* Cuvier, 1825 is endemic to the Himalayan-Hengduan Mountains. Many of its ecological traits are still poorly understood although important from a scientific standpoint as a highly specialized bamboo feeder. To understand its food habits and space-use, we carried out a field study from April 2002 to May 2003 in Fengtongzhai Nature Reserve, China. The results showed that red pandas almost exclusively fed on *Bashania faberi*, but not on *Yushania brevipaniculata* in the study area. Besides differences in nutritional quality, accessibility to food items is perhaps another factor affecting their utilization of bamboo species. *B. faberi* leaves are the highest in crude protein, being the primary year-round food source; new shoots and fruits of *Sorbus*, and *Rubus* are nutritious and digestible, seasonally occurred in their diet. Red pandas seemed to select most nutritious food items to feed on. The home range of red pandas averaged 2.2 km^2 across individuals (2.6 km^2 for the males and 1.7 km^2 for the females), and overlapped extensively (ranging 18.9–78.1%). No significant difference was found in monthly percentage of total home range used among seasons and sexes. The daily movement distance was 455 m (447 m for the females and 463 m for the males), significantly affected by sexes and months. Our findings indicated that food resource significantly influenced behaviour of red pandas in foraging and space use, and their behavioural responses are adaptive being helpful to energy intake and maintenance.

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Key words: *Ailurus fulgens*, food habits, home range, daily movement, *Bashania faberi*, *Yushania brevipaniculata*

Introduction

As with the giant panda *Ailuropoda melanoleuca* the red panda *Ailurus fulgens* Cuvier, 1825 is also endemic to the Himalayan-Hengduan Mountains of China (Wei *et al*. 2000, Choudhury 2001). Two subspecies, namely *A. f. fulgens* and *A. f. styani*, are both found in China, with

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Nujiang River in Yunnan province a natural barrier to separate them (Wei *et al*. 1999a). Due to massive habitat loss, increasing human activity and poaching, the total population was estimated to decrease as much as 40% over the last 50 years in China (Wei *et al*. 1999a). Today, the red panda is listed on Appendix I of CITES (Convention on International Trade in Endangered Species) and classified as Category II species under the Wild Animal Protection Law of China, with over 30 nature reserves established in its distribution range (Wei *et al*. 1999a).

Wise conservation planning requires overall information on biological needs of a species (Siew *et al*. 2004), of which, knowledge on spatial use is essential to understand its ecological requirements, social structure and interactions among individuals. Occupying an unusual ecological niche among the Carnivora, the red panda has evolved to specialize highly as a bamboo-feeder, making it extremely important from a scientific standpoint (Glatston 1989, Wei *et al*. 1999a). However, only two studies, both with short-term monitoring periods (9–10 months) and small sample size (1 or 2 focal animals), have been conducted in China (Johnson *et al*. 1988, Reid *et al*. 1991). Home range, movement pattern and their causal factors need further studies (Pradhan *et al*. 2001a).

Food has a significant influence upon microhabitat utilization and foraging by the red panda (Wei *et al*. 1999b, 2000, Pradhan *et al*. 2001b, Zhang *et al*. 2004, 2006). Usually, multiple bamboo species grow in its each mountainous range. However, the red panda is assumed to select the most nutritious one (Wei *et al*. 1999b). In Wolong Nature Reserve, China, the red panda almost exclusively feeds on *Bashania faberi*, except occasionally it consumes new spring shoots of *Fargesia robusta* (Johnson *et al*. 1988, Reid *et al*. 1991). Red pandas usually select the most nutritious food items (Johnson *et al*. 1988, Reid *et al*. 1991, Wei *et al*. 1999b).

From April 2002 to May 2003, we conducted a field study to understand the food habits and space-use of red pandas in Fengtongzhai Nature Reserve, China. Three goals were included in our research: (1) to determine bamboo selection and diet composition of red pandas in the study area, (2) to delimit the general pattern of space use, mainly focusing upon home-range utilization and daily movement, and (3) to understand how food resource influences behaviours in foraging and space use of red pandas.

Material and methods

Study area

In March 2002, we constructed a field research base in the core area of Fengtongzhai Nature Reserve (102°48'–103°00'E, 30°19'–30°47'N), Baoxing County, Sichuan Province, China, covering a study area of about 20 km^2. Collection of data and samples began in April 2002, and ended in May 2003.

