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Activity patterns of wild red pandas in Fengtongzhai Nature Reserve, China

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Abstract
To describe general patterns of activity in wild red pandas (*Ailurus fulgens*) we used radio-telemetry in the field from May 2002 to April 2003 in Fengtongzhai Nature Reserve, China. Our results indicated a circadian activity rate of 48.6% (±12.4), with two peaks at 700–1000 h and 1700–1800 h. The activity rhythm was characterized by frequent active periods interspersed with rests. Red pandas were more active during the day than at night, and crepuscular activity rates were intermediate. Activity rate was higher in spring and summer–autumn than winter. On average, red pandas rested 4.96±0.90 times per day, with long rests of greater than 2 h constituting 73.2% of the total duration. A lower circadian activity rate and higher frequency of long rests in winter may be a heat loss adaptation under cold environmental conditions.

Keywords: *Red panda* (Ailurus fulgens), *activity pattern*, *activity rate*, *rest*, *Fengtongzhai Nature Reserve*

Introduction

The red panda (*Ailurus fulgens*) is confined to the southern slopes of the Himalayas, from Nepal to Myanmar to China (Roberts & Gittleman 1984; Johnson et al. 1988; Wei et al. 1999a). Two subspecies, *A. f. fulgens* and *A. f. styani*, have been discerned. *A. f. fulgens* is found throughout the Himalayas, whereas *A. f. styani* is endemic to southwestern Sichuan and eastern Yunnan, China (Wei et al. 1999a; Choudhury 2001). It is believed that the global population is approximately 16,000–20,000, and that habitat loss and poaching are major threats to this species (Choudhury 2001). Red pandas are listed as Endangered on IUCN Red List (Choudhury 2001; Hilton-Taylor 2001) and as a category II under Chinese conservation law, being confronted with increasing human activities.

Red pandas occupy an unusual ecological niche among the Carnivora as they are highly specialized bamboo feeders, akin to the giant panda (*Ailuropoda melanoleuca*). They have developed a number of anatomical adaptations to bamboo including an elongated radial sesamoid, relatively large skull with widely flaring zygomatic arches, and relatively large molar and premolar teeth (Roberts & Gittleman 1984). These features enhance the efficiency of bamboo ingestion (Roberts & Gittleman 1984; Hu et al. 1985; Johnson et al. 1988; Wei et al. 1999b).

Activity patterns are an important aspect of animal behavior and they are often related to metabolism and energetic constraints (Zhou et al. 2007). Environmental factors such as food type and abundance, weather conditions and human disturbance are also known to affect activity patterns (Amstrup & Beecham 1976; Roth & Huber 1986; Machutchon 2001; Winne & Kech 2004; James et al. 2006). Despite much effort being made to understand red panda conservation (Wei et al. 1999a; Choudhury 2001), habitat selection (Wei et al. 2000; Sunita et al. 2001; Zhang et al. 2004, 2006) and feeding (Wei et al. 1999b; Wei et al. 1999c), less is known about its activity in the wild. Hodgson (1847) reported that wild red pandas were more active at dawn, dusk, and during the night from observations in Nepal. More than 100 years later, Johnson et al. (1988) reported a similar result from Wolong Nature

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Reserve, China. However, Reid et al. (1991) claimed that two red pandas (wearing radio collars) in the same reserve were more active during the day. These studies have observed one or two animals only and not across all seasons. We expect that seasonality is likely to play a major role in red panda activity because they are known to reduce metabolism at low environmental temperatures by reducing peripheral circulation, skin temperature and heat loss to the environment (Johnson et al. 1988; McNab 1988; Reid et al. 1991). The resting metabolic rate of red pandas during winter falls to 41% of their normal rate (Johnson et al. 1988; McNab 1988). However, Johnson et al. (1988) and Reid et al. (1991) claimed there were no seasonal patterns in rest periods, especially for long rests of greater than 2 h.

To comprehensively describe activity patterns in red pandas, we attached radio collars to six red pandas in Fengtongzhai Nature Reserve, China, and monitored them for a full 12 months. First, we hoped to clarify generality in activity patterns exhibited by red pandas. Second, we hoped to resolve the controversy regarding seasonality in activity for this species.

Materials and methods

Study area

We conducted fieldwork from May 2002 to April 2003 in Fengtongzhai Nature Reserve (102°48′–103°00′E, 30°19′–30°47′N), Sichuan, China (Figure 1). The reserve covers approximately 390 km^2 of rugged ridges and narrow valleys and varies in elevations from 1000 to 4896 m above sea level. Spring is from April to June, summer and autumn from July to October, and winter from November to March. The average annual temperature is 5.9–7.2°C, humidity is 79–83% and rainfall is 730–1300 mm. Mean daily highest temperatures occur in July from 15.1 to 16.3°C, and lowest temperatures are in January from –4.0 to 2.7°C.

