Pakistan J. Zool., vol. 52(6), pp 2129-2133, 2020 DOI: https://dx.doi.org/10.17582/journal.pjz/20181106121124

Relationship between Giant Panda *Ailuropoda melanoleuca* Habitat use and Disturbance Density in the Daxiangling Mountains, Sichuan, China

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Article Information
Received 06 November 2018
Revised 12 March 2019
Accepted 06 May 2019
Available online 25 August 2020

Authors' Contribution
CZ and BW are the main contributors of this research. JR is the person in charge of this project. QS and MMAR revised the manuscript.

Key words
Giant panda, Daxiangling mountains, Disturb density, Road, Conservation

ABSTRACT

The giant panda *Ailuropoda melanoleuca* is one of the most iconic mammals in the world. The species has experienced declines in its habitat and population due to human disturbance. To protect this species, we investigated the relationship between giant panda habitat use intensity and human disturbance density in the Daxiangling Mountains. The results indicated that, among multiple kinds of disturbances, roads affected the giant panda habitat use significantly. In addition, roads caused the giant panda habitat use intensity to decline sharply. The giant panda nearly stopped using the habitat when road density was more than 0.4 km/km^2. Thus, road density should be considered in the protection program. Furthermore, in areas inhabited by giant pandas, we recommend to optimizing and enhancing increased regulations to minimize the expansion and impact of roads.

INTRODUCTION

The giant panda *Ailuropoda melanoleuca* was one of the most threatened mammals once. Although it is categorized as Vulnerable on the IUCN Red List (Swaisgood *et al*., 2016), keeping in view the importance of the animal in the conservation world perspective, the protection work should not be ignored, especially the small population in the Daxiangling Mountains, where pandas remain threatened by various human disturbances (Sichuan Provincial Forestry Department, 2015).

Understanding how human activities affect pandas is essential for effective management and protection of this species. Human disturbances are known to affect wild animals in many ways. Roads and logging lead to forest loss and habitat fragmentation (Way, 1977; Van Dyke *et al*., 1986; Andrews, 1990; Carr *et al*., 2002; Zhao *et al*., 2014), consequently reducing genetic exchange (Zhu *et al*., 2010; Zhu *et al*., 2011; Qi *et al*., 2012). Hunting can threaten local populations; for example, in Baoxing County, 117 giant pandas were hunted before 1989 (Hu, 2001). Human disturbance decreases species richness (Suntsov *et al*., 2009).

Many studies showed that disturbance density could affect wildlife habitat use. Forman (1995) pointed that, with some species, a threshold could be found in the relationship between animal population density and behavior and road density. In some researches, this threshold has been demonstrated. For example, moose *Alces alces* exhibited a pronounced response to roads when road density reached approximate threshold of 0.4 and 0.2 km/km^2 in winter and summer respectively (Beyer *et al*., 2013). In the case of the giant panda, the influence of many aspects of human disturbance has be investigated (Ran *et al*., 2003; Li *et al*., 2003; Bearer *et al*., 2008; Zeng *et al*., 2009; Gong *et al*., 2012; Zhao *et al*., 2017). However, few studies have

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0030-9923/2020/0006-2129 $ 9.00/0

focused on the relationship between giant panda habitat use and disturbance density, hence leaving a lacuna in the process of development of a comprehensive protection plan.

To obtain more knowledge about how human disturbance affects giant pandas, we studied the relationship between giant panda habitat use and human disturbance density in the Daxiangling Mountains. Our main goals were to determine which kinds of disturbance had greater influence on the habitat use of giant pandas; to investigate how the impacts of disturbance on habitat use varied with disturbance density; and suggesting measures to improve conservation plans for the giant panda according to the results of our studies.

MATERIALS AND METHODS

Study area

The field survey was conducted in the Daxiangling Mountains, Sichuan, China (Fig. 1). The climate is humid, the mean annual temperature is 16℃ and annual rainfall is 1,300–2,000 mm (Hu, 2001). The vegetation is mainly broad-leaved forest below 1,500 m elevation, at 1,500–2,500 m it is mainly mixed forest, and above 2,500 m it is primarily coniferous forest (Hu, 2001). The highest peak is 3,552 m. In the Daxiangling Mountains, the primary human disturbances are roads, hydropower stations, residences, mining, collection of bamboo shoots, logging and trapping (Ran *et al*., 2006; Sichuan Provincial Forestry Department, 2015).