The Reserve covers about 390 km^2 of rugged ridges and narrow valleys, varying in elevations from 1000 to 4896 m. Spring lasts from April to June, summer–autumn from July to October, and winter consists of the remaining months. The average annual temperature, humidity and rainfall are 5.9–7.2°C, 79–83% and 730–1300 mm, respectively. The mean daily highest temperature occurs in July, ranging from 15.1–16.3°C, and the lowest temperature occurs in January, ranging from –4.0–2.7°C (Baoxing Weather Station, unpubl.).

Vegetation shows characteristic vertical zonation. Subtropical evergreen broadleaf forest occurs below 1500 m, where dominant trees are *Cinnamomum wilsonii* and *C. longepaniculatum*. Mixed evergreen and deciduous broadleaf forest is prevalent at elevations of 1500–2000 m, and the most common deciduous trees are *Pterocarya stenoptera*, *Betula* sp. and *Acer* sp. Mixed conifer and deciduous forests dominated by *Tsuga chinensis*, *Pinus armandii*, and *Betula* sp. occur between 2000 and 29 000 m. Conifer forests at elevations of 2900–3500 m have a prominent domination of *T. chinensis*, *P. armandii* and *Abies faxoniana* species. Shrubs or grasslands are found above 3500 m.

Two bamboo species, *Yushania brevipaniculata* and *B. faberi*, are dominant in the study area. The former occurs in the lower-middle part of the hillside (mainly below 2500 m in elevation) and the latter in the upper part (mainly above 2500 m in elevation). *Y. brevipaniculata* is much higher than *B. faberi* (3.0–6.0 m versus 1.0–2.5 m).

Food habits and nutritional composition of *Y. brevipaniculata*

Red pandas are rarely observed in the wild, thus we used fresh droppings left by pandas to gather information on their food habits. On average, no less than 30 fresh droppings per month in the study area were collected for analysis. Collected droppings were oven or sunlight-dried and different items, such as bamboo leaves, shoots, fruits and hairs were carefully separated and weighed. Food items

were roughly digested when passing through the digestive tract of pandas, and therefore easily separated (Wei *et al*. 1999c). The percentage of each food item in the diet of pandas was estimated by the weight of dry matter.

Samples of *Y. brevipaniculata*, including leaves, new shoots, old shoots and stems were collected three times in each season in the study area. Each time, the wet weight for each category of samples collected weighed about 1.0 kg. Crude protein was determined following Macro-Kjeldahl procedure, crude fat was measured with Soxhlet procedure, cell wall constituents, such as cellulose, hemicellulose and lignin were analyzed by the methods outlined by Van Soest (1982). The nutritional quality ratio was defined as the ratio of crude protein to cellulose plus lignin (Hu *et al*. 1985, Reid *et al*. 1991).

Although two bamboo species of bamboo occurred in our study area, we only analyzed nutritional composition in *Y. brevipaniculata*. The data on nutritional composition in *B. faberi* was noted in Hu *et al*. (1985).

Capturing and monitoring of red pandas

Red pandas were chased up into trees by dogs, and then were captured, which was approved by the wildlife authorities of the Sichuan Forestry Bureau, China. Following capture, red pandas were immobilized with injections of Ketamine Hydrochloride at 6–8 mg kg^{-1}, measured, weighed, instrumented with 150–152 mHz radio collars (Telonics Coporation, Mesa, Arizona, USA), and then released at capture sites. We attempted to locate these red pandas every one or two days using a hand-held H-shaped antenna and radio-receiver (Telonics Corporation, Mesa, Arizona, USA). Bearings of radio signals were obtained with a compass, and then were used to obtain triangulated locations. To ensure accuracy in telemetry locations and reduce the likelihood of signal bounce, we established several stations on a ridge to locate red pandas. Distances from stations to estimated locations usually were < 500 m, which could reduce variation from bearing errors (Deat *et al*. 1980). We also plotted all locations on 1:50 000 topographic maps after each positioning trial was made, and then made a visual assessment. We distorted those locations which were apparently separated from our study area by ecological barriers, such as rivers or farmlands.