Vegetation follows vertical zonation. Subtropical evergreen broadleaf forest occurs below 1500 m above sea level, where the dominant trees are *Cinnamomum wilsonii* and *C. longepaniculatum*. Mixed evergreen and deciduous broadleaf forest are prevalent at elevations of 1500–2000 m and the most common deciduous trees are *Pterocarya stenoptera*, *Betula* sp. and *Acer* sp. Between 2000 and 2900 m mixed conifer and deciduous forest dominates, as do the conifers *Tsuga chinensis* and *Pinus armandii*, and deciduous *Betula* sp. Conifer forest is dominant at elevations of 2900–3500 m; shrubs and grass lands occur above 3500 m.

Two bamboo species, *Yushania brevipaniculata* and *Bashania faberi*, dominate the study area. The former occurs in the lower-middle part of the hillside and the latter in the upper part, constituting the main food source for red pandas.

Data collection and coding

Chased by domestic dogs up into trees, six red pandas were captured in early April 2002 with

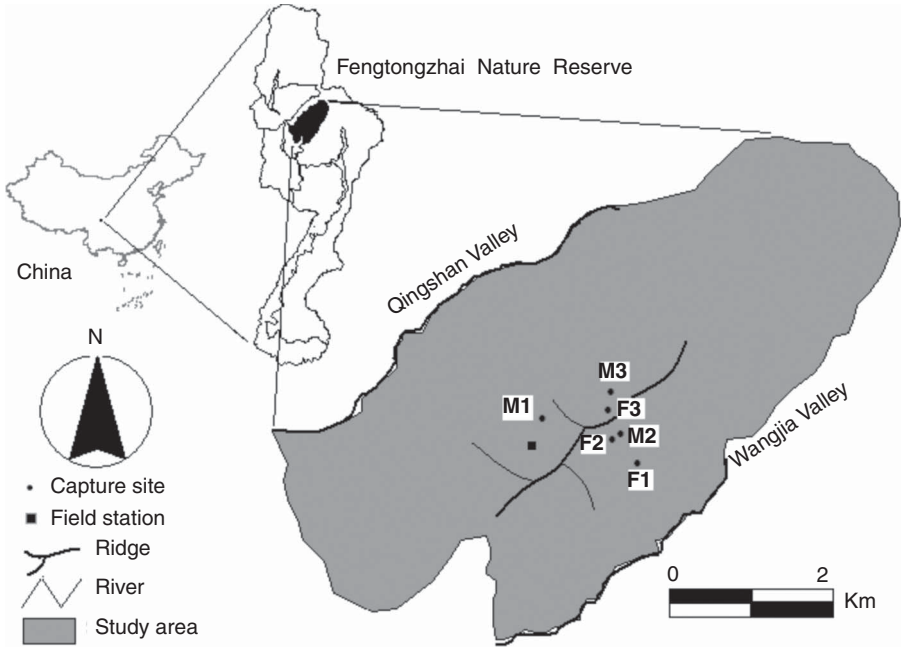

Figure 1. Study area and capture sites for six red pandas in Fengtongzhai Nature Reserve, China.

Table I. Individual status, monitoring duration and activity rate for six red pandas.

Individual	Sex	Age class	Body mass (kg)	Monitoring duration (h)	Duration with 24 h consecutive data (day)	Activity rate (%) (Mean ± SD)
M1	♂	Adult	5.5	864	29	45.1 ± 16.0
M2	♂	Adult	5.9	840	31	52.2 ± 14.0
M3	♂	Adult	5.9	912	25	51.5 ± 4.8
F1	♀	Adult	5.7	864	31	43.3 ± 9.3
F2	♀	Adult	6.0	864	29	52.8 ± 15.6
F3	♀	Adult	ND	912	27	47.4 ± 6.7

ND, not determined.

the approval of the Sichuan Forestry Bureau, China (Figure 1). These pandas were immobilized with ketamine hydrochloride at 6–8 mg kg^{-1}, equipped with 150–152 MHz radio collars (Telonics Corporation, Mesa, AZ, USA), and then released at the capture site. According to on-the-spot measurements of body mass and tooth eruption (Hu et al. 1992), we identified them as three adult males and three adult females (Table I).

Signals from the transmitters were received periodically through a hand-held H antenna (Telonics Corporation, Mesa, AZ, USA). Pulses of around 100 beats per minute (bpm) indicated activity and signals of around 60 bpm indicated inactivity. We recorded this data as binomial variables, 0 for inactive and 1 for active (Paisley & Garshelis 2006).

