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Habitat use by giant pandas *Ailuropoda melanoleuca* in the Wanglang Nature Reserve, Sichuan, China

Dong-Wei Kang¹, Hong-Wei Yang¹, Jun-Qing Li^{1*}, You-Ping Chen² and Lian-Jun Zhao²

Abstract

Background: To better understand the ecological requirements of the giant panda *Ailuropoda melanoleuca* in the wild, field surveys were carried out at both the microhabitat scale and foraging site scale in Wanglang National Nature Reserve, Sichuan, China.

Results: The results indicated that (1) at the microhabitat scale, giant pandas usually occupied habitats with a high fallen-log density, lower shrub density, and bamboo coverage of 50% to 75%; (2) at the foraging site scale, pandas usually used sites with higher bamboo densities and taller and larger-diameter bamboo; and (3) giant pandas may abandon plots when the proportion of young bamboo decreases below average in the environment.

Conclusions: The availability of young bamboo is an important driving force in habitat selection by giant pandas, which could provide important reference for the conservation of giant pandas and their habitats.

Keywords: Foraging site; Giant panda; Habitat use; Microhabitat

Background

The giant panda *Ailuropoda melanoleuca* is a flagship species for efforts related to habitat conservation, is one of the most important rare and endangered species in the world, and is a category I protected species on the *Red List* of China (Wei et al. 2000). Despite efforts by the government, international organizations, and local people, loss and fragmentation of panda habitat threaten the species throughout its range (State Forestry Administration 2006; Shen et al. 2008). Thus, a deeper understanding of the habitat requirements of the giant panda is needed to develop specific conservation strategies for this endangered species.

A knowledge on the habitat requirements of animal species provides important information needed for conservation planning and policy making (Pan et al. 1998; Hu 2001; Ouyang et al. 2001; Wang et al. 2002; Liu et al. 2005, 2006; Yang et al. 2006; Xu et al. 2006; Swaisgood et al. 2010; Wang et al. 2010; Wei et al. 2011), but species-habitat relationships can vary among different

regions (Hu 2001; Wei et al. 2011; Panthi et al. 2012). For example, an abundance of research indicates that giant pandas usually use primary forests (Ran et al. 2003, 2004; Wang et al. 2006), although some research suggests that they also use secondary forests (Zhang et al. 2002a). Others reported that pandas use both primary and secondary forests equally with no significant habitat preference (Zeng et al. 2002; Zeng et al. 2003), so land managers should use caution if they wish to apply one region's conservation measures to another region (Wei et al. 2011). However, understanding the habitat requirements of an animal species in a specific area and then developing site-specific conservation strategies should be considered because this knowledge is important for managers who wish to implement effective conservation measures.

We report the results of field surveys on giant panda habitat in the Wanglang Nature Reserve. We identified variables related to giant panda habitat at the microhabitat scale and foraging site scale (Zhang et al. 2002b). The objective of our study was to discriminate habitat features which can be used to explain the habitat use of pandas in this area. By studying foraging sites used by giant pandas, we aimed to draw some general conclusions related to

* Correspondence: lijunqing8100@gmail.com

¹The Key Laboratory for Silviculture and Conservation of Ministry of Education, Beijing Forestry University, Beijing 100083, China
Full list of author information is available at the end of the article

factors that drive habitat selection. These insights should deepen our understanding on the habitat requirements of giant pandas and facilitate identification of appropriate management strategies in this area.

Methods

Study area

Field work was conducted in the Wanglang National Nature Reserve (Figure 1), one of China's first nature reserves established to protect the giant panda in 1965, which is located in the northern part of Pingwu County (103°50' to 104°58' E, 32°49' to 33°02' N) and is host to 27 pandas (State Forestry Administration 2006). The

reserve covers approximately 320 km² with elevations ranging from 2,320 to 4,891 m. The reserve receives 862.5 mm of rainfall annually, with the lowest mean air temperature of -6.1°C in January and the highest at 12.7°C in July (Wang and Li 2008). Giant pandas in the reserve mainly feed on *Fargesia denudate* (Chen et al. 2003).

