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Den selection by the giant panda in Foping Nature Reserve, China

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Abstract

The natal den is important to reproduction success of the giant panda *Ailuropoda melanoleuca*. In this study, we tested the differences between natal dens of the giant panda and reference caves by three statistical methods, and derived the main factors influencing den selection by the giant pandas by principal component analysis (PCA). The results of difference tests indicated that nine variables, including visibility at a height of 1 m, rain proofing, aspect, position, gradient, canopy cover, coverage of bamboo, distance to water and human disturbance were significantly different. The result of PCA indicated that canopy cover was the most important factor in natal den selection by giant pandas. Distance to water, coverage of bamboo and degree of rain proofing were also important factors determining den selection by the giant pandas in Foping Nature Reserve.

Keywords: *Ailuropoda melanoleuca*, den selection, Foping Nature Reserve, giant panda, natal den

Introduction

To increase reproductive success, some mammals select suitable dens to give birth and foster their pups (Magoun and Copeland 1998). The selection of a natal den is under strong evolutionary pressure because it affects the fitness of individuals directly (Martin 1995). There are two elementary functions of dens: one is to evade predators, another is to maintain a stable microenvironment for rearing offspring (Reichman and Smith 1990; Laurenson 1994; Magoun and Copeland 1998). To match these needs, the location and physical features of a den are two key factors which are considered in den site selection (Reichman and Smith 1990; Laurenson 1993; Fernandez and Palomare 2000).

The giant panda, *Ailuropoda melanoleuca* (David, 1869), is recognized as one of the most endangered species in the world and much effort has been devoted toward its conservation

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since 1980 (Pan 2001). As a K-strategy species, the giant panda is extremely sensitive to environmental changes, especially in the breeding season (Hu 2001). The mortality of giant panda pups in nature is quite high due to predators (Wei et al. 1997; Hu 2001). A female giant panda gives birth and fosters its offspring in the den for 100–130 days (Pan 2001). During this denning period, the mother spends most of the time with its pup in the den. A suitable natal den and den site is vital for the survival of the giant panda's offspring (Hu 1981). It provides shelter from predators, and protects giant panda pups from bad weather, therefore increasing the breeding success of the giant panda (Pan 2001).

Although it is important to understand the effects of the physical structure of natal dens and den site characteristics on the breeding success of giant pandas, there is limited information about den selection by this species in the natural habitat, except for a few studies that briefly document some den characteristics (Hu et al. 1985; Yong 1989; Deng 1992; Pan 2001). In the Minshan Mountains of Sichuan, the giant panda mainly uses a large hole at the base of conifer trees as a natal den (Hu et al. 1985; Deng 1992). In contrast, the giant panda in the Qinling Mountains prefers to use natural limestone caves in which to give birth and foster offspring (Yong 1989; Liang and Li 1993; Pan 2001). So far, the giant panda's den and microhabitat selection, especially den site selection, remain unknown.

The aims of this study are to describe the spatial characteristics of the dens used by the giant panda in Foping Nature Reserve, and to find the important factors that influence den selection. Due to the high density of the giant panda population in Qinling Mountains (Liu and Zhang 2003), the breeding success might be limited by the shortage of suitable limestone caves in the natural habitat. Knowledge about den selection may help in developing a conservation and management strategy for this rare and endangered species in the protected areas.

Methods

Study area

The research was conducted in Foping Nature Reserve, Shaanxi Province, China. Foping Nature Reserve is located on the southern slope of the middle range of the Qinling Mountains (33°33'–33°46'N, 107°41'–107°55'E). The main function of this nature reserve is to protect the giant panda population and its habitat. The reserve covers an area of approximately 290 km², and the elevation ranges from about 980 to 2900 m. Vegetation types in the reserve include conifer forests, mixed conifer and broadleaf forests, deciduous broadleaf forests, shrub and meadow (China Vegetation Compiling Committee 1980; Ren 1998). There are two dominant bamboo species, which comprise the pandas' staple food, namely *Bashania fargesii* Keng f. and Yi and *Fargesia qinlingensis* Yi and J. X. Shao (Ren 1998; Liu and Zhang 2003). They are mostly understorey species, and only *Fargesia qinlingensis* appears as pure bamboo groves at the top of the mountain. The distribution of the two species varies with elevation. *Bashania fargesii* occurs mostly below 1900 m, while *Fargesia qinlingensis* is located at higher altitudes of more than 1900 m (Liu and Zhang 2003). The reserve is also the core zone of the giant panda's distribution area in the Qinling Mountains, where about 80 giant pandas occur (State Forestry Administration of China 2006).