We attempted to monitor the activity status of each panda for at least three days in the middle of each month. Field monitoring was conducted at a cabin within the reserve. Usually, we recorded signals at an interval of 15 min, giving four activity samples per hour. We did not combine data collected in April 2002 to give the animals a full month to adjust to the collars.

Data analysis

We tabulated all the ones and zeros for each time of the day across sessions to obtain a measure of the proportion of time spent active. We only included in the analysis those data obtained during monitoring periods of 24 consecutive hours. The activity rate at each time of day was calculated as the proportion of activity readings, and the circadian activity rate as the proportion of those spent active among 24 h. Rest, judged by inactivity readings, was classified into three types according to its duration: long (>2 h), medium (1–2 h) and short (≤1 h). Based on Reid et al. (1991), activity was defined as crepuscular (1 h before and 2 h after dawn, plus 2 h before and 1 h after dark), nocturnal or diurnal.

To determine differences between means, one-way ANOVA was used when data were normally distributed followed by Bonferroni multiple comparisons. A Mann–Whitney U-test or Kruskal–Wallis test was used on non-parametric data. Data are presented by mean±SD, except when specified. The significant level was set at 0.05.

Results

We could not collect 24 h of consecutive data in April 2003 because the batteries in the radio collars became almost exhausted. Occasionally, we failed to receive signals from the transmitters in the other months, perhaps due to movement of our focal animals outside the study area or due to topographic signal interference. Over the year we were able to collect 172 complete 24 h monitoring sessions (Table I).

The circadian activity rate of red pandas averaged 48.6% (±12.4), with two peaks at 700–1000 h (with 60.3% activity rate per hour) and 1700–1800 h (with 58.4% activity rate per hour), respectively (Figure 2). The lowest active period occurred from 2000 to 2300 h with the activity rate of 35.7% per hour (Figure 2). On average, red pandas were more active in the daytime (53.3%±8.18), intermediate at dawn and dusk (48.6%±8.86) and less at night (44.2%±7.34).

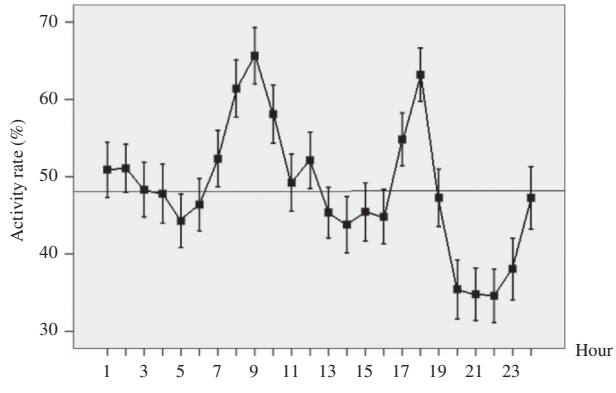

Figure 2. Activity rate (%) for six red pandas in Fengtongzhai Nature Reserve, China, by hour of the day (data are Means ± SE; the horizontal line is the mean activity rate).