Data analysis

Nonparametric estimators (eg kernel contouring) are less influenced by outliers than other estimators of home-range size (Silverman 1986, Worton 1989, Seaman and Powell 1996), areas of home ranges of red pandas were thus estimated by 95% fixed kernel estimates. The overlapping percentage of home ranges between individuals was calculated as

$$Hc^2/(Ha \times Hb) \times 100\%$$

where H*a* and H*b* are areas of home ranges occupied by individuals *a* and *b*, and H*c* represents the area of the communal part between them. To determine percentage of total home range used by month, we first calculated the area of home range in each month based on the monthly location subset, and then divided it by the total home range. The daily movement distance (m) was defined as the direct distance between animal locations on consecutive days (Siew *et al*. 2004).

The effects of sex and month on daily movement distance were examined through two-way ANOVA. Comparison of means was made using ANOVA if data sets conformed to normal distribution, or through Kruskal-Wallis *H*-test or Mann-Whitney *U*-test if sets departed from a normal distribution.

Results

Six red pandas were captured in early April 2002 for radio tracking in the study area (Fig. 1). These red pandas, including 3 males and 3 females, were all considered adults, based on their body mass and tooth eruption (Table 1).

During the research period, red pandas were found to exclusively feed on *B. faberi*, and not on *Y. brevipaniculata*. Leaves of *B. faberi* were their primary year-round food item, constituting the major part of their diet. Shoots of *B. faberi*, fruits of *Sobus* spp. and *Rubus* spp. were other important seasonal diets of pandas during spring and autumn. In addition, mammal hair and moss were occasionally found in droppings of red pandas (Table 2).

Nutritional contents varied in different parts of *Y. brevipaniculata* (Table 3). Crude protein was highest in leaves, followed by new shoots and lowest in stems. Similarly, nutritional quality ratio was highest in leaves, and lowest in stems.

A total of 1215 telemetry locations were obtained, averaging 203 locations per individual (Table 1). The home range size of red pandas averaged 2.2 km^2 for all individuals – 2.6 km^2 for males and 1.7 km^2 for females. Home ranges extensively overlapped across intra-sexual or inter-sexual individuals (Fig. 1), ranging from 18.9 to 78.1% (Table 4). The overlapping percentage was higher for the females (44.1%) than for the males (38.6%).

Monthly percentage of total home range used was similar between sexes (30.1 ± 10.5% versus 27.1 ± 10.0%, $F_{1, 22} = 0.51$, $p = 0.48$) (Table 5). No

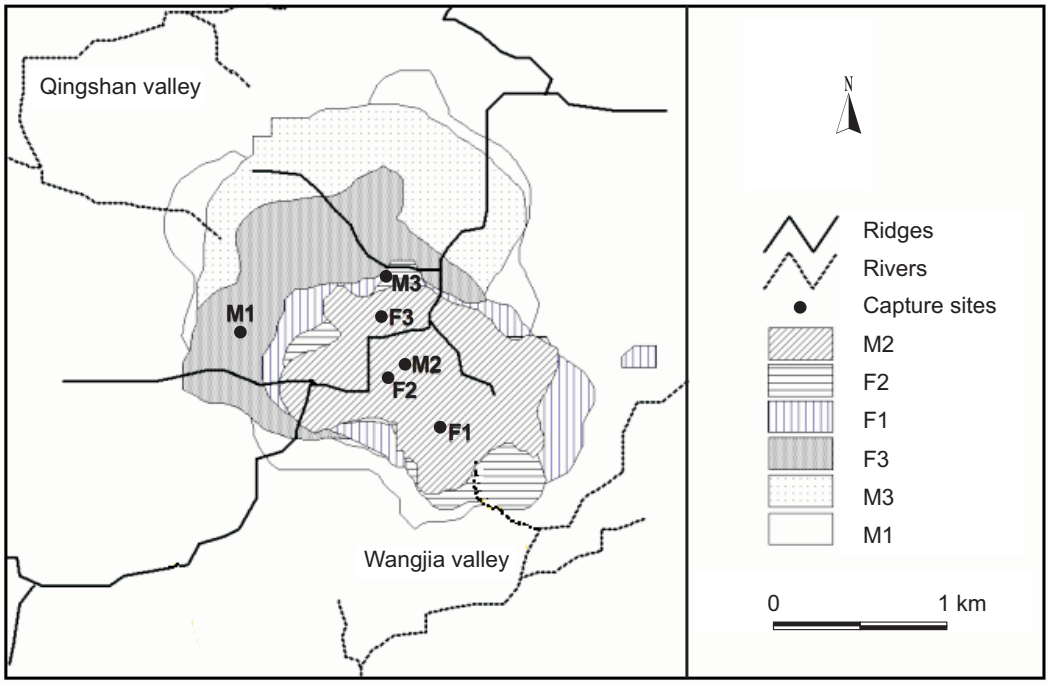

Fig. 1. Capture sites and home ranges for the six red pandas *Ailurus fulgens* monitored from April 2002 to May 2003 in Fengtongzhai Nature Reserve, China.