Sampling method

Habitat use at the microhabitat scale

In January, March, May, and June 2011, we conducted field surveys along 40 transects (Figure 1) in Wanglang Nature Reserve and repeated the surveys in April, May, July, and August 2012. All transects were established along an elevational gradient to ensure that each sampled transect contained typical and representative panda habitat. Each transect was at least 2 km long.

The location of panda-use plots along each transect was primarily determined by the presence of feces (Wei et al. 2000; Zhang et al. 2006, 2009). Habitat features were studied using 20 × 20-m sample plots. Panda signs more than 100 m apart from each other merited the establishment of different plots. In each 20 × 20-m plot centered on a feces location, two 2 × 10-m rectangular and perpendicular transects were established to investigate the densities of trees and shrubs (Wei et al. 2000; Zhang et al. 2006, 2009), with these rectangular plots placed so that their diagonals crossed at the feces location (Zhang et al. 2006, 2009). Each side of a rectangular transect was parallel to the corresponding side of the 20 × 20-m square plot. Non-use plots were established every 100 m at different elevations along the transects to reflect the surrounding environment and also included the start and end plots at each end of the transect which were used as non-use plots (Zhang et al. 2011). Non-use plots were sampled in the same way as use plots. Table 1 describes the 13 microhabitat variables measured. In total, 515 plots were sampled for analysis (186 use plots and 329 non-use plots).

Habitat use at the foraging site scale

Five 1 × 1-m bamboo sites were established to investigate bamboo characteristics, such as bamboo density, basal diameter of old bamboo, height of old bamboo, young-bamboo density, and the proportion of young bamboo at each site (Table 1), and they were at the center of 20 × 20-m plots and the center of each 10 × 10-m plot in 2012 (Wei et al. 2000; Zhang et al. 2006, 2009). However, only four 1 × 1-m bamboo sites were randomly placed in each 10 × 10-m plot in 2011, but we also used these data as a reference.

The bamboo sites surveyed in the panda-use plots were divided into two categories: forage and non-forage sites. A forage site was defined as a small area where remnants of bamboo foraged by giant pandas were found