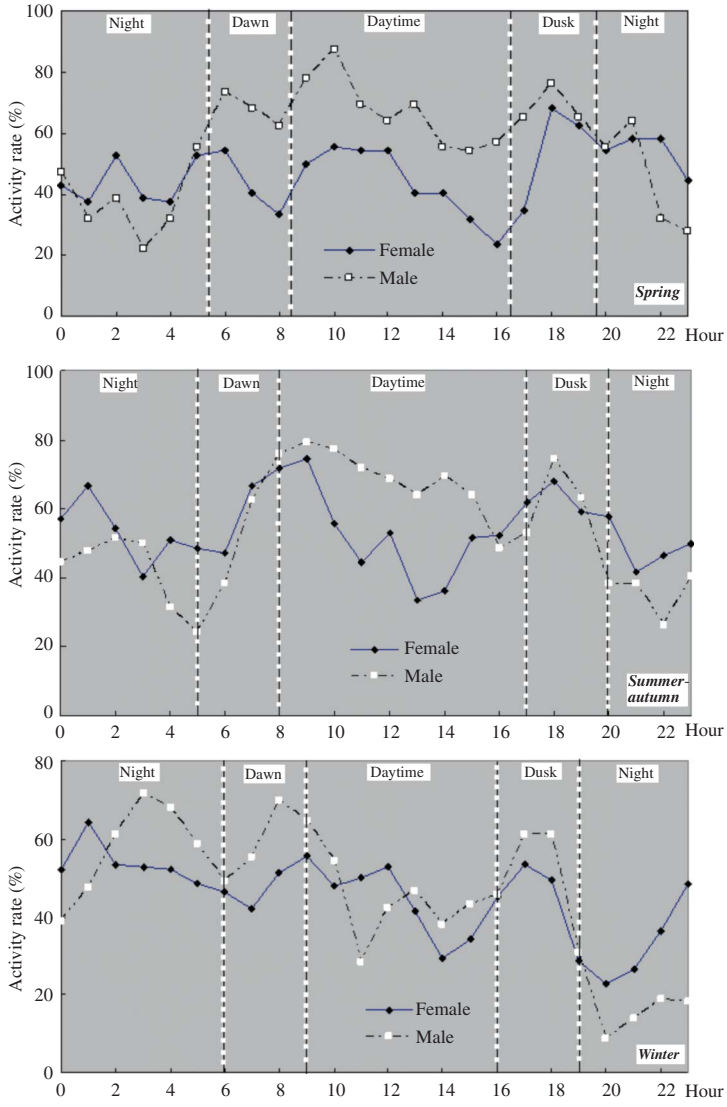

Figure 3. Circadian activity rate (%) of male and female red pandas across seasons.

Activity patterns tended to differ between the sexes across seasons (Figure 3), but the average rates were similar (males: 49.5%±13.3; females: 47.9%±11.6). Activity varied with season (F=7.58, df=2, P=0.001) and was lower in winter (42.2%±13.9) and higher in spring (51.9% ± 7.90, P=0.047) and summer–autumn (54.3%±8.83, $P \leq 0.01$). Red pandas were most active in September (maximum activity rate was 61.7%) and least active in March (minimum was 21.0%) (Figure 4).

On average, red pandas rested 4.96±0.9 times per day, including 2.23±0.69, 1.42±0.80 and 1.31±0.81 times for long rests (mean duration: 4.02±1.24 h), medium rests (mean duration: 1.59±0.45 h) and short rests (mean duration: 0.79±0.21 h), respectively. Long rests constituted 73.2% of the total duration. Both long and medium rests varied

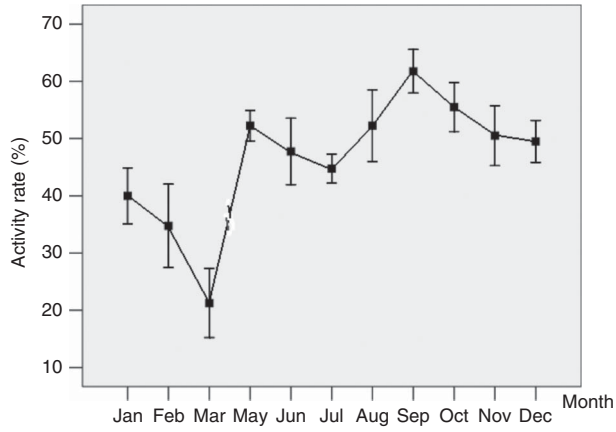

Figure 4. Activity rate (%) for six red pandas in Fengtongzhai Nature Reserve, China, by month of the year (data are Means ± SE).

Table II. Frequencies (Mean ± SD) and duration (in h) of long (>2 h), medium (1–2 h) and short rests (≤1 h) for six red pandas.

	Long rests		Medium rests		Short rests	
Seasons	Frequency	Duration	Frequency	Duration	Frequency	Duration
Spring	1.94 ± 0.69	3.85 ± 0.77	1.86 ± 0.64	1.52 ± 0.13	1.64 ± 1.06	0.82 ± 0.11
Summer–autumn	2.07 ± 0.81	3.86 ± 1.27	1.43 ± 0.87	1.60 ± 0.50	1.43 ± 0.80	0.82 ± 0.13
Winter	2.51 ± 0.44	4.22 ± 1.40	1.17 ± 0.72	1.54 ± 0.50	1.02 ± 0.60	0.69 ± 0.27

across seasons (long rests: F=4.54, df=2, P=0.015; medium rests: F=3.32, df=2, P=0.043). The frequency of long rests was significantly lower in spring (1.94±0.18) than in winter (2.51±0.13) (P=0.02); medium rests were significantly higher (1.86±0.22 *vs.* 1.19±0.16, P=0.038) (Table II). Differences in the frequency of short rests in spring and winter was marginally significant (1.64±0.20 *vs* 1.00±0.14, P=0.056).