significant difference was found among seasons (27.5 ± 12.3% for spring, 28.0 ± 9.9% for summer–autumn, 29.7 ± 9.9% for winter, $F_{1, 21} = 0.10$, $p = 0.91$). The daily movement distance averaged 455 m across all individuals, 463 m for the males, marginally significantly higher than that for the females (447 m) (two-way ANOVA: $F_1 = 3.74$, $p = 0.053$). Month affected daily movement distance significantly ($F_{11} = 2.14$, $p = 0.016$). The daily movement distance is shortest (365 ± 296 m) in January and longest (573 ± 382 m) in December.

Table 1. Individual status, number of locations and areas of home ranges for the six radio-collared red pandas *Ailurus fulgens* in the Fengtongzhai Nature Reserve, China. * – calculated as 95% fixed kernel estimates, M – males, F – females.

Individual	Sex	Age class	Body mass (kg)	Number of locations	Area of home range (km^2)*	Monitoring duration (month)
M1	M	adult	5.5	197	3.8	12
M2	M	adult	5.9	196	1.2	12
M3	M	adult	5.9	201	3.0	12
F1	F	adult	5.7	201	1.7	12
F2	F	adult	6.0	209	1.3	12
F3	F	adult	–	211	2.2	12

Table 2. Percentage of dry matter by weight in droppings of the red pandas *Ailurus fulgens* in Fengtongzhai Nature Reserve, China.

Food item	April	May	June	July	August	September	October	November	December–March
Bashania faberi leaf	95.8	7.1	25.09	95.1	96.3	78.7	70.4	95.0	99.9
Bashania feberi shoot	4.2	92.8	74.89	4.9					
Sorbus					0.8	20.9	29.5	5.0	
Rubus					0.9				
Ribes					0.1	0.3			
Hair		0.1	0.01		1.7	0.01			0.1
Moss					0.2	0.04			
Others			0.01			0.05	0.1		
Sample size of droppings	34	31	30	30	33	31	30	31	30. 5 (average)

Table 3. Percentage of nutritional contents and nutritional quality ratio in *Yushania brevipaniculata* in Fengtongzhai Nature Reserve, China. * – according to Hu *et al*. (1985), old shoots of *Y. brevipaniculata* refer to 1-year-old shoots during the period from autumn to spring of the next year, ** – data not available.

Item	Sample size	Crude protein	Crude fat	Hemicellulose	Cellulose	Lignin	Ash	Nutritional quality ratio
Leaf	3	12.32	3.27	36.11	28.8	11.15	6.65	0.31
New shoot	3	11.43	_**	_**	_**	_**	_**	_**
Old shoot*	3	8.35	0.44	22.86	47.63	14.85	2.27	0.13
Branch	3	5.64	0.38	29.12	39.14	15.38	6.06	0.10
Stem	3	2.08	0.2	22.78	48.18	17.1	2.04	0.033

Table 4. Overlapping area (km^2) (below the diagonal) and percentage (above the diagonal) of home ranges for the red pandas *Ailurus fulgens* in the Fengtongzhai Nature Reserve, China.

Individual	F1	F2	F3	M1	M2	M3
F1		56.4	42.3	24.7	63.4	25.4
F2	1.1		33.5	24.7	78.1	18.9
F3	1.2	1.0		53.7	27.7	60.3
M1	1.2	1.1	2.1		21.9	72.5
M2	1.1	1.1	0.8	1.0		21.3
M3	1.1	0.9	2.0	2.8	0.9	

Table 5. Percentage of total home range of red pandas *Ailurus fulgens* used by month and the daily movement distance (m) of pandas recorded in the Fengtongzhai Nature Reserve, China.

