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RESEARCH ARTICLE

How do two giant panda populations adapt to their habitats in the Qinling and Qionglai Mountains, China

Xuehua Liu · Tiejun Wang · Ting Wang · Andrew K. Skidmore · Melissa Songer

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Abstract The spatial separation of the Qinling Mountains from the western mountains has caused morphological and genetic distinctions of giant pandas. Could this separation also cause the pandas' behavior change? In this research, we focused on the pandas' movement pattern and selected two wild panda groups in Foping and Wolong Nature Reserves (NR) to represent the populations in the Qinling and Qionglai Mountains, respectively. We hypothesized that the Qinling pandas have developed a different seasonal movement pattern compared with the pandas in the western mountains. We analyzed the radio tracking data from two NRs by using GIS. Our results showed the following significant differences: (1) The Foping pandas live most of the year in the low elevation areas and move higher during June and remain through August while the Wolong pandas live most of the year in the high elevation areas and move lower in April and stay through June; (2) Comparing their low and high elevational areas shows the distinct spatial patterns between reserves, forming two obviously separated clusters in Foping but a single-compact cluster in Wolong; (3) Foping pandas move an average of 425 m±147 s.d. daily, while Wolong pandas move an average of 550 m±343 s.d. daily; and (4) Three habitat factors (i.e., terrain, temperature, and bamboo nutrient) were taken as the driving forces and analyzed, and they showed a strong support explanation to these different movement behaviors of pandas in two NRs. Our findings have important implications for management, for instance, it needs to be careful considering the behavior difference of the pandas when reintroducing them to the wild.

Keywords Driving forces · Foping Nature Reserve · Giant panda · Movement behavior · Wolong Nature Reserve

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X. Liu (✉) · T. Wang
School of Environment, Tsinghua University, Beijing 100084, China
e-mail: xuehua-hjx@tsinghua.edu.cn

T. Wang · A. K. Skidmore
Department of Natural Resources, Faculty of Geo-information Science and Earth Observation (ITC), University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

M. Songer
Conservation Ecology Center, Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal, VA 22630, USA

Introduction

The giant panda is a worldwide famous, rare, and endangered animal species. Its world's remaining population is composed of six local populations occupying six different mountain ranges (Fig. 1). The history of this geographic isolation is unknown, but currently spatial distance, habitat fragmentation, and natural and anthropogenic barriers (like rivers and railways) prevent genetic exchange among local populations and therefore separate the Qinling panda population in the north from all other populations in the western mountains (SFA 2006; Zhu et al. 2011) (Fig. 1).

Prior to 2002, studies failed to show genetic differences between various local populations (Lü et al. 2001). However, later studies documented the morphological and genetic distinctions (Wan et al. 2003, 2005; Zhao et al. 2013) used to support the designation of the Qinling pandas as a separate subspecies: *Ailuropoda melanoleuca qinlingensis*, which has raised a subsequent debate on giant panda subspecies issue (China Daily 2006). No matter how such debating progress, the most important thing is to know and understand more about this endangered species and consequently conserving this species and its fragmented habitat. The segregation of the remaining wild population, estimated at 1,596 individuals in 2004 (SFA 2006), calls for a thorough comparison of local

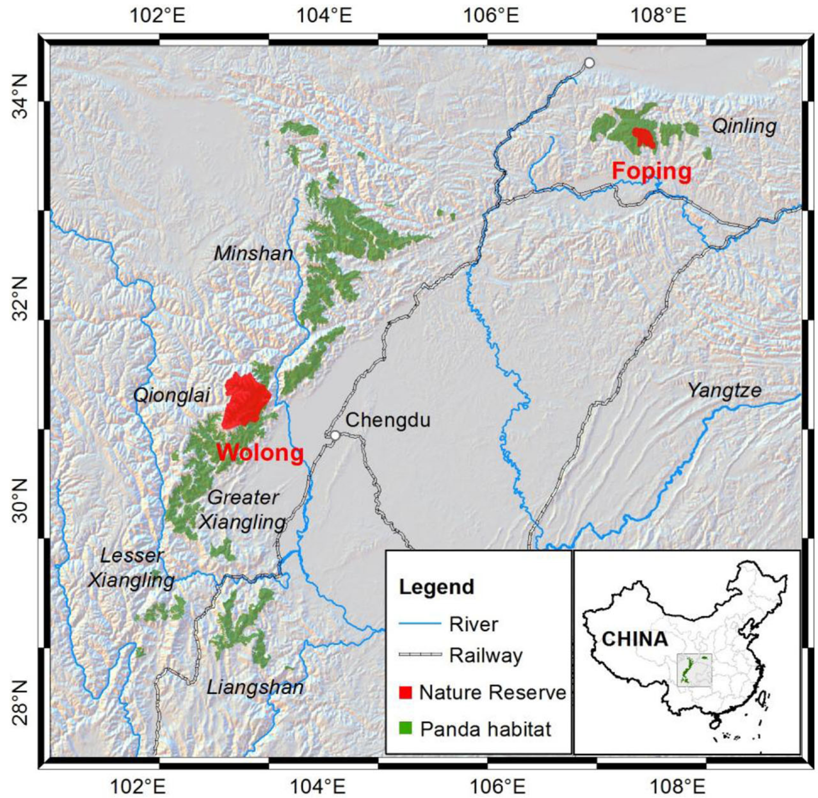

Fig. 1 Distribution of the remaining panda habitats with the location of Foping and Wolong Nature Reserves

populations and more evidence on these local populations' dynamic change.

