GIANT PANDA MOVEMENTS IN FOPING NATURE RESERVE, CHINA

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Abstract: Observing the giant panda (Ailuropoda melanoleuca) in the remote mountains of Foping Nature Reserve (NR), China, is difficult due to the dense vegetation and steep terrain. Radiotracking is an effective way to study this animal and understand its behavior and habitat use. We used radiotracking data from 3 male and 3 female pandas to study their movement patterns between 1991 and 1995 in Foping NR. Our results show that the pandas in Foping NR occupied 2 distinct seasonal ranges (specifically, winter and summer activity ranges) and had a regular seasonal movement between the winter range below 1,950 m and the summer range above 2,160 m. The pandas climbed from the winter to the summer habitats within a period of 8 days from 7 to 15 June, and descended to the winter habitat between 1 September and 6 October. Therefore, the pandas spent about three-fourths of the year (average 243 days) in their winter activity range and an average of 78 days in the summer activity range. Our results provide managers with more accurate information about the pandas’ movements quantitatively and visually, which can contribute to panda conservation.

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Key words: Ailuropoda melanoleuca, China, Foping Nature Reserve, geographic information system, giant panda, movement pattern, quantitative study, tracking.

The giant panda is an endangered species. It is a solitary animal, which makes observation difficult in remote mountain areas covered with dense vegetation. In the forested mountains of China, radiotracking should be an effective way to study the giant panda and understand its behavior and habitat use.

Some work on the movement of the giant panda has been undertaken in Wolong NR in Qionglai Mountains and Changqing NR in Qinling Mountains. Analysis of the radiotracking data showed that the pandas in Wolong NR remained at a high elevation for most of the year and fed on Bashania fangiana bamboo. They moved down to a lower elevation during May and June to forage on shoots of Fargesia robusta bamboo (Hu et al. 1985). The pandas in Changqing NR exhibited a different movement pattern compared with the pandas in Wolong NR (Pan et al. 1988). These pandas stayed for most of the year at low elevations feeding on Bashania fargesii bamboo and occupied high-elevation areas to feed on Fargesia spathacea bamboo from June to August.

Movement patterns of panda populations on different mountains may differ and therefore remain unclear (Pan et al. 1988). The pandas in Foping NR remain an enigma even though they have been the subject of numerous studies. The first panda population and distribution survey was carried out in Foping NR in 1973 (Shaanxi Biological Resources Survey 1976). Preliminary ecological observations were conducted in Foping NR during the 1970s and 1980s (Wu 1981, 1986; Yong 1981, 1989; Ruan 1983). More advanced ecological research has been done in Foping NR. Yong et al. (1993, 1994) analyzed the panda population and distribution as well as movement habit. Li et al. (1997) reported their work on panda population viability analysis in Foping NR. Research on panda habitat has recently started (Yang et al. 1997, 1998; Ren et al. 1998; Yang and Yong 1998). It has been reported that there are 2 main seasonal habitats in Foping NR occupied by pandas as their winter and summer habitats, and the pandas move between these 2 seasonal habitats (Pan et al. 1988, 1989; Yong et al. 1994). However, it is not as clear when, where, and how the animals move. In this study, we present data on the giant panda and its habitat. Radiotelemetry was introduced to track the giant pandas in Foping NR during 1991–1995. The achievements of the radiotracking program in Foping have not been published internationally, with only descriptive results in 2 Chinese reports by Yong et al. (1994) and Pan et al.
Our aim was to gain some insights on the characteristics of panda movement, such as activity patterns, period of moving, areas of activity range, duration of seasonal activities, as well as the distance of movement.

STUDY AREA

Foping Nature Reserve (33°32′–33°45′N, 107°40′–107°55′E) is located in the middle part of the Qinling Mountains, the northernmost panda refuge in China (Fig. 1). The reserve covers an area of approximately 290 km², and the elevation ranges from about 980 to 2,900 m. There are 4 drainage systems in the reserve: the XiHe, DongHe, JinShuiHe, and LongTanZi rivers. Annual rainfall was approximately 920 mm (1976–1995). The average lowest temperature, −3 °C, occurred in January, and the average highest temperature, about 28 °C, occurred mostly in July (1976–1995). Radiotracking was carried out in the SanGuanMiao–GuangTouShan region (Fig. 1).