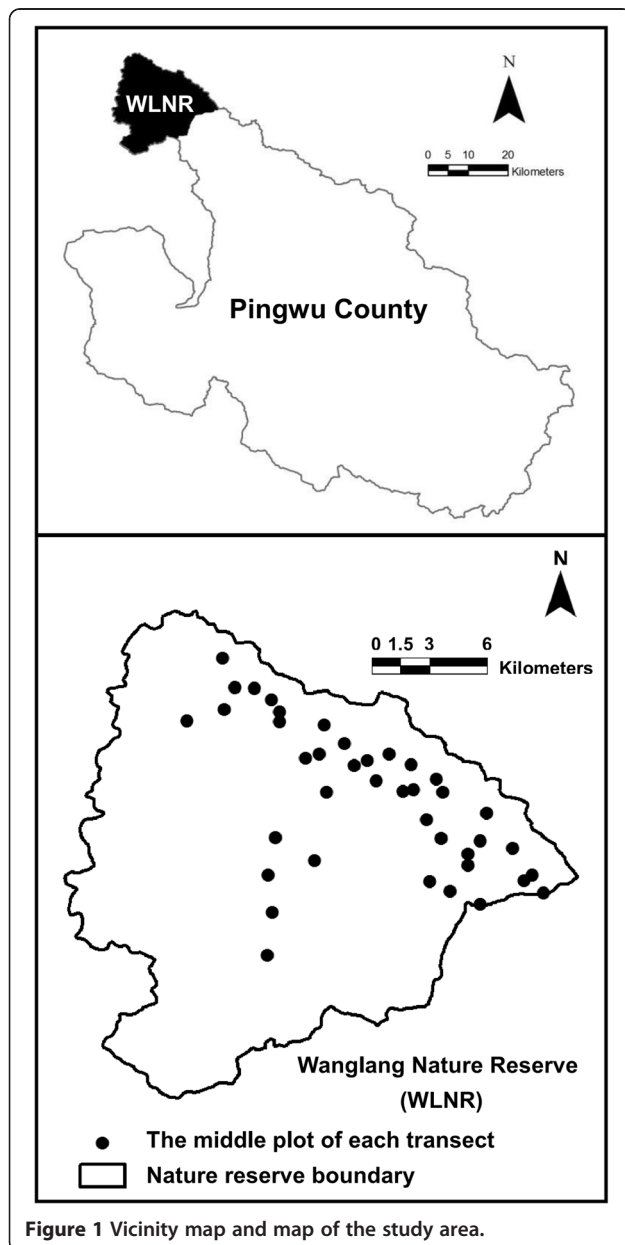


Table 1 Descriptions and definitions of variables used in this study

Scale	Variable	Description
Microhabitat scale	Slope aspect (deg)	Nine categories: no aspect (slope of <5°), north, northeast, east, southeast, south, southwest, west, and northwest
	Slope (deg)	Five categories: <10°, 10° to 20°, 20° to 30°, 30° to 40°, and ≥40°
	Canopy (%)	Canopy of overstory in sampling plot, four categories: <25%, 25% to 50%, 50% to 75%, and ≥75%
	Shrub coverage (%)	Coverage of shrubs in the sampling plot, four categories: <25%, 25% to 50%, 50% to 75%, and ≥75%
	Bamboo coverage (%)	Coverage of bamboo in the sampling plot, four categories: <25%, 25% to 50%, 50% to 75%, and ≥75%
	Tree size (cm)	Average breast diameter (DBH) of trees in each 100-m ² square plot nearest to the center of a 400-m ² plot
	Tree dispersion (m)	Average distance of the nearest tree to the center in each 100-m ² square plot
	Tree density	Average number of trees in two 20-m ² rectangular transects in a 400-m ² plot
	Shrub size (cm)	Average DBH of shrubs in each 100-m ² square plot nearest to the center of a 400-m ² plot
	Shrub dispersion (m)	Average distance of the nearest shrub to the center in each 100-m ² square plot
	Shrub density	Average number of shrubs in two 20-m ² rectangular transects in a 400-m ² plot
	Fallen-log density	Total number of fallen logs (>10 cm in diameter) in a 400-m ² plot
	Tree stump density	Total number of tree stumps (> 10 cm in diameter) in a 400-m ² plot
Foraging site scale	Bamboo density	Number of culms in a 1 × 1-m bamboo site
	Old-bamboo size (mm)	Average basal diameter of culms in a 1 × 1-m bamboo site (five old bamboo culms were measured randomly at each site)
	Old-bamboo height (m)	Average height of culms in a 1 × 1-m bamboo site (five old bamboo culms were measured randomly at each site)
	Young-bamboo density	Number of young bamboo culms in a 1 × 1-m bamboo site
	Young-bamboo proportion (%)	Proportion of young bamboo culms in a 1 × 1-m bamboo site

(Zhang et al. 2009). Bamboo sites surveyed in the non-use plots were defined as control sites that reflected the surrounding environment. In total, 1,456 bamboo sites (151 forage sites, 413 non-forage sites, and 892 control sites) were sampled for analysis.

Data analysis

To describe habitat characteristics and compare habitat differences of panda-use and non-use plots, we used a χ^2 test to compare discrete variables; for continuous variables, we used independent-sample *t* tests when data were normally distributed and the Mann–Whitney *U* test when the distributional assumptions were not met. To identify factors that differentiated microhabitat characteristics of panda-use and non-use plots, variables showing a significant difference between these two types of plots were subsequently analyzed with a logistic regression analysis. Also, to ensure that variables were independent, only variables with clear biological meaning were considered during subsequent analysis for those with absolute correlation coefficients of >0.70 (Schweiger et al. 2012).