Thompson (1990) argued that an important theoretical and empirical concern in evolutionary biology is the effect of spatial variation on the divergence of quantitative traits among populations. Many previous studies have supported the hypothesis that spatial variation influences the animals' behavior and morphology. Examples include two subspecies of *Peromyscus maniculatus* with various climbing ability (Thompson 1990), two shorebird subspecies of *Limosa lapponica* with various weights and migrating routes (Wilson et al. 2007), and two turtle subspecies of *Chelodina mccordi* with differing morphological characters (Kuchling et al. 2007). Smadja and Ganem recognized two subpopulations of the house mouse (*Mus musculus musculus* and *Mus musculus domesticus*) from the border of a hybrid zone (Smadja and Ganem 2002) and further deepened their research on the divergence of odorant signals within and between two subpopulations (Smadja and Ganem 2008). This case confirmed on one hand that the various environmental conditions can change the species traits and behavior and, on the other hand, the species can also positively adapt to the environment for better survival.

The current giant panda populations, distributed in the six mountains with various environmental characteristics, utilize their habitat space differently. In order to make further research on the seasonal movement pattern of the giant panda population in the northern Qinling Mountains and other panda populations in the far western mountains, two wild panda groups from Foping and Wolong Nature Reserves (NRs) were selected to represent the local populations in the Qinling and Qionglai Mountains, respectively. Both have relatively large local panda populations with 76 and 143 individuals in Foping and Wolong NRs, respectively, according to the third national-level panda survey conducted during 1999–2003 (SFA 2006). Under spatial separation for a long historical time, we hypothesized that the Qinling panda population's seasonal movement pattern described by Liu et al. (2002) is different from other panda populations in the western mountains, such as the Wolong panda population. In this study, we discussed how each group optimized their movement behavior strategies in the context of habitat.

Methods

Study areas

Foping NR (33° 32'−33° 45' N, 107° 40'−107° 55' E), established in 1978, is centrally located in the Qinling Mountains, the northernmost mountain range of the giant pandas in China. It covers 297 km^2 with an elevation range from 980 to 2,900 m. The average annual rainfall and temperature were approximately 920 mm and 11 °C. The lowest monthly average temperature, −3 °C, occurred in January, and the highest monthly average temperature (about 28 °C) occurred in July. Broad vegetation types include conifer forests, mixed conifer and broadleaf forests, deciduous broadleaf forests, and shrub (CVCC 1980; Ren et al. 1998). Two main bamboo species compose the pandas' staple food: *Bashania fargesii* and *Fargesia qinlingensis* (Tian 1989, 1990; Yong et al. 1994; Ren et al. 1998; Jin et al. 2007; Fig. 2a). They are mostly understory species; only *F. qinlingensis* appears as pure bamboo groves at the top of the mountain. The distribution of two bamboo species varies with elevation. *B. fargesii* occurs mostly below 1,900 m, while *F. qinlingensis* is located at altitudes of higher than 1,900 m.

Wolong NR (102° 52'−103° 24' E, 30° 45'−31° 20' N), established in 1963, is located in the Qionglai Mountains which is centrally located within the current giant panda range in China and covers 2,000 km^2 with an elevation range from 1,120 to 6,250 m. It is a transitional zone from the Sichuan Basin to the Qinghai-Tibet Plateau. There are more than 100 mountain peaks with elevations >5,000 m (Zhang 1983). The whole area inclines from the northwest to the southeast (Li et al. 1983). The average annual rainfall and average annual temperature are about 959 mm and 8.7 °C. The highest and lowest temperatures are about 30 °C and −14 °C, respectively. The reserve supports a rich diversity of plants, with obvious vertical distribution of the natural vegetation, including evergreen broadleaf forest, evergreen and deciduous broadleaf mixed forest, conifer and broadleaf mixed forest, conifer forest, frigid bush and meadow, and alpine sparse vegetation (WNR and SNC 1992; Ouyang et al. 1995). The two bamboo species used by giant pandas are *Fargesii robusta* distributed below 2,700 m and *Bashania fangiana* growing above 2,700 m (Fig. 2b).

Giant pandas use the whole elevation range in Foping (Liu 2001), but only areas below 3,700 m in Wolong (Liu et al. 1997, 1998). In Foping, the giant pandas' low elevation activities occur below 1,950 m and high elevation activities occur above 2,150 m; while in Wolong, the giant pandas' low elevation activities occur below 2,700 m and high elevation activities occur above 2,700 m and below 3,700 m (Schaller et al. 1985; Liu 2001; Liu et al. 2002; Liu et al. 2008; Fig. 2).