Discussion

Our study area borders Wolong Nature Reserve (102°52′–103°24′E, 30°45′–31°25′N) on the north, and similar climatic and topographical features enable us to compare red panda activity patterns on a broader scale (Table III). Our results are similar to those reported by Reid et al. (1991). The focal animal in Johnson et al. (1988) was an eight-month-old sub-adult female and occupied a much larger home range (3.4 km^2 over nine months) than the focal animals in Reid et al. (1991) (0.94–1.11 km^2) and those presented here (males: 2.6±1.21 km^2 males; females: 1.7±0.45 km^2, see Zhang et al. (2009)). The focal sub-adult female followed by Johnson et al. (1988) did not occupy a stable home range and its crepuscular and nocturnal behavior may have been to avoid being predated by *Panthera pardus*, *Neofelis nebulosa*, *Cuon alpinus*, *Martes flavigula*, *Catopuma temmincki* or *Aquila chrysaeos* while traversing widely (Reid et al. 1991; Hu et al. 1992).

Red pandas seemed to exhibit a bimodal daily activity pattern, peaking in the morning and at dusk (Figure 2). Similar to Reid et al. (1991), our study shows that red pandas are more active during the day than at night with intermediate levels of activity at dawn and dusk. Of activity periods, 44.8% occurred during the day, 30.2% at dawn and dusk, and 25% at night. Red pandas are therefore predominately diurnal.

Red pandas are clearly more active during summer, autumn and spring, and this likely corresponds to seasonal changes in diet. In summer and autumn, fruits from *Sorbus* spp. constitute a large proportion of the red panda diet (Wei et al. 1999b; Zhang et al. 2009). Compared to bamboo, which is their year-round food source and extremely abundant in the study area, this fruit is sparse and uncommon. Red pandas would have to spend more time searching for it, resulting in an obvious increase in activity rate. New bamboo shoots sprout quickly in late April in the study area, and are a primary seasonal resource for red pandas (Zhang et al. 2009) although of lower nutritional value (Hu et al. 1985; Wei et al. 1999b). In winter, red pandas can ingest over 1.5 kg of fresh bamboo leaves daily, but in spring when they

Table III. Summary comparison between this study and those of Johnson et al. (1988) and Reid et al. (1991).

Items	Johnson et al. (1988)	Reid et al. (1991)	This study (2002-2003)
Focal animal	1 sub-adult female	1 adult male, and 1 adult females	3 adult males, and 3 adult females
Duration of field monitoring	9 months	9 months	1 year
Activity rate (%)	36.5	Male: 45; Female: 49	Males: 49.5; Females: 47.9
Monthly variation in activity rate	Not significant	Significant	Significant
Activity rate in different parts of the day	Crepuscular>night>daytime	Daytime>crepuscular>night	Daytime>crepuscular>night
Frequency of long rests per day	2.1 ± 0.9	Male: 1.7±0.7; Female: 1.5±0.7	Male: 2.10±0.73; Female: 2.34±0.64
Duration of long rests per day	4.2 ± 2.3	Male: 4.6±2.3; Female: 4.4±2.0	Male: 3.88±1.19; Female: 4.11±1.30
Seasonal variation in frequency of long rests	Not significant	Not significant	Significant

primarily feed on new shoots they ingest more than 4 kg (Wei et al. 1999b). It is therefore not surprising that red pandas are more active in spring than winter. In addition, the females seemed less active than the males in spring and summer–autumn (Figure 3), perhaps reflecting the effect of their reproductive status, which could become pregnant in spring and give birth in summer–autumn (Glatston 1989; Hu et al. 1992).

Although a bamboo specialist, red pandas retain a simple stomach, no caecum, and a short gastrointestinal tract (Roberts & Gittleman 1984; Johnson et al. 1988; Reid et al. 1991; Wei et al. 1999b), and can only consume 18–30% of dry bamboo matter (Wei et al. 1999b). Consequently, it is reasonable that red pandas developed an adaptive strategy of frequent active periods and rest to conserve energy while ensuring the digestive tract is full of bamboo (Johnson et al. 1988).

Like other small and medium-sized mammals, such as Matschie's tree kangaroo (*Dendrolagus matschiei*) and the binturong (*Arctictis binturong*), red pandas can reduce their metabolic rate under low environmental temperatures with little effect on their core temperature (Johnson et al. 1988; McNab 1988; Reid et al. 1991). If individuals reduce peripheral circulation to conserve energy in winter, this presumably occurs at rest and should be short-lived to avoid hypoxia (Reid et al. 1991). In contrast to Johnson et al. (1988) and Reid et al. (1991), our study shows that in winter red pandas have a lower circadian activity rate and a higher frequency of long rests, which is probably an adaptation to cold environmental conditions through heat loss reduction. The higher frequencies of medium and short rests in spring seem to be more related to seasonal fluctuations in diet.

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