Month	Percentage of total home range used		Daily movement distance (m)	
	Female	Male	Female	Male
2002				
April	26.7	15.6	457	458
May	16.9	20.4	389	488
June	43.4	41.9	503	301
July	48.1	26.3	534	484
August	22.5	30.8	414	468
September	17.6	19.7	327	399
October	24.3	35.0	359	609
November	22.7	41.5	319	545
December	37.8	38.4	540	599
2003				
January	38.6	18.0	486	244
February	24.7	15.6	565	477
March	37.5	21.9	468	486
Mean ± SD	30.1 ± 16.2	27.1 ± 14.8	447 ± 84	463 ± 107

Discussion

Food habits and feeding strategy

Most herbivores possess a gastrointestinal tract adapted to their diets; a long gut helps with the retention of food, and microbial populations harbored facilitate utilization of plant food (Sibly 1981, Dierenfeld *et al*. 1982, Hofmann 1989, Hume 1993). Although specialized for handling a diet of bamboo, the red panda possesses a simple stomach, no caecum, and a short gastrointestinal tract (Roberts and Gittleman 1984). However, bamboo is a low-quality food, due to high cellulose and low cell solubles (Dierenfeld *et al*. 1982, Wei *et al*. 1999b). The red panda consumes less than 30% of dry matter in bamboos (Warnell *et al*. 1989, Wei *et al*. 1999c). To meet its needs for nutrient and energy, the red panda was found to exhibit some interesting optimal foraging strategies under selective pressure (Wei *et al*. 1999b, c).

We did not collect samples of *B. faberi* in our study area for nutritional analysis; data on its nutritional components is available from a study conducted in Wolong Nature Reserve in middle 1980s. Fengtongzhai Nature Reserve borders Wolong Nature Reserve on the north; the difference in nutritional components of *B. faberi* in the two Reserves can be assumed minimal due to similar climatic and environmental conditions. Our findings indicate that red pandas fed exclusively on *B. faberi* in our study area. Compared with *Y. brevipaniculata*, the crude protein of *B. faberi* is higher in leaves (15.2–15.7% versus 12.3%) and shoots (14.8% versus 11.4%) exhibiting the nutritional quality ratio of 0.43 versus 0.31 (Hu *et al*. 1985). It seems that red pandas prefer the more nutritious bamboo species.

However, caution should be taken for this explanation, for the difference in crude protein between the two bamboos is fairly small. Being small in body mass, red pandas were often found to use elevated objects, such as fallen logs that provide easier access to bamboo leaves (Johnson *et al*. 1988, Wei *et al*. 2000, Zhang *et al*. 2004, 2006), which implies that height of bamboo stems constitute a limiting factor for the animal when determining what species to feed on. The taller bamboo stems are, the lower accessibility of

Table 6. Stem height (m) and crude protein content (%) of sympatric bamboo species in habitats of red pandas *Ailurus fulgens*. Data from Hu *et al*. (1985), Yonzon (1989), Wei *et al*. (1995, 1999a), Yi (1997) and this study.

Locality	Staple-food bamboos			Other bamboos in sympatry					
	Species	Height (m)	Crude protein in leaves (%)	Species	Height (m)	Crude protein in leaves (%)	Species	Height (m)	Crude protein in leaves (%)
Wolong Nature Reserve	*B. faberi*	1.0–2.5	14.5	*Fargesia robusta*	2.0–5.0	13.20			
Fengtongzhai Nature Reserve	*B. faberi*	1.0–2.5	14.5	*Y. brevipaniculata*	3.0–6.0	13.25			
Mabian Dafengding Nature Reserve	*Qiongzhuea macrophylla*	1.5–3.0	15.45	*Yushania glauca*	3.0–6.0	13.85	*Chimonobambusa pachystachys*	3.0–6.0	
Yele Nature Reserve	*Bashania spanostachya*	1.0–3.5	14.65–16.57	*Fargesia dulcicula*	3.0–4.0		*Fargesia exposita*	3.0–4.5	
Langtang National Park	*Himalayacalamus falconeri*	2.95	15.9	*Thamnocalamus aristatus*	3.7	13.5			

bamboo leaves for it to forage. Therefore, it is not surprising that red pandas would be forced to forage on relatively shorter bamboos. Compared with *B. faberi*, *Y. brevipaniculata* was much taller (1.0–2.5 m versus 3.0–6.0 m) (Table 6). Lower accessibility to this bamboo species might force red pandas to only feed on *B. faberi*. Concerning the negative relationship between digestibility, and crude protein with twig diameter (Searle *et al*. 2005), shorter bamboos (being the staple food source for red pandas) are coincidently richer in nutrients than are sympatric higher ones. Similar phenomena were also found in other mountains where red pandas reside (Table 6).