Radio tracking giant pandas

Radio tracking was conducted in the Wuyipeng region of Wolong NR and in the Sanguanmiao region of Foping NR. Radio tracking data were collected daily with a MOD-500 telemetry collar, a TR-2 receiver, and an RA-2AK hand-held H-style antenna (Telonics, Mesa, Arizona, USA). During the period of 1981 to 1995, radio tracking was a very applicable approach for wildlife research and often used, such as in giant panda movement research in Wolong Nature Reserve by Hu (1990), in Changqing Nature Reserve by Pan et al. (1989), and in Foping Nature Reserve by Yong et al. (1994); also in the female mule deer movement research by Garrott et al. (1987).

In the Sanguanmiao region of Foping, radio tracking started in May 1991 and ended in December 1995. Fifty-nine receiving towers were distributed along the ridge of the mountain for tracking pandas during the summer and autumn seasons, and through the river valley for tracking pandas during the winter and spring seasons (Liu 2001; Liu et al. 2002). Six pandas (three males and three females) were fitted with telemetry collars and tracked for different periods (Table 1a).

In the Wuyipeng region of Wolong, radio tracking started in March 1981 and ended in April 1983. Sixty-eight receiving towers were used across the radio tracking region (Wang 2006; Liu et al. 2008). Also six pandas (three males and three females) were fitted with telemetry collars and tracked for different periods (Table 1b).

Tracking data analysis

In Foping NR, there were 1,760 raw records from the radio collar latitude–longitude telemetry transformed to Universal Transverse Mercator (UTM) coordinates. The location of the giant panda was calculated from the cross point of two bearings received at two towers (White and Garrott 1990). We eliminated data in cases (Liu 2001; Liu et al. 2002) where: (1) there was no cross point found by two bearings, (2) the cross point obtained was located on another side of the mountain-top, and (3) only one bearing was available. After removing these data, 1,639 records remained.

In Wolong NR, raw tracking data were organized and inputed to the software Locate III (Nams 2006) using three bearings received at three towers to triangulate the location. A total of 2,247 raw locations were obtained from the Locate program. We eliminated wrong data for the following four reasons (Liu 1997; Liu et al. 2008): (1) no calculation resulted, (2) the area required to reach a 95 % confidence level was >0.6 ha, (3) after displaying the location on a digital elevation model, we found it occurred in a place where the radio signal

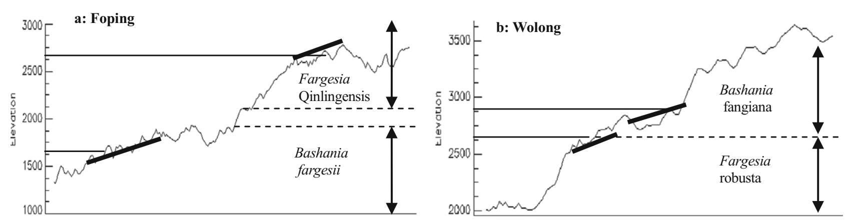

Fig. 2 The vertical profile of elevations of Foping (**a**) and Wolong (**b**) Nature Reserves, with the giant pandas' preferred ranges illustrated with *thick-dark lines*

Table 1 The detailed information of radio tracked giant pandas in Foping and Wolong Nature Reserves

Tracking number	Sex	Age in different year (year)					Tracking duration	Tracking days/months
		1991	1992	1993	1994	1995		
(**a**) In the Sanguanmiao region of Foping Nature Reserve								
127	M1	10a	11a	12a	13a	14a	May 91–May 95	465/34
043	F1	12a	13a				July 91–August 92	106/9
065	M2		<1c	2 s	3 s	4 s	February 92–December 95	463/34
045	F2		6a	7a	8a	9a	May 92–December 95	400/29
005	M3				15a	16a	April 94–December 95	213/20
083	F3					<2 s	January 95–August 95	113/9
(**b**) In the Wuyipeng region of Wolong Nature Reserve								
		1981		1982		1983		
1	M1	2.5 s		3.5 s		4.5 s	March 81–April 83	777/26
2	F1	>12a		>13a			March 81–August 82	412/14
3	F2	2.5 s		3.5 s			April 81–March 82	220/8
4	M2	>12a		>13a		>14a	December 81–April 83	494/17
5	F3			>12a		>13a	January 82–January 83	375/13
6	M3			>12a		>13a	December 82–April 83	144/5

"c", "s", and "a" represent panda cub (<1.5 years), sub-adult (1.5–<5 years), and adult (>=5 years), respectively

could not pass through, or (4) the location was far from the surrounding days' locations. After removing these data, 2,109 records remained.

We used ArcMap GIS produced by ESRI to analyze movement behavior and compare between two panda populations. In Foping, the winter and summer activity ranges were calculated based on a minimum convex polygon, excluding the transition range from these two seasonal activity ranges because it is used only as a temporary movement corridor (White and Garrott 1990). In Wolong, the total activity range was calculated by the same minimum convex polygon method because the winter and summer activity ranges overlap.

We calculated the distances giant pandas traveled over two consecutive days and averaged the distance for each month for Foping and Wolong. Statistics were applied through SPSS software. Mann–Whitney *U* test at 95 % C.I. significant level was adopted to assess for significant difference.