Broad vegetation types include conifer forests, mixed conifer and broadleaf forests, deciduous broadleaf forests, shrub, and meadow (ECVC 1980, Ren et al. 1998). Two main bamboo species compose the pandas' staple food: *Bashania fargesii* and *Fargesia spathacea* (Pan et al. 1988; Tian 1989, 1990; Yong et al. 1994; Ren et al. 1998). They are mostly understory species; only *F. spathacea* appears as pure bamboo groves at the top of the mountain. The distribution of the 2 species varies with elevation. *B. fargesii* occurs mostly below 1,900 m, while *F. spathacea* is located at altitudes of higher than 1,900 m.

There were 60 to 70 giant pandas within Foping NR, with an average density of 1 panda/5 km² according to the survey conducted in 1990 (Table 1; Yong et al. 1993). DongHe and XiHe rivers are 2 areas with more pandas (about 75% of the panda population in Foping NR).

About 300 local people resided within the nature reserve during 1998. They were concentrated in 5 village groups within the nature reserve: SanGuanMiao, XiHe, JieShang, XiaHe, and DaChengHao groups. Land-use activities were farming and mushroom production, both of which influence the remaining panda habitat.

Table 1. Sub-populations (individual) and densities (individual/km²) of giant pandas in watersheds of the Foping Nature Reserve, China, in 1990 (Yong et al. 1993).

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Area (km²)</th>
<th>Number of pandas</th>
<th>Density (individual/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DongHe</td>
<td>54</td>
<td>26</td>
<td>0.5</td>
</tr>
<tr>
<td>XiHe</td>
<td>71</td>
<td>23</td>
<td>0.3</td>
</tr>
<tr>
<td>LongTanZi</td>
<td>15</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>YueBa</td>
<td>59</td>
<td>7</td>
<td>0.1</td>
</tr>
<tr>
<td>HuangTongLiang</td>
<td>38</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>HeiLongTan</td>
<td>33</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>XiaHe</td>
<td>23</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>Approx. 290</td>
<td>60 to 70</td>
<td>Average 0.2</td>
</tr>
</tbody>
</table>
These activities mainly were located in the river valleys as well as the area near the southern boundary.

**METHODS**

Our study describes the seasonal movement and activity range of the giant panda. However, “movement” and “migration” are terms used interchangeably. In this paper, we use the term “movement” to describe the giant panda’s changing position (Baker 1978). Due to the existence of 2 distinct seasonal activity ranges of the giant pandas in Foping NR, we adopted the terms “winter activity range” and “summer activity range” for this study.

Radiotracking equipment (Telonics, Mesa, Arizona, USA) was used only in the SanGuan-Miao–GuangTouShang region (Fig. 1) and consisted of a MOD-500 telemetry collar, a TR-2 receiver, and an RA-2AK hand-held H-style antenna. Fifty-nine receiving towers were used across the radiotracking region. They were distributed along the ridge of GuangTouShan Mountain (approx. east to west) for tracking pandas during the summer and autumn seasons, and through the DongHe River valley (approx. south to north) for tracking pandas during winter and spring seasons. Six pandas (3 males and 3 females) were fitted with telemetry collars and tracked for different periods, the longest lasting from 1991 to 1995 (Table 2). Tracking started in May 1991 and stopped in December 1995. Data were collected daily.

There were 1,760 raw records from the radiocollar latitude–longitude telemetry transformed to Universal Transverse Mercator (UTM) coordinates. The location of the panda was estimated from the cross point of 2 bearings received at 2 towers by triangulation (White and Garrott 1990). After careful checking, the final data set contained 1,639 records. We eliminated 3 kinds of raw records: (1) no cross point could be found by 2 bearings; (2) the cross point obtained was located on another side of the mountaintop; (3) only 1 bearing was available, which could not form an animal location. All samples were plotted on a background map. The centers of each panda’s winter, summer, and mating activity ranges were obtained by calculating the average of the UTM X- and Y-coordinates. The centers of the activity ranges were displayed to discern their spatial separation. The distance between all tracking locations and the centers of each panda’s winter, summer, and mating activity ranges was calculated and plotted to obtain an impression of the spread of each individual and its activity center.