To describe habitat characteristics of giant pandas at a foraging site scale, we used a one-way analysis of variance (ANOVA) test to compare means of variables among different bamboo site groups when data were normally distributed and a Kruskal–Wallis test when the distributional assumptions were not met. For those variables showing a significant difference, we then used a least significant difference (LSD) multiple comparison to test whether or not significant differences existed between all members when data were normally distributed and a Games–Howell multiple-comparison test when the distributional assumptions were not met. Furthermore, when the data type of the proportion of young bamboo was measured using percent, we used the Kruskal–Wallis test and Games–Howell multiple-comparison test to analyze such variables.

Results

Habitat use at the microhabitat scale

Seven (3 discrete and 4 continuous variables) of the 13 variables significantly differed between panda-use and non-use plots ($p < 0.05$): slope aspect, shrub coverage, bamboo coverage, tree dispersion, shrub size, shrub

Table 2 χ^2 test of discrete variables in panda-use and non-use plots

Variable	Habitat type	Frequency (proportion)	
		Use plots (n = 186)	Non-use plots (n = 329)
Slope aspect	No aspect	12 (0.06)	13 (0.04)
	North	15 (0.08)	23 (0.07)
	Northeast	15 (0.08)	23 (0.07)
	East	29 (0.16)	50 (0.15)
	Southeast	18 (0.10)	56 (0.17)
	South	12 (0.06)	39 (0.12)
	Southwest	29 (0.16)	52 (0.16)
	West	15 (0.08)	45 (0.04)
	Northwest	41 (0.22)	28 (0.09)
$\chi^2 = 29.33, d.f. = 8, p = 0.00$			
Slope	<10°	50 (0.27)	76 (0.23)
	10°~20°	64 (0.34)	110 (0.33)
	20°~30°	59 (0.32)	95 (0.29)
	30°~40°	12 (0.06)	41 (0.12)
	≥40°	1 (0.01)	7 (0.02)
$\chi^2 = 7.15, d.f. = 4, p = 0.13$			
Canopy	<25%	34 (0.18)	79 (0.24)
	25%~50%	81 (0.44)	118 (0.36)
	50%~75%	59 (0.32)	111 (0.34)
	≥75%	12 (0.06)	21 (0.06)
$\chi^2 = 3.74, d.f. = 3, p = 0.29$			
Shrub coverage	<25%	111 (0.60)	149 (0.45)
	25%~50%	61 (0.33)	110 (0.33)
	50%~75%	13 (0.07)	56 (0.17)
	≥75%	1 (0.01)	14 (0.04)
$\chi^2 = 19.45, d.f. = 3, p = 0.00$			
Bamboo coverage	<25%	14 (0.08)	168 (0.51)
	25%~50%	34 (0.18)	83 (0.25)
	50%~75%	83 (0.45)	54 (0.16)
	≥75%	55 (0.30)	24 (0.07)
$\chi^2 = 140.24, d.f. = 3, p = 0.00$			

density, and fallen-log density (Tables 2 and 3). None of the correlation coefficients among these seven variables exceeded 0.70, and thus, all of them were analyzed using a logistic regression analysis. Ultimately, bamboo coverage, shrub density, and fallen-log density were entered into the prediction equation, but only bamboo coverage and fallen-log density significantly contributed to the difference between use and non-use plots ($\chi^2 = 132.82, d.f. = 3, p < 0.01$; Table 4), with an overall correct prediction rate of 73.7%. Giant pandas

Table 3 Mann-Whitney U test of continuous variables in panda-use and non-use plots