Driving forces data and analysis

Based on the researches of Hu (1990) on the Wolong panda population and Pan et al. (1989) on the Qinling panda population, terrain, temperature, and bamboo nutrient were selected as three major driving forces which drive the giant panda populations of Foping and Wolong NRs to have adapted the different seasonal movement behaviors.

The terrain factor considers elevation and slope together in this research. We used digital elevation model and its calculated slope model with a scale of 1:100,000. The frequencies of pixels of the two nature reserves were plotted in a three dimensional way through a Matlab program.

Temperature data were collected from Foping and Wolong NRs during 1980 and 1996 in order to match with the radio tracking periods. We calculated the yearly mean, highest, and lowest temperatures for both NRs through an Excel software.

Bamboo nutrient data were mostly obtained through reference searching. For the few data for Foping bamboos, we used data from our measuring since no reference data was available. We compared the nutrient contents by grouping into Foping NR and Wolong NR high and low elevation areas with two different staple bamboo species in order to clearly give the reason for panda seasonal movement behavior.

The other factors, such as human disturbance, vegetation types, precipitation, etc., may have certain roles on giant pandas' seasonal movement, but we did not analyze them.

Results

Elevational and directional patterns of giant panda seasonal movement

Comparison of panda movements between two reserves shows very different elevational and directional patterns (Fig. 3). The Foping panda population lives most of the year in lower elevation areas below 1,950 m (an average elevation of approximately 1,686 m±102 s.d.) and the pandas move to the higher elevation areas above 2,150 m (an average elevation of approximately 2,490±151 s.d. m) during June and

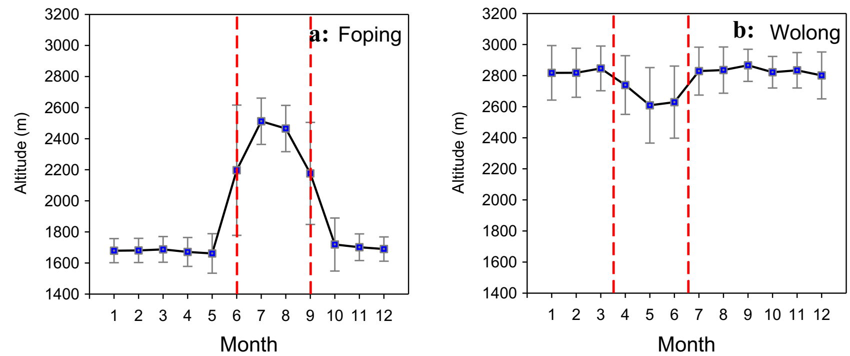

Fig. 3 The elevation ranges and periods of giant panda movements in Foping and Wolong Nature Reserves. The *red dash lines* in the figure show the periods of seasonal movement of the giant pandas in two nature reserves

remains there through August. However, The Wolong panda population shows the opposite pattern and the pandas live most of the year in the middle and subalpine mountain areas above 2,700 m (an average elevation of approximately 2,850 m±172 s.d.) and move down in April to lower elevations below 2,700 m (an average elevation of approximately 2,664 m±223 s.d.) and stay through June. The elevational range of panda movement is about 800 m in Foping but only about 200 m in Wolong between low and high elevation areas, which had a significant difference between low and high elevation areas in Foping and Wolong ($p<0.01$ in both Wolong and Foping; Mann–Whitney test) shown by Fig. 4.

Spatial patterns of giant panda seasonal movement

Both Foping and Wolong panda populations show seasonal movements between two different bamboo habitats with two different bamboo species, respectively. Comparing low and high elevational activities within both reserves shows significantly different medians ($p<0.01$ in both Wolong and Foping; Mann–Whitney test). The tracking data shows their distinct spatial patterns too between two reserves (Fig. 5). In Foping, tracking locations form two obviously separated clusters for low and high elevation ranges (Fig. 5a). In Wolong, tracking locations form a comparatively compact cluster in space, but the slight separation of points in two seasonal periods of April to June and July to March next year can still be seen (Fig. 5b).

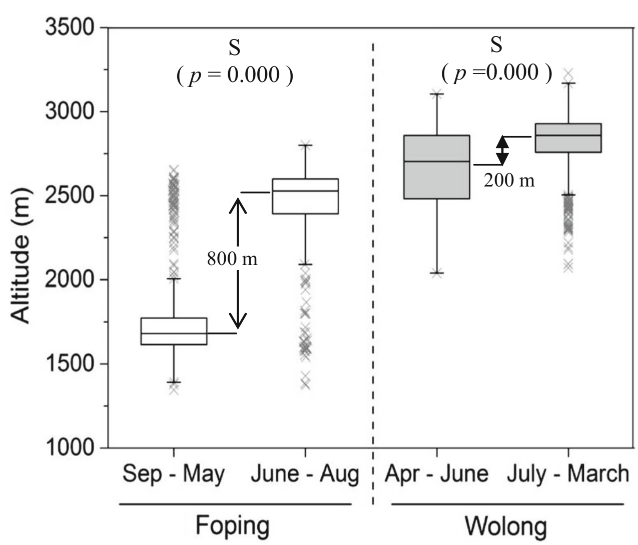

Fig. 4 *Boxplots* show the elevation differences between two seasonal locations between the periods of September to May next year (staying in low elevation area) and the period of June to August (staying in high elevation area) in Foping Nature Reserve and between the periods of April to June (staying in low elevation area) and the period of July to March next year (staying in high elevation area). *S* means that there is a significant difference between two seasonal elevational ranges in two natural reserves