According to previous studies (Pan et al. 1988, Yong et al. 1994) and local expertise, there are 2 seasonal activity ranges in Foping NR. Giant pandas move from the winter to the summer activity ranges during May and June, generally, and descend from the summer to the winter activity ranges during August and September. To determine the exact period for pandas to move up and down between 2 seasonal activity ranges, we calculated and plotted the average elevations of 6 pandas from May to June and August to October for each year. The periods for pandas to change their seasonal activity ranges were subjectively defined according to the contours of average elevation. The length of the periods that pandas remain in 2 seasonal activity ranges was then calculated.

These movement periods defined 3 elevation ranges: winter, summer, and transition ranges. Because the elevation data were nonnormally distributed, the nonparametric boxplot method (Moore and McCabe 1998) was used, and the upper and lower whiskers (SPSS 1997:40–41) of the boxplots defined the elevation ranges of the pandas’ winter and summer activity. We hypothesize that there is a significant difference between the elevations of the pandas’ winter and summer activity ranges.

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**Table 2. Tracking information on 6 radiocollared pandas in Foping Nature Reserve, China. Based on the definitions of Hu et al. (1985) and Schaller et al. (1985), pandas were classified as cub (c; <1.5 years old), sub-adult (s; 1.5 to <5 years), and adult (a; ≥5 years old).**

<table>
<thead>
<tr>
<th>Tracking number</th>
<th>Sex</th>
<th>Age (yr) during tracking year</th>
<th>Tracking duration</th>
<th>Tracking days/months</th>
</tr>
</thead>
<tbody>
<tr>
<td>panda127</td>
<td>M</td>
<td>10a 11a 12a 13a 14a</td>
<td>May 91–May 95</td>
<td>465/34</td>
</tr>
<tr>
<td>panda043</td>
<td>F</td>
<td>12a 13a</td>
<td>Jul 91–Aug 92</td>
<td>106/9</td>
</tr>
<tr>
<td>panda085</td>
<td>M</td>
<td>&lt;1c 2s 3s 4s</td>
<td>Feb 92–Dec 95</td>
<td>463/34</td>
</tr>
<tr>
<td>panda045</td>
<td>F</td>
<td>6a 7a 8a 9a</td>
<td>May 92–Dec 95</td>
<td>400/29</td>
</tr>
<tr>
<td>panda005</td>
<td>M</td>
<td>15a 16a</td>
<td>Apr 94–Dec 95</td>
<td>213/20</td>
</tr>
<tr>
<td>panda083</td>
<td>F</td>
<td>&lt;2s</td>
<td>Jan 95–Aug 95</td>
<td>113/9</td>
</tr>
</tbody>
</table>
The area of both the winter activity range and the summer activity range during different years for each adult panda (e.g., panda005, panda127, panda043, and panda045) was calculated by the minimum convex polygon method (White and Garrott 1990). The transition range was excluded from these 2 seasonal activity ranges because it is used only as a temporary movement corridor. Two hypotheses were formulated: that male pandas had larger winter and summer activity ranges than female pandas, and that pandas used a larger area for winter activity than for summer activity.

Fig. 2. Activity patterns of 6 giant pandas from radiotracking points in the SanGuanMiao–GuangTouShan region in Foping Nature Reserve, China, from 1991 to 1995. All 6 maps show 2 clearly defined areas with very dense tracking points (as shown in the bottom left panel). The lower cloud of tracking points represents the pandas’ winter activity range, while the upper cloud is the summer activity range. The area between the activity ranges represents the transition range.
We calculated the average monthly distance pandas traveled over 2 consecutive days for an overview of the monthly pattern in a year, and to test the hypothesis that adult male pandas move farther within 2 consecutive days than adult female pandas. All hypotheses in the study were tested using the Mann-Whitney U-test at $\alpha = 0.05$.