Leaves of *B. faberi,* that possess a higher crude protein and nutritional quality ratio compared with the other bamboo items, are the most important and the only year-round food item in the diet of red pandas. In addition, new shoots and fruits of *Sorbus* and *Rubus* represent seasonal food sources. Although lower in crude protein, new shoots can be digested more effectively by the red pandas (Wei *et al*. 1999c), and fruits of *Sorbus* and *Rubus* generally have a higher caloric density than bamboo parts (Reid *et al*. 1991). In sum, red pandas exhibited a foraging strategy based on accessibility, digestibility and nutritional quality adapted for maximizing their energy intake.

Space use

In general, home ranges of female mammals are presumed to be determined, in part, by food abundance and distribution. In addition to food, male home range is strongly influenced by mate-seeking activities (Sandell 1989, Garshelis 2004). Consequently, home ranges occupied by males' are often expected to be larger than those of females (Bunnell and Tait 1981, Stirling and Derocher 1996, McLoughlin *et al*. 1999). Although little is known about the mating system of wild red pandas, males in our study occupied larger home ranges than females (2.6 km^2 versus 1.7 km^2). The home range size of red pandas was larger in our study than that reported by Reid *et al*. (1991), but smaller than reported by Johnson *et al*. (1988), although the methods adopted were different. Reid *et al*. (1991) radiocollared only two animals (1 adult male and 1 adult female), and their home ranges were based on a 9-month monitoring period that did not include the mating season. The focal animal in Johnson *et al*. (1988) was a subadult female, being 8 months old when captured, and may not have established its stable home range.

In our study, extensive overlapping of home ranges was found among red pandas, similar to the giant panda, another highly specialized bamboo feeder (Hu *et al*. 1985). In Wolong Nature Reserve, home ranges of a female and a male red panda overlapped more than 60% (Reid *et al*. 1991). As a poor-quality food source, bamboo is abundant and maintains a constant nutrient level, enabling animals to subsist on this food source (Hu *et al*. 1985, Johnson *et al*. 1988). In productive habitats, animals are not reported to protect resources from intrusion by other individuals (Carpenter and MacMillen 1976). In addition, low energy intake may be another limiting factor for red pandas to develop their territorial behaviours.

No significant difference was found in monthly percentage of total home range used among seasons and between sexes. However, percentages in May and September were very low and in sync between sexes, perhaps reflecting effects by distribution of their preferred food items (new shoots in May and fruits in September). In June and October, when their preferred food sources decreased respectively, red pandas moved much widely to search for, resulting in the increased percentages of total home range used during these months.

Daily movement of the males was slightly larger than that of the females. In Wolong Nature Reserve, males moved longer distances daily than females (325 m ± 210 versus 235 m ± 169) (Reid *et al*. 1991). However, the daily distance moved in our study was much larger than that reported by Reid *et al*. (1991), but slightly smaller than that noted by Johnson *et al*. (1988).

Food effects and behavioural response

Our results demonstrated the effects of food upon behaviour of red pandas. For pandas,

potential food items were usually different in nutritional quality, and leaves on different bamboo species varied in their accessibility. Correspondingly, to maximize their daily energy intake, red pandas often selected the most nutritious items to consume. Due to the abundance of bamboo resource in the environment, and the limitation in energy intake, red pandas did not develop territorial behaviours and their home ranges overlapped extensively. All these behavioural responses are adaptive in energy intake and maintenance, ensuring successful survival and reproduction of red pandas in the wild.

Acknowledgements: This study was supported by projects of the National Basic Research Program of China (973 Program, 2007CB411600), National Natural Science Foundation of China (30670203, 30670305), CAS Innovative Research International Partnership Project (CXTDS 2005-4), and Sichuan Provincial Science and Technology Fund for Distinguished Young Scholars (07ZQ026-017). Mrs. B. Yang, M. Wang, X. Zhang, M. Gao, Y. Luo and G. Li participated in the fieldwork. Sichuan Forestry Bureau and Fengtongzhai Nature Reserve provided generous assistance for this project. We thank the three anonymous referees for their constructive comments.

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Received 28 February 2008, accepted 3 March 2009.

Associate editor was Joseph F. Merritt.