Areas of activity range of giant panda

The spatial dispersion patterns of tracking locations help explain the difference in home range sizes between Foping and Wolong. In Foping, the average total panda activity range is 5.5 km^2±2.3 s.d. for males and 4.4 km^2±1.0 s.d. for females, while the activity ranges in Wolong are larger at 10.7 km^2±1.2 s.d. for males and 9.9 km^2±1.1 s.d. for females (Table 2). The total activity ranges for Wolong pandas differs from Foping pandas and also from Hu's research findings in Wolong (Hu 1990). According to Hu, a male usually has an activity range of about 6–7 km^2 and a female has a smaller activity range of about 4–5 km^2 which showed similar to the situation in Foping NR.

Daily movement distances of giant panda

Daily movement distances of two panda populations are also different (Fig. 6). Foping pandas move an average of 425 m±147 s.d. daily with a maximum of 700 m±143 s.d. in September and a minimum of 284 m±49 s.d. in February (Fig. 6a), while Wolong pandas move an average of 550 m±343 s.d. daily with a maximum of 681 m±485 s.d. in April and December and a minimum of 432 m±338 s.d. in August (Fig. 6b). In Wolong, the daily movement distance of pandas had a large standard deviation year round as just mentioned, while in Foping the larger standard deviation occurred in May, June, and September when the animals are moving for mating and seasonal movement.

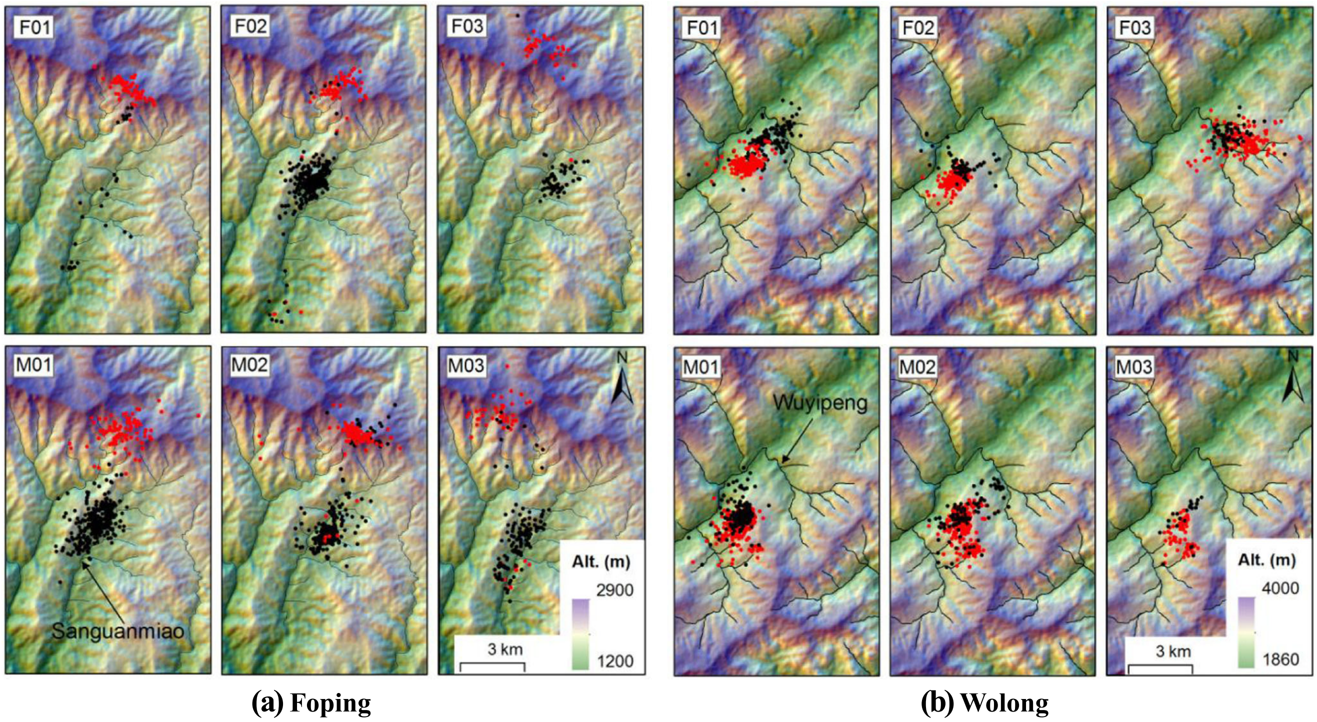

Fig. 5 The spatial distributions of radio tracking locations of six panda individuals collected, respectively in Foping Nature Reserve in 1991–1995 (**a**), and Wolong Nature Reserve in 1981–1983 (**b**). *F* and *M* represent female and male, respectively. *Black points* represent the panda locations in a period of September to May next year in Foping and in a period of April to June in Wolong. *Red points* represent the panda locations in a period of June to August in Foping and in a period of July to March next year in Wolong

Three driving forces

Different terrain patterns were shown in Fig. 7. Foping has more area within the low elevation range (i.e., 203 km^2 below 1,950 m and 62 km^2 between 1,950 and 2,900 m) and Wolong has more area at high elevation range (i.e., 780 km^2 between 2,700 and 3,700 m and 544 km^2 below 2,700 m). Foping has more areas with slope of 0–30° at the low elevation range of 1,600–1,800 m (about 42 km^2, comparing with 29 km^2 with slope >30°), whereas Wolong has more areas with slope of 10–40° at the high elevation range of 2,800–3,100 m (about 145 km^2, comparing with 80 km^2 with slope >40°).