RESULTS

Panda Seasonal Activity Patterns

Each panda had 2 well-delineated winter and summer activity ranges (Fig. 2). In the winter range, panda045, panda065, and panda005 stayed on the western side of the DongHe River, while panda043, panda083, and panda127 occupied the eastern side of the DongHe River. In the summer range, panda043 and panda127 stayed mostly along the eastern ridge of GuangTouShan Mountain, while panda045 and panda065 used both the southern and northern slopes on the eastern side of GuangTouShan Mountain. The summer range of panda005 was located at the western side of GuangTouShan Mountain. The summer range of panda083 was on the northern side of the GuangTouShan ridge, far from other individuals.

The centers of 6 pandas’ winter and summer activity ranges, as well as mating sites for female panda043 and panda045, showed that giant pandas maintained space between individuals and their different activities (Fig. 3). In the summer range, panda083 and panda005 stayed away from the other 4 pandas (i.e., panda043, panda045, panda065, and panda127) that were living near each other. The distances between the centers in the winter range were slightly larger than the distances of the centers in the summer range. We found that the mating sites of 2 females (i.e., panda045 and panda043) were situated in the ShuiJingGou Valley, located at the southern part of the tracking area. Female panda083 was 1.5 years old in 1995 and had no mating activity.

The distances of all panda tracking locations to the centers of an individual panda’s winter (Fig. 4a) and summer (Fig. 4b) activity ranges show that the different pandas have various distances spreading from their winter and summer activity centers. In the winter range, panda043 (female) and panda005 (male) had the largest spread distance (about 1,200 m), and panda127 (male) the smallest spread distance (about 400 m). While in the summer activity ranges, the distances of panda locations to their centers were shorter than those in the winter season. Panda005 had the largest spread distance (about 750 m) and panda127 the shortest distance (about 450 m). The outliers in the figure indicate that the pandas sometimes spread very far from their activity centers.

Periods of Movement between and Duration in Winter and Summer Activity Ranges

Giant pandas in Foping NR remained in their winter activity ranges at about 1,700 m from October to May in the following year and occupied the summer activity ranges at an elevation of approximately 2,500 m during July and August (Fig. 5a). They transferred between the winter and the summer activity ranges during June and September (Fig. 5a). The pandas’ transfer between 2 seasonal activity ranges is associated with a large change in elevation (shown by the standard deviations in Fig. 5a). However, once the pandas were in the winter or the summer activity ranges, they maintained activities at a relatively constant elevation with a standard deviation of about 150–300 m.
We found that pandas moved up quickly from the winter to the summer activity ranges within a range of 8 days from 7 to 15 June (Fig. 5b), but took about 36 days from 1 September to 6 October to descend from the summer to the winter activity ranges (Fig. 5c). Therefore, the pandas spent 44 days (i.e., transfer period) transferring between 2 seasonal activity ranges. Consequently,
the giant pandas stayed in the winter range for approximately 243 days from 7 October to 6 June in the second year (i.e., autumn–winter–spring period) and in the summer range for only 78 days from 16 June to 31 August (i.e., summer period).

### Elevation Ranges for Three Activity Ranges

The elevations of the tracking points in both the autumn–winter–spring period and the summer period have smaller ranges than the elevation of the tracking points in the transfer period (Fig. 6). The winter activity range was from about 1,410 to 1,950 m, and the summer activity range was from about 2,160 to 2,800 m. Therefore, the pandas remained below 1,950 m in the autumn–winter–spring period and above 2,160 m in the summer period. There is a significant difference between the medians of elevation of these 2 activity ranges (df = 1, \( P < 0.01 \), Mann-Whitney \( U \)). The elevation gap between the upper whisker of the winter elevation range and the lower whisker of the summer elevation range from 1,950 to 2,160 m is defined as the transition range.

### Areas of the Two Seasonal Activity Ranges

Each panda had a varied area of winter and summer activity ranges during different years (Table 3). In general, the average winter activity range (about 3.3–3.6 km\(^2\)) was larger than the average summer activity range (about 1.4–3.3 km\(^2\)). Male pandas, on average, used larger summer activity range (3.3 km\(^2\)) than female pandas (1.4 km\(^2\)), while male and female pandas used similar areas (3.3 and 3.6 km\(^2\)) in the winter activity range.