Identification of natal dens

We searched each valley and visited all limestone caves found in the study area. A "natal den" was defined when at least the two following criteria were satisfied: (1) there was

evidence that the pandas had collected stems and leaves of trees or bamboo for preparation of the main chamber; (2) the presence of hairs and/or droppings of giant panda around the den (Hu et al. 1985; Yong 1989). Females may use more than one den during the parturition and rearing period (Pan 2001), and all dens found were considered for further analyses. To minimize impacts on giant pandas and pups by our investigation, all fieldwork was conducted in winter, when giant pandas and their pups move away from their dens (Hu 2001). In addition, because female giant pandas may use the same den in subsequent years (Pan 2001), we took precautions not to modify the natal dens and den sites.

Den description

The location of each den was determined using a global positioning system (GPS) to generate a map layer in ArcView3.2a (Environmental Systems Research Institute, Redlands, CA, USA). Topographical characteristics such as general aspect, slope position of natal den, gradient, and elevation were recorded. The physical characteristics of each den and vegetation cover were described and quantified. These physical characteristics included entrance width and height, main chamber width, height and depth, entrance orientation, whether the den was rain proof and wind proof. Entrance width and height, main chamber width, height and depth were measured with a fibreglass tape. Elevation was measured by altimeter. General aspect, gradient and entrance orientation were measured by compass.

For each den, the distances to the nearest standing tree and bamboo forest were measured with tape. Distances to a permanent water source and proximity of human activities were estimated using established GIS map layers. Visibility at 1 m height from the den was estimated by placing one observer at the den at a height of 1 m. A vegetation-sampling plot (20 m × 20 m) was established at each den site to estimate the canopy cover, percentage cover of shrubs and bamboo forest, average diameter of standing trees at breast height, average height of standing trees, shrubs, and bamboos. Additionally, vegetation type was recorded at the den site. We measured standing trees' diameters at breast height with fibreglass tape.

We chose a nearby, unused, limestone cave as reference cave for each den to compare with the natal dens. To minimize the bias caused by the size of reference cave, only the caves that have enough volume for a giant panda living inside were selected as reference caves. We investigated and measured these reference caves using the same methods as described above.

Statistical analyses

Three statistical methods were utilized to test significant differences between dens and reference caves. Firstly, the Kolmogorov–Smirnov *Z*-test was employed to test the normality of the data. Proportional data, such as vegetation cover, do not usually meet the requirements for normality (Zar 1996); therefore, we used an arcsine transformation to normalize the data. Other data that were not normally distributed were transformed using a log or square-root transformation. For variables distributed normally, independent-samples *t* test was used to test for differences; otherwise, a Mann–Whitney nonparametric test was employed. Chi-square test was also used to test the significant differences of nominal variables, including vegetation type, den entrance orientation, and general aspect of den site.

Principal component analysis (PCA) was employed to reveal the significant factors determining den selection by the giant panda (Ramsey and Schafer 1997). Only variables with significant differences between natal dens and reference caves were selected as the variables set of PCA. The principal components with initial eigenvalue>1 were utilized to detect the significant factors and their sequence. In order to eliminate the interference caused by related variables, all data were standardized and examined using Kendall's correlation analysis ($P=0.005$, two-tailed test) before PCA. All statistical analyses were conducted using SPSS for Windows (v. 13.0).

Results

Den characterization

A total of 32 natal dens and 32 reference caves were investigated, from October 2004 to November 2005. Most natal dens were located beneath cliffs, with bamboo cover in front. Of the 23 variables, nine differed significantly between natal dens and reference caves (Table I). No significant differences were found between natal dens and reference caves for measurement of entrance and main chamber ($P>0.05$). Natal dens of giant pandas have a short visibility distance in front at a height of 1 m ($P<0.0001$), far nearer than that of reference caves. Rain proof performance of natal dens was better than that of reference caves ($P<0.0001$). Most natal dens were located on the south or southeast slopes, which significantly differed from reference caves ($\chi^2=15.249$, $df=7$, $P<0.0001$). Both position

Table I. Characteristics of natal dens of the giant panda *Ailuropoda melanoleuca* and reference caves in Foping Nature Reserve, China.