The temperature data of Foping and Wolong NRs during 1980 and 1996 were compared in Fig. 8. It was found that both reserves have similar annual highest temperatures (28 °C in Foping and 30 °C in Wolong), while Foping has the higher annual lowest (−3 °C) and mean temperatures (11 °C) compared to Wolong (−11 and 8.5 °C).

The nutrient contents of staple bamboo species in Foping and Wolong NRs were shown in Table 3. In Foping, *B. fargesii* at low elevations generally has higher nutrient content than *F. qinlingensis* at high elevations except bamboo branches, while it is reverse that in Wolong, *B. fangiana* at high elevations has higher nutrient content than *F. robust* at low elevations except bamboo shoots. These can partially explain the giant pandas' seasonal migration behavior and owe winter habitat and summer habitat in a year. It is also clear from Table 3 that the *F. qinlingensis* at high elevations show high nutrient levels in bamboo branches which can give giant pandas a strong nutrient support in the summer season in Foping.

Discussion

The research results have clearly shown that the two panda populations in Foping and Wolong NRs have obviously

Table 2 The areas of activity range (km^2) of giant pandas in low and high elevation ranges in Wolong and Foping Nature Reserves

	Low elevation range			High elevation range			Whole range		
	Male	Female	Average	Male	Female	Average	Male	Female	Average
Wolong	–	–	–	–	–	–	10.7±1.2	9.9±1.1	10.2±1.1
Foping	3.6±1.9	3.3±1.0	3.4±1.5	2.6±1.2	1.4±0.7	2.0±1.1	5.5±2.3	4.4±1.0	4.9±1.7

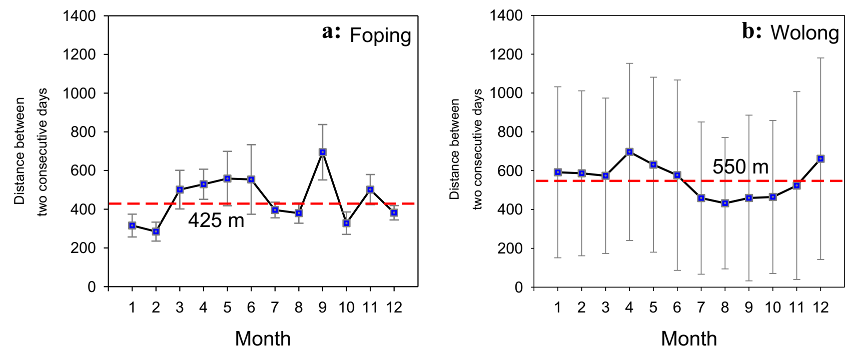

Fig. 6 Monthly average distance of daily panda movements with standard deviations in Foping (**a**) and Wolong (**b**) Nature Reserves. The *red dash lines* represent the annual average distance

adopted the different seasonal movement behaviors, respectively, to fit to their different habitat environments. Remote tracking have been applied widely as a very useful and successful approach to research on various animal behaviors, such as movement (Liu et al. 2002, 2008), long-distance migration (Thouless 1995), habitat selection (Liu et al. 2005) etc., which is certified by this study too. By using tracking data, more detailed animal behaviors on movement elevation and direction pattern, spatial pattern of locations, areas of activity range, and daily movement distance can be analyzed and the differences of the two panda populations in Foping and Wolong NRs can be further compared to explore the animal's adoptability to the diverse environments.

Terrain, climate, and vegetation regimes affect habitat conditions and therefore influence panda movement behavior and patterns. More directly, three habitat factors were chosen to explore the difference of giant pandas' seasonal movement behaviors in Foping and Wolong NRs, which are (i) terrain with considering elevation and slope, (ii) temperature, and (iii) bamboo nutrient. Researches done by Pan et al. (1989), Hu (1990), and Yong et al. (1994) had also used these three factors to explain the pandas' movement mechanism. Our study made more detailed data analysis on these three driving factors.

The terrain difference in Foping and Wolong NRs has caused the two panda populations to respond to their terrain environment in different ways. Those areas with more flat slope and larger space at low elevation in Foping NR and at high elevation area in Wolong NR seem to be more attractive to the giant pandas since they spend the majority of the time in these areas, thus conserving energy required for daily movements. Larger space with proper bamboo growing provides pandas with more food as well as individual territory. From Fig. 2, we can see the terrain characteristics determine that Wolong pandas are limited in the areas between 2,500 and 3,000 m, called 'the remained flat ground in the high-mountain' with a very steep terrain surrounding and a small distance between two major bamboo habitats. This might be also a reason for the result shown in Fig. 5: panda locations showing a relatively compact cloud in Wolong. However, there exists a wide transitional zone in Foping between two typical bamboo habitats, which caused the Foping panda population to move longer between the high and low elevation areas. Figure 4 shows the significant differences between two seasonal elevation range both for Foping and Wolong NRs, which is a robust quantitative evidence.