There was no significant difference between adult male and female pandas’ winter (df = 1, \( P > 0.05 \), Mann-Whitney \( U \)) and summer (df = 1, \( P > 0.05 \), Mann-Whitney \( U \)) activity ranges. Adult male pandas used a similar area for their winter range (3.6 km\(^2\)) as they do for their summer range (3.3 km\(^2\); df = 1, \( P > 0.05 \), Mann-Whitney \( U \)). However, for adult female pandas, the used area in the winter activity range (3.3 km\(^2\)) was significantly larger than the used area in the summer activity range (1.4 km\(^2\); df = 1, \( P < 0.05 \), Mann-Whitney \( U \)).

### Distance Moved over Two Consecutive Days

Giant pandas in Foping NR traveled about 300 m with small distance variation during January and February and traveled a slightly larger distance of about 400 m with also small distance variation during 2 summer months (Jul and Aug) as well as 2 winter months (Oct and Dec; Fig. 7). During the other months, pandas traveled farther than 400 m within 2 consecutive days with slightly larger distance variation. The average monthly moving distances during March, April, May, June, and September had very large variations. There was no statistically significant difference in 2 consecutive days’ movement distance between adult male and female pandas (df = 1, \( P > 0.05 \), Mann-Whitney \( U \)). Even during April, June, and September, there was no statistically

### Table 3. Area (km\(^2\)) of winter and summer activity ranges for 4 adult pandas (male panda005 and panda127; female panda043 and panda045) in different years in Foping Nature Reserve, China, 1991–1995. The comparison was tested using the Mann-Whitney \( U \) test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Winter activity range</th>
<th>Summer activity range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male(^{a,c}) Female(^{a,d})</td>
<td>Male(^{b,c}) Female(^{b,d})</td>
</tr>
<tr>
<td>Area</td>
<td>3.1 2.3 4.3 1.4</td>
<td>5.2 2.7 2.1 0.7</td>
</tr>
<tr>
<td></td>
<td>1.1 4.2 1.6 1.2</td>
<td>2.2 2.6 2.3 2.4</td>
</tr>
<tr>
<td></td>
<td>6.0 4.5</td>
<td>4.2</td>
</tr>
<tr>
<td>Average area</td>
<td>3.6 3.3 3.3 1.4</td>
<td>6 5 4 4</td>
</tr>
</tbody>
</table>

\(^{a}\) Male and female’s winter activity ranges: \( P > 0.05 \).

\(^{b}\) Male and female’s summer activity ranges: \( P > 0.05 \).

\(^{c}\) Winter and summer activity ranges of males: \( P > 0.05 \).

\(^{d}\) Winter and summer activity ranges of females: \( P < 0.05 \).
significant difference in the distance traveled within 2 consecutive days (df = 1, $P > 0.05$, Mann-Whitney $U$), although there was a difference between adult male and female pandas in these 3 months (Fig. 7).

**DISCUSSION**

The giant pandas’ activity pattern in Foping NR shows spatially distinct winter and summer seasonal activity ranges. Spatial distribution patterns of these 5-year radiotracking data for 6 pandas show some overlaps in their activity ranges. However, it illustrates the overlap of activity ranges in a relatively long period, not an individual panda’s daily locations because we found that the panda individual occupied the different locations in space when we plotted the radiotracking points day by day.

The elevation change of the pandas’ activity in June (from 7 to 15 Jun) and September (from 1 Sep to 6 Oct) indicates a regular annual movement between the winter and summer activity ranges. This confirms work by Pan et al. (1988) in the neighboring Changqing NR, but with a small difference: the seasonal movement in Changqing NR occurs between May and June, and September to October. The pandas in Foping NR take only 2–3 days for moving upwards over 1 year. The average value of 8 days (from 7 to 15 Jun) represents the range for all pandas for the whole period of 5 years. Yong et al. (1994) analyzed 12 months of radiotracking data (from Apr 1991 to Apr 1992) of only 2 pandas. Due to the limited data used by Yong et al. (1994), their result about the period for pandas to move up to a higher elevation differs from our results. The defined transfer periods (from 7 to 15 Jun and from 1 Sep to 6 Oct) and the transition range (from 1,950 m to 2,160 m) of the pandas can be used not only to find the boundaries of elevation range of the winter or the summer activity ranges, but also to help estimate the area of the winter and the summer activity ranges separately.

