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Assessing the impact of climate change on the habitat distribution of the giant panda in the Qinling Mountains of China

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ABSTRACT

Climate change threatens global ecosystems and the maintenance of biodiversity via its impacts on the survival of individual species and the preservation of their ecological functions. The effects of