Variable	Mean (mean rank)		Z value	p value
	Use plots	Non-use plots		
Tree size	32.20 (250.30) (n = 180)	29.07 (233.80) (n = 299)	-1.26	0.21
Tree dispersion	2.86 (218.27) (n = 180)	3.08 (253.08) (n = 299)	-2.67	0.01
Tree density	2.51 (252.60) (n = 186)	2.55 (261.05) (n = 329)	-0.62	0.53
Shrub size	2.41 (280.19) (n = 184)	2.03 (243.21) (n = 328)	-2.71	0.01
Shrub dispersion	2.05 (265.97) (n = 182)	1.88 (247.30) (n = 325)	-1.38	0.17
Shrub density	4.74 (212.09) (n = 186)	7.24 (283.96) (n = 329)	-5.27	0.00
Fallen-log density	1.96 (283.17) (n = 186)	1.65 (243.77) (n = 329)	-2.99	0.00
Tree stump density	0.77 (272.83) (n = 186)	0.65 (249.62) (n = 329)	-1.95	0.05

usually occupied habitats with a higher fallen-log density, a lower shrub density (Table 3), and bamboo coverage of 50% to 75% (Table 2).

Habitat use at the foraging site scale

Four of the five bamboo site variables significantly differed among the different bamboo site groups: bamboo density, old-bamboo size, old-bamboo height, and young-bamboo proportion ($p < 0.05$, Table 5). Multiple comparisons showed that the bamboo density, old-bamboo size, and old-bamboo height in forage sites were all significantly larger than those in both non-forage and control sites ($p < 0.05$, Table 6). Giant pandas usually used bamboo sites with a higher bamboo density, taller bamboo height, and larger bamboo diameter. However, proportions of young bamboo in forage and non-forage sites were all significantly lower than that in control sites ($p < 0.05$, Table 6), and no significant difference existed between forage and non-forage sites ($p > 0.05$, Table 6).

Table 4 Logistic regression analysis (backward stepwise (conditional) method) of seven microhabitat variables with significant differences

Variable	B	SE	Wald	Significance
Bamboo coverage	1.19	0.13	84.61	0.00
Shrub density	-0.25	0.14	3.34	0.07
Fallen-log density	0.24	0.12	4.27	0.04
Constant	-0.74	0.12	40.80	0.00

B, regression coefficient; SE, standard error.

Table 5 ANOVA and Kruskal-Wallis test for foraging site variables among different bamboo site groups

Variable	Mean (SD) or Mean (rank)			F or χ^2	p value
	Forage sites (n = 151)	Non-forage sites (n = 413)	Control sites (n = 892)		
Bamboo density	52.50 (912.01)	44.40 (785.42)	38.89 (671.08)	52.99	0.00
Old-bamboo size	7.18 (1.67)	6.34 (1.89)	6.48 (1.85)	11.64	0.00
Old-bamboo height	2.25 (913.97)	2.04 (757.77)	1.94 (683.55)	41.58	0.00
Young-bamboo density	5.34 (766.97)	4.84 (736.35)	4.79 (718.35)	1.95	0.38
Young-bamboo proportion	9.97 (643.16)	10.77 (697.88)	12.18 (757.12)	12.56	0.00

Discussion

Microhabitat use

Many factors affect habitat use by giant pandas, such as food distribution, concealment conditions, body size, and so on (Wei et al. 2000; Zhang et al. 2009). Of the 13 variables tested in this study, 7 significantly differed between panda-use and non-use plots (Table 2); however, only bamboo coverage, shrub density, and fallen-log density were entered into the prediction equation, indicating that they were the most important indicators of habitat use by giant pandas.

Giant pandas feed almost exclusively on bamboo (Hu 2001; Yang et al. 2006; Zhang et al. 2009), so the life of giant pandas is directly influenced by the availability of bamboo. Habitat with lower bamboo coverage is not a suitable giant panda habitat because of the additional energy required for pandas to forage for food in such areas (Hu 2001). However, areas with high bamboo coverage impede the travel of pandas requiring the expenditure of additional energy (Hu 2001). Thus, habitat with medium levels of bamboo coverage provides adequate food for giant pandas and also allows pandas to more easily move across the landscape.