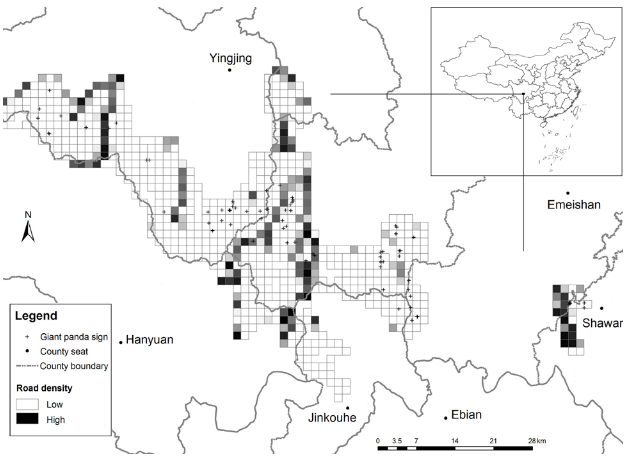

Fig. 1. The locations of giant panda signs in the study area in the Daxiangling Mountains, Sichuan, China.

Methods

The study area was divided into 688 2-km² plots (Fig. 1) and surveyed by 30 investigators during May–September 2012. Investigators followed a transect greater than 1.5 km, searching for signs (e.g. faeces, signs of feeding) of giant pandas in each plot. If signs of the giant panda could be found in a plot, the plot was treated as a giant panda used plot. If a plot satisfied both of the following requirements, it was treated as a non-use plot. i. No signs had been found in the plot, and ii. No signs had been found in neighboring eight plots (because the radius of the giant panda's home range is about 1.5 km (Hu, 2001). Signs of giant pandas were geographically referenced using a GPS. GPS readings were also recorded at all locations of human disturbance i). Roads, ii). Residences, iii). Hydropower stations, iv). Mines, v). Bamboo shoot collection sites, vi). Logging and tree-felling sites and vii). Trap sites). The road system was obtained from Google Earth (Google Inc., Mountain View, USA) and government maps. As all the roads used by four-wheeled vehicles within the study area had analogous characteristics, roads were treated as one type of disturbance in this study.

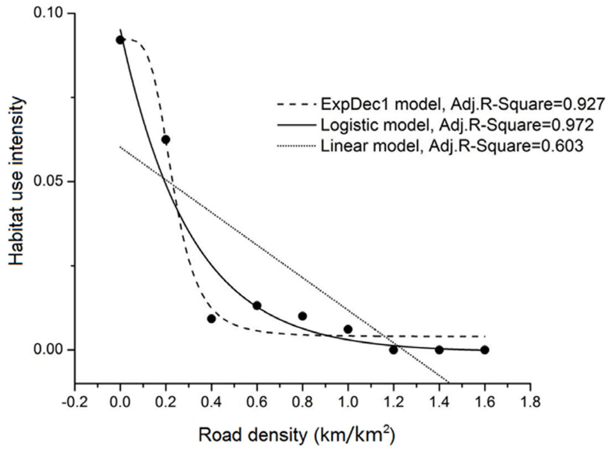

Fig. 2. Line and curve-fitting analysis of the relationship between the giant panda's habitat use intensity and road density.

We analysed the relationship between giant panda habitat use and human disturbance density in two steps. Firstly, we investigated which types of disturbance were the main factors affecting giant panda habitat use. Secondly, we studied how the influence of the main types of disturbance on the intensity of giant panda habitat use varied from the disturbance density.

We conducted independent sample t tests to compare variables between used plots and non-use plots when data were normally distributed, Mann-Whitney U tests were used when the distributional assumptions were not met. Then, Binary Logistic Regression with a forward stepwise procedure was employed, plot type

Table I. Significant difference analysis on density between the gird giant panda used and not used.

Variables	Mean±SD		U	F
	Use plot	Non-use plot		
Road	0.16±0.58	0.43±0.90		0.002**
Residence	0.05±0.21	0.07±0.27		0.579
Mine	0.02±0.12	0.06±0.31	0.321	
Hydropower station	0.05±0.21	0.10±0.39	0.585	
Logging or tree-feeling site	0.03±0.18	0.06±0.30		0.523
Bamboo shoot collection site	0.13±0.42	0.06±0.30		0.109
Trap site	0.07±0.25	0.03±0.22	0.114	

U stand for Mann-Whitney U tests, F stand for independent sample t tests, ** indicate the value of $P < 0.01$

(used plots and non-use plots) was treated as the dependent variable, while disturbances were the independent variables. To investigate the influence of the main types of disturbance on the intensity of habitat use varying from the disturbance density, the disturbance density was divided into nine degrees. The giant panda habitat use intensity in each disturbance density degree was counted from giant panda signs. Linear, logistic and exponential decay-fitting analyses were used to visualize the relationship between disturbance density and habitat use intensity and to test if a threshold could be found visually.