Characteristics	Natal den ($n=32$)	Reference cave ($n=32$)	P
Width of entrance (cm)	137.00 $\pm$ 17.715	157.09 $\pm$ 9.631	0.444
Height of entrance (cm)	116.11 $\pm$ 14.044	90.78 $\pm$ 5.966	0.733
Width of chamber (cm)	131.58 $\pm$ 20.692	127.00 $\pm$ 11.886	0.802
Height of chamber (cm)	113.00 $\pm$ 13.071	80.74 $\pm$ 7.750	0.876
Depth of chamber (cm)	239.00 $\pm$ 13.059	200.26 $\pm$ 13.629	0.879
Visibility at a height of 1 m (m)	12 $\pm$ 1.648	42 $\pm$ 4.571	<0.0001
Performance of wind proofing	1.16 $\pm$ 0.043	1.28 $\pm$ 0.092	0.396
Performance of rain proofing	1.25 $\pm$ 0.070	1.75 $\pm$ 0.090	<0.0001
Dryness of chamber	1.59 $\pm$ 0.161	1.69 $\pm$ 0.188	0.923
Orientation of entrance	2 ^a , 3 ^a	2 ^a	0.059
Elevation (m)	1864 $\pm$ 18.560	1877 $\pm$ 21.615	0.643
Aspect	1 ^a	1 ^a , 3 ^a	<0.0001
Position	1.19 $\pm$ 0.083	1.66 $\pm$ 0.132	0.003
Gradient (°)	47 $\pm$ 1.314	41 $\pm$ 1.519	0.005
Vegetation type	2 ^a	2 ^a	0.368
Canopy cover	3.50 $\pm$ 0.110	3.09 $\pm$ 0.094	0.005
Average height of arbors	4.00 $\pm$ 0.142	3.00 $\pm$ 0.149	0.742
Coverage of shrub	1.19 $\pm$ 0.070	1.25 $\pm$ 0.078	0.549
Average height of shrub	1.25 $\pm$ 0.092	1.32 $\pm$ 0.104	0.539
Coverage of bamboo	3.22 $\pm$ 0.098	3.38 $\pm$ 0.178	0.038
Average height of bamboo	2.03 $\pm$ 0.071	2.00 $\pm$ 0.110	0.822
Distance to water (m)	74 $\pm$ 12.437	221 $\pm$ 25.680	<0.0001
Intensity of human disturbances	3.28 $\pm$ 0.081	3.78 $\pm$ 0.087	<0.0001

Values are means $\pm$ SE. ^aMode of nominal variable.

($P=0.003$) and gradient ($P=0.005$) of natal dens significantly differed from reference caves, which were located higher and on steeper slopes than reference caves. Canopy cover ($P=0.005$) of natal dens, as well as coverage of bamboo ($P=0.038$), differed from reference caves. The distance from natal dens to water differed from reference caves ($P<0.0001$), the natal dens being closer to a permanent water source. The difference of variable human disturbance intensity between natal dens and reference caves was also significant ($P<0.0001$), the natal dens being further from human disturbances.

Important factors determining den selection by the giant panda

Results from the correlation analysis indicated that all nine significantly different variables were uncorrelated. Nine variables were analysed by PCA. The first four principal components met the criterion of an eigenvalue >1 and together explained 73.621% of the variance of natal dens (Table II).

Concerning the correlation of each variable with that of the four axes (Table III), principal component 1 ordered sites by canopy cover, intensity of human disturbance, and visibility at a height of 1 m, which are related to the safety of the dens, and can be described as the safety factor. Principal component 2 ordered sites by distance to water, and can be described as the water factor. Principal component 3 can be explained as the food factor, relating to coverage of bamboo. Finally, principal component 4 ranked sites by the degree of rain proofing, and is termed the structure factor.

Table II. The eigenvalues of the den site selection by the giant panda *Ailuropoda melanoleuca*. Total variance explained through principal component analysis.

Principal component	Eigenvalues	% of variance	Cumulative %
1	2.118	23.533	23.533
2	1.716	19.069	42.602
3	1.502	16.686	59.288
4	1.290	14.333	73.621

Table III. Correlation of variables with the first four principal components derived from 32 natal dens of the giant panda *Ailuropoda melanoleuca* in Foping Nature Reserve, China.