Temperature can be an important climatic factor for animals. Giant pandas prefer cool habitats in general (Zhou et al. 1999). When temperatures rise in spring and summer, pandas in the two reserves use different strategies in response to their environment. In Foping, they avoid the rising temperatures by moving up in June to the high elevation area with cool environment. In contrast, the Wolong pandas descend down in April to the low elevation area. A possible reason for this difference could be that summer temperature in low elevation area in Foping is higher than their preferred temperature, with an annual mean temperature 3 to 4° higher than the one in Wolong. From an ecological perspective, the movement to the

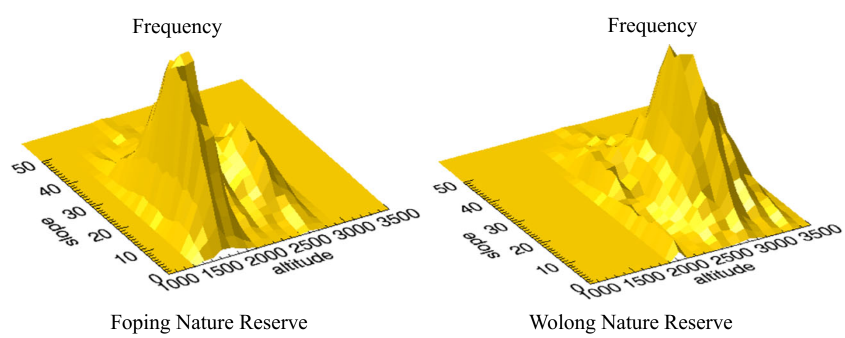

Fig. 7 3D illustrations of pixel frequency of terrain with different elevations and slopes in Foping and Wolong Nature Reserves. Slope and elevation data were derived from a digital elevation model (*DEM*) with a spatial resolution of 30 m×30 m

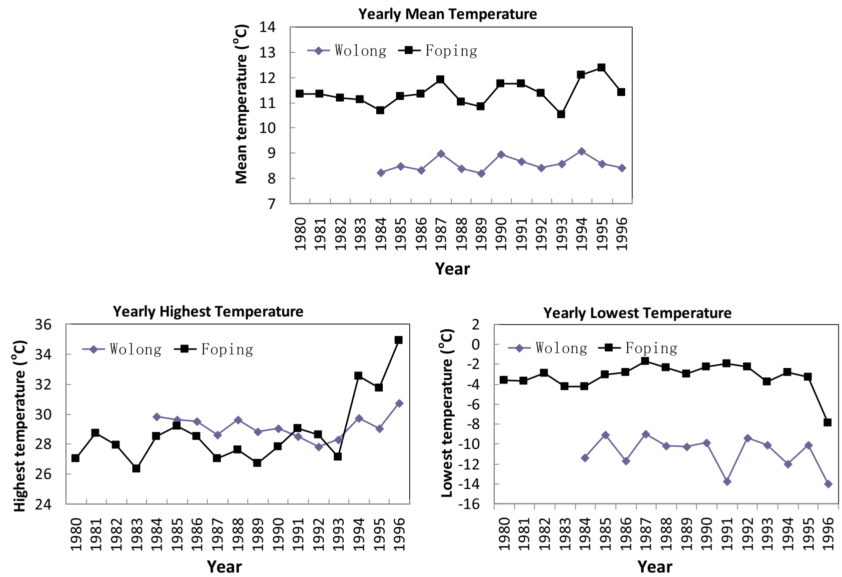

Fig. 8 Comparison of yearly mean temperature between Foping and Wolong Nature Reserve

lower elevation below 2,600 m in Wolong may directly coincide with the bamboo shooting of *F. robusta*.

Bamboo nutrients are another key factor driving the pandas' seasonal movement (Yong et al. 1994; Wei et al. 1996; Pan et al. 2001). Giant pandas have been obligate bamboo grazers as far back as two million years ago (Jin *et al*. 2007). However, as herbivores with the unspecialized digestive tract of carnivores and dependent on a low nutrient and low energy plant, the giant pandas have had to adopt an efficient feeding strategy to survive (Schaller et al. 1985). High levels of bamboo quality (e.g., species, palatability, and nutrition) and quantity (e.g., spatial distribution, abundance, and handling efficiency) are essential for pandas to find suitable forage (Reid et al. 1989). Although there are more

Table 3 The nutrients (%) in two staple food bamboo species in Wolong and Foping Nature Reserves individually