Our study took a statistical approach to define the vertical seasonal activity ranges of the giant panda. Our results showed that the area above approximately 2,160 m is the pandas’ summer range and the area below about 1,950 m is the pandas’ winter range. However, Pan et al. (1988) found that the winter range in their study area of Changqing NR, neighboring to Foping NR, was below 1,900 m and the summer range was above 2,300 m.

Estimating the area of the pandas’ winter and summer activity ranges provides us with an image of how pandas use their territory. In panda research, the terms “winter activity range” and “summer activity range” have not often been used. The total of winter and summer activity ranges can be compared with those in Wolong NR. The average total activity range of males is 6.2 km$^2$ and of females 4.7 km$^2$ in Foping NR. In Wolong NR, 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$^2$ (Hu 1990). However, the measure of home ranges of the pandas in Wolong NR included the areas for seasonal movement, i.e., the transition area. Thus, the average home range (including the transition range) of the pandas in Foping NR might be larger than the average home range of the pandas in Wolong NR.

Limited summer habitat—only about 15% of the nature reserve (Liu et al. in press)—might be a reason for pandas in Foping NR to move into close proximity at the top of the GuangTouShan Mountain. The food (e.g., *F. spathacea* bamboo) in the panda summer habitat grows in dense groves, and the pandas stay in the summer habitat for just 2.5 months (about 78 days). This may explain why pandas can stay near each other. Hu (1990) also concluded that the giant panda is able to survive in a small activity range if plenty of bamboo is available. According to the local staff in Foping NR, the summer range of female panda083 in 1995 on the northern slope of
GuangTouShan was assumed to be the dispersion behavior because she was only 2 years old and used an area far away from other individuals.

Based on the work in Wolong NR, Hu (1990) concluded that the giant pandas are inactive for most days of a year and have a movement distance of 500 m or less. Our results showed that the giant pandas have varied distances of movement in different time periods. Within 2 consecutive days, movement distance can be <300 m on average in January and February, between 300 m and 400 m in July, August, October, and December, or >400 m in March, April, May, June, September, and November. Apparently, the period of March and April is the mating season of the pandas and they increased their moving distance. In May, the bamboo in the low-elevation area started shooting, and the pandas moved in a wider range and traversed greater distances per day to search for new bamboo shoots. During June and September, the pandas ascended to and descended from the summer activity ranges and covered larger distances. Male and female pandas have different movement distances in different months. On average, male pandas move larger distances than females, which agrees with the finding in Wolong NR that "the male usually walks farther than the female" (Hu 1990:26). The period for pandas to transfer between 2 seasonal activity ranges in Foping NR generally coincides with that of the giant panda group in the neighboring nature reserve in the Qinling Mountains: moving up the mountain from middle April to early June and moving down from early September to October as in Changqing NR (Pan et al. 1988). The pandas in Wolong NR, however, while living in a different mountain range (the Qionglai Mountains), live in the B. fangiana bamboo area above 2,700 m for most of the year. They move down to the F. robusta bamboo area below 2,700 m only in late April or early May until the middle of June when the F. robusta bamboo shoots come out. Some of the pandas even stay in the B. fangiana bamboo area all year (Pan et al. 1988). Panda ecology in these 2 mountain ranges is thus not the same, which may have important implications for evaluating terrain characteristics for suitability of panda reintroduction.

**MANAGEMENT IMPLICATIONS**

Our results provide managers with more accurate information about pandas’ movements quantitatively and visually, which can contribute to panda conservation in several ways: (1) The pandas’ moving periods we found will guide local staff and managers in panda tracking and reduce the chance of missing tracking data. (2) Winter and summer activity ranges defined by elevation ranges can be applied to panda habitat management, for instance, to calculate the size of these panda activity ranges and to estimate indirectly the panda population based on available winter habitat and average area of panda winter activity range. (3) The difference in panda movement patterns found between Foping NR and its neighboring Changqing NR, as well as far-away Wolong NR, shows wildlife managers and ecologists that various strategies need to be taken into account in scientific research and panda population surveys in different geographical regions.

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