Variable	Component			
	1st	2nd	3rd	4th
Position	0.461	0.588	-0.070	0.335
Aspect	0.414	0.553	0.442	-0.005
Gradient	-0.028	-0.348	-0.355	0.676
Distance to water	0.059	-0.655	0.588	0.050
Intensity of human disturbances	0.713	-0.416	-0.290	-0.040
Performance of rain proofing	0.328	-0.108	0.014	-0.788
Visibility at a height of 1 m	0.700	0.318	0.086	0.134
Canopy cover	-0.790	0.454	0.083	-0.068
Coverage of bamboo	0.014	-0.147	0.855	0.269

Discussion

Habitat selection refers to a hierarchical process of behavioural responses that may result in the disproportionate use of habitats to influence survival and fitness of individuals (Svardson 1949; Jones 2001). Many factors are involved in an organism's choice of habitat. The selection of den site is under strong evolutionary pressure and is complicated by the interaction of many environmental factors (Williams 1966; Yan and Cheng 1998).

The giant pandas in the Qinling Mountains usually give birth and foster their offspring in natural limestone dens (Yong 1989; Pan 2001). Before parturition, a female giant panda will visit several limestone caves and choose a suitable cave as the natal den (Hu et al. 1985; Pan 2001). A "suitable den" depends on the structure and physical features, as well as habitat characters around the den, matching the need of a female giant panda and its offspring (Pan 2001). Previous studies showed that the giant panda prefers dens located on the middle part of south-facing slopes, and ranging from 1600 to 1800 m (Yong 1989; Liang and Li 1993). Our results show that the giant panda in the Foping Nature Reserve tends to utilize those dens with good shelter, close to water and food resources. A similar conclusion was drawn in a comparison of 18 giant panda dens between Wolong and Foping which indicated that the giant panda in the Foping Nature Reserve tends to utilize those dens with good shelter that are windless and sunny, and close to water and food (Deng 1992). Furthermore, the natal dens in Foping demonstrated that the giant panda preferred an altitude of around 1850 m, and that rain proofing and the degree of human disturbance were also important factors in natal den selections.

Shelter is one of the three most important factors affecting wildlife habitat (Song 2001). Animals tend to select areas with good cover in accordance with anti-predator strategy (Yan 1998). A well-sheltered cave can provide the panda pups with protection from predation (Hilden 1965). In the present study, the result of PCA (Table III) showed that safety was the most important factor influencing den selection by the giant panda in Foping Nature Reserve. The giant panda selects a den in coniferous and broadleaved mixed forest with high coverage of canopy (Table I), which provides good shelter, helping to camouflage the den and therefore increase probability of survival of the pups. The short visibility at a height of 1 m, and lower intensity of human disturbance around the den sites (Table I), also suggested that the giant panda tends to select a safe place as a den.

Female giant pandas usually spend all their time in the den with the pup without feeding for at least the first week or longer (Hu 2001; Pan 2001). Because the pup cannot walk out with the female until 3 months old, a short distance to water will allow a female giant panda to decrease the investment in drinking and spend more time looking after the pup during this period. High density of bamboo provides sufficient food that allows the female giant panda to decrease the investment in seeking food, as well as reducing the risk of predation, even though giant pandas do not prefer such high-density bamboo forest during the non-breeding period (Hu 2001). Of 32 dens, 30 natal dens (94%) were located on a sunny slope. Sunny slopes can provide more warmth for growing pups and decrease the female panda's heat loss. On the premise of safety, a medium gradient and a short distance to water will reduce the energy consumption expended by the female in feeding and drinking activities during the breeding period. All of these were evidence that both the survival and fitness of female pandas and pups are improved through den selection, after the tradeoff between the fitness of the female giant panda and offspring survival.

Generally, the process of habitat selection by an animal can be described in two steps: first, a rough selection based on general habitat patterns on a large scale; second, a refined selection based on microhabitat characters (Hilden 1965; Pan 2001). This helps to describe

the process of den site selection by the giant panda. On the premise that several dens are available, vegetation type and canopy cover are key factors that determine primary den site selection by the giant panda. Furthermore, microhabitat features such as distance to water, general aspect, and bamboo cover will then determine which den will be used to give birth.

Dens are important in the persistence of giant panda populations as they provide shelter from extreme temperature, moist microclimate, predation pressure and suitable places to rear young. Because of the locally high density of giant pandas, a shortage of natural dens may limit the growth of wild populations. Therefore, den sites should be increased in suitable sites, and the results of this study may provide some useful guidance in this. It may be possible to reshape existing limestone caves, or to provide artificial dens in appropriate places to substitute for natural dens in some areas where the habitat is suitable but natural dens are insufficient. In addition, to improve reproduction success of the giant panda in the Qinling Mountains, human disturbances should be kept away from the dens used by giant pandas. A habitat-monitoring programme is also necessary to monitor the dynamics of habitat in Qinling Mountains.

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