Table II. Variables to distinguish habitat from non-use plots through logistic regression.

Variable	B	Wald	P
Road	-5.614E-4	4.719	0.030
Constant	-2.192	239.444	0.000

B stand for the regression coefficients, Wald stand for Chi-square value, *P* stand for *P* value.

RESULTS

101 locations of giant panda signs and 301 locations of human disturbance (63 residences, 76 hydropower stations, 45 mines, 48 bamboo shoot collection sites, 35 logging or tree-felling sites and 34 trap sites) were recorded. The distribution of giant panda signs and roads is presented in Figure 1.

Only roads showed a difference between used plots and non-use plots (Table I). By logistic regression analysis, only road disturbance entered into the final model and made a significant contribution to used plots from non-use plots, with an overall correct prediction rate of 91.3%.

Our results indicated that at a road density greater than 1 km/km^2, no giant panda sign had been found. In line- and curve-fitting analyses, Exp Dec1 model and logistic model had better fits than the linear model (Fig. 2). Both the Exp. Dec and logistic models showed a significant decrease in habitat use intensity at density less than 0.4 km/km^2, whereas at road density more than 0.4 km/km^2, habitat use intensity appeared to be close to zero.

DISCUSSION

Both disturbance and habitat variables are important predictors of animal distribution (Morrison, 2001; Bhattarai and Kindlmann, 2013; Kolipaka *et al*., 2017). The habitat requirements of the giant panda have been studied comprehensively (e.g. Ran *et al*., 2004; Liu *et al*., 2005; Qi *et al*., 2009; Gong and Song, 2011; Kang *et al*., 2011; Zhang *et al*., 2011; Wei *et al*., 2017); however, the influence of disturbance density on the giant panda has been little studied.

Our research showed that, compared with non-use plots, less extent of roads, residences, mines, hydropower stations, logging or tree-felling sites were found in the giant panda used plots. However, there was no significant difference between used and non-use plots in some types of disturbances, implying thereby that these disturbances may have little influence on giant panda habitat use. Previous research indicated, from the aspect of disturbance distance, roads had a significant influence on giant panda habitat use (Zhao *et al*., 2017). Our research demonstrated that road density had a significant influence on the giant panda habitat use among seven kinds of disturbances. Thus, combined with previous findings, we point out that road disturbance was the major factor affecting giant panda habitat use in the Daxiangling Mountains.

According to Forman (1995), there was a threshold between the road density and wildlife populations; above the threshold of 0.6km/km^2, the populations of large animals will decline. Similar results were reported for gray wolves (Wydeven *et al*., 2001). However, our research demonstrated a different relationship between road density and large animals. Fig. 2 showed that the relationship between road density and the intensity of habitat use by giant pandas could be represented by a curve with either of two shapes. The pattern of the response of habitat use intensity to the road density effectively defines a 'road density tolerance zone'. The upper limit of the tolerance zone is 0.4 km/km^2; the giant panda appeared to almost not use the habitat when the road density was more than 0.4 km/km^2. Moreover, giant panda habitat use intensity declined sharply if roads occurred in the plots. Lin (2006) pointed out that in different situations, the maximum allowable road density may not be the same; if the habitat fragment is less than 1000 km^2, the maximum allowable road density should be lower than 0.6 km/km^2. Previous studies indicated that the giant panda habitat in Daxiangling Mountains was isolated from other mountains and spanned less than 1000 km^2 (Xu *et al*., 2006; Zhang *et al*., 2007; Zhu *et al*., 2010). Thus, for the giant panda in Daxiangling Mountains, the maximum allowable road density should be lower than 0.4 km/km^2.

According to our study, roads were the main disturbance affecting giant panda habitat use. Therefore, we recommend enhanced regulation to minimize the expansion and impact of roads. Furthermore, the road density should be considered in the protection program.

ACKNOWLEDGEMENTS

This study was supported by Key Fund Project of Sichuan Provincial Education Department (18ZA0543), Special Fund of Yibin University (2017RC04), and the Sichuan Forestry Department. We thank the fourth giant panda survey team of Sichuan Province.

Statement of conflict of interest

The authors declares that there is no conflict of interests.

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