Bamboo part	Nutrients	Wolong Nature Reserve		Foping Nature Reserve	
		Bashania fangiana at high elevation	*Fargesii robusta* at low elevation	*Fargesia qinlingensis* at high elevation	*Bashania fargesii* at low elevation
Shoot	Total sugar	–	–	0.47[b]	3.11[e]
	Crude protein	4.07[a1]	10.53[a2]	4.30[b]	20.10[c]
	Crude fat	0.56[a1]	1.27[a2]	0.55[b]	2.41[c]
Leaf	Total sugar	21.48[a1]	16.98[a2]	1.40[b]	1.42[b]
	Crude protein	19.44[a1]	16.19[a2]	11.20[b]	13.70[d]
	Crude fat	3.37[a1]	3.14[a2]	1.47[b]	2.03[d]
Branch	Total sugar	–	18.59[a2]	2.14[e]	1.13[e]
	Crude protein	11.95[a1]	5.10[a2]	5.21[e]	5.36[d]
	Crude fat	2.35[a1]	1.12[a2]	6.69[e]	0.98[d]
Stem	Total sugar	22.57[a1]	18.00[a2]	1.40[b]	1.49[b]
	Crude protein	4.42[a1]	2.49[a2]	2.33[b]	3.21[c]
	Crude fat	0.81[a1]	0.48[a2]	0.47[b]	0.76[c]

The grey shading means higher level nutrients in bamboos between low and high elevation areas. En dash means data not available. Letters a–e represents five data sources. Higher nutrient contents were shaded by grey color

[a] From Qin et al. (1993, on P100 for a1 and P142 for a2)

[b] From Liu (2008)

[c] From Wang et al. (2012)

[d] From He (2009)

[e] With underline: from our sample measuring

than seven bamboo species in Wolong and four species in Foping, pandas only choose the most abundant and widely distributed *B. fargesii* and *F. qinlingensis* in Foping (Pan et al. 1988; Ren et al. 1998; Liu et al. 2005), and *F. robusta* and *B. fangiana* in Wolong (Schaller et al. 1985; Hu 1990; Liu et al. 2008) as their constant food resources throughout the year. Laboratory analysis showed that the nutrient content of their preferred bamboo species is higher than other bamboo species.

In addition, bamboos *F. robusta* in Wolong and *B. fargesii* in Foping all have tall (>4 m) and thick stems which is not preferred by giant pandas. However, there exists a very specific "ZhuYangZi" *B. fargesii* habitat in Foping with short (about 2 m height) and dense culms with more branches (Liu 2001). This is where the giant pandas stay for most time of the year in Foping. Wolong NR lacks this habitat. Radio tracking reveals that the highest grazing frequency occurs in the elevation ranges which are all covered well by bamboo (Liu et al. 2002, 2005, 2008). We might predict that the high nutrient, palatability, and digestibility of the bamboo shoots make them preferred by giant pandas, which attracts the giant pandas in Wolong to move from the high elevation area to low elevation area in spring.

Other factors, such as human disturbance, vegetation types, and precipitation may play certain roles on giant pandas' seasonal movement, but we did not analyze them due to the following reasons. For human disturbance factor, the local panda populations both in Wolong and Foping have been adapting to their habitat environments for a long history and therefore the human's impacts could hardly make the whole local panda populations change their seasonal movement behavior specifically inside the two national nature reserves. A recent study conducted by Zhang et al. (2014) showed that Foping pandas are still using the summer habitat during May to August and stay in the winter habitat during the rest time of the year based on their new collected GPS tracking data in Foping. We have also not found any publication to show the Wolong panda population has changed the movement pattern till now.

For vegetation type and land-use factor, we should say that they follow naturally the elevation change in a sequence from low to high elevation by broadleaf forest, mixed broadleaf and conifer forest, and conifer forest, which play the role of shelter in both nature reserves and could not make serious sense to different panda seasonal movement patterns unless bamboos disappear. For precipitation factor, we also do not feel it has a strong role on causing the giant pandas' different movement patterns in Wolong and Foping.

The different movement strategies of Foping and Wolong panda populations result from their evolution and adaptation to different environments. Regardless of whether or not the Qinling panda is a distinct subspecies, there are clearly differences in the movement behavior strategies between the Qinling and Qionglai panda populations. Our research could encourage more effort toward investigating the differences and dynamic adaptations between giant panda populations, and our results may influence the government toward making new regulations and funding for conserving the species. For better protection of the fragmented Qinling panda population, more conservation attention is urgently needed, especially since all giant panda mountains fall under the China Western Development Plan which will increase the habitat fragmentation and the negative impacts on the panda habitats, specifically on the Qinling panda population. Understanding more about this animal species would also have major implications for management and reintroduction efforts. For instance, one important implication for management of our findings is that we need to carefully consider the different habits of the pandas from various mountains when reintroducing them among the various local population sources. In addition, based on the small low elevation range of the giant pandas in Wolong, we should stop the local people activities' encroaching to this area during April to June.

Conclusion and recommendation

The paper analyzed the seasonal movement patterns of two giant panda populations in Foping and Wolong Nature Reserves and explained three major driving factors (elevation, temperature, and bamboo nutrition). The results showed the significant difference on their movement behaviors. The Foping pandas live most of the year in the low elevation areas and move higher during June and remain through August; while the Wolong pandas live most of the year in the high elevation areas and move lower in April and stay through June. This tells us that it is necessary to carefully take the local habitat conditions and the pandas' movement habit into account during the reintroduction work.

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