Fallen logs usually serve as passageways connecting different habitat areas and allow pandas to travel more easily within their habitat. Additionally, an abundance of fallen wood is an important characteristic of old-growth forests; based on this study, giant pandas typically occupy habitats with high fallen-log densities, which is consistent with previous reports stating that giant pandas require old-growth forest habitats (Zhang et al. 2011). Furthermore, shrubs are not a food of giant panda, and habitats with lower shrub densities could reduce the energy expenditure of giant panda when moving about (Wei et al. 2000).

Foraging site use

A panda can eat 10~18 kg of fresh leaves or stems or about 40 kg of new shoots per day and will spend more than 50% of the day foraging (Hu 2001; Zhang et al. 2009), so pandas need to conserve energy and search for high-quality food. Bamboo sites with a high density of bamboo, tall bamboo, and large-diameter bamboo stems

provide high levels of biomass and high-quality and adequate food resources for giant pandas; this allows pandas to maximize their energy and nutrient intake in this type of foraging site and helps them reduce energy expenditures when moving in search of food (Zhang et al. 2009).

Giant pandas primarily feed on young bamboo shoots (Hu 2001; Zhang et al. 2009), and young bamboo provides high-quality food for giant pandas. This research confirms that proportions of young bamboo at both forage and non-forage sites were all significantly lower than that at control sites. Furthermore, no significant difference was found between forage and non-forage sites, which indicates that giant pandas would need to leave their current use plots when the proportion of young bamboo falls below average in the environment and search for sites with higher-quality food.

Conclusions

In conclusion, the availability of young bamboo is an important driving force in habitat selection by giant pandas.

Table 6 Multiple comparisons of four foraging site variables with significant differences

Variable	Category	Mean difference	Significance	95% Confidence interval
Bamboo density	F-C	13.62	0.00	(7.82, 19.41)
	N-C	5.51	0.00	(2.10, 8.92)
	F-N	8.11	0.01	(1.96, 14.25)
Old-bamboo size	F-C	0.70	0.00	(0.38, 1.02)
	N-C	-0.13	0.22	(-0.35, 0.08)
	F-N	0.83	0.00	(0.49, 1.18)
Old-bamboo height	F-C	0.31	0.00	(0.19, 0.43)
	N-C	0.10	0.02	(0.01, 0.19)
	F-N	0.21	0.00	(0.08, 0.34)
Young-bamboo proportion	F-C	-2.21	0.01	(-4.03, -0.39)
	N-C	-1.41	0.02	(-2.63, -0.20)
	F-N	-0.80	0.59	(-2.72, 1.12)

F-C, forage-control sites; N-C, non-forage-control sites; F-N, forage-non-forage sites.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

DWK designed the study, performed the experiments and the statistical analysis, and drafted the manuscript. HWY participated in the performance of the experiments. JQL conceived of the study and participated in the design of the study. YPC and LJZ participated in the design of the study. All authors read and approved the final manuscript.

Acknowledgements

This study was supported by the National Key Technology Research and Development Program in the 11th Five-Year Plan of China (2008BADB0B04) and the National Natural Science Foundation of China (31170500). We would like to thank Xiaorong Wang, Zhiwei Yuan, Chunping Luo, Chunping Liang, Yong Zheng, Jie Ouyang, Jixu Zhao, Gaoshan Lan, Hualong Zhou, Xiaorong Xie, Yunxi Li, Xiong Gao, Wenlong Jiang, Yubo Zhang, and Lijuan Duan for participating in the fieldwork.

Author details

¹The Key Laboratory for Silviculture and Conservation of Ministry of Education, Beijing Forestry University, Beijing 100083, China. ²Wanglang National Nature Reserve Administration Bureau, Sichuan 622550, China.

Received: 28 September 2012 Accepted: 10 May 2013

Published: 30 September 2013

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doi:10.1186/1810-522X-52-23

Cite this article as: Kang et al.: Habitat use by giant pandas *Ailuropoda melanoleuca* in the Wanglang Nature Reserve, Sichuan, China. *Zoological Studies* 2013 **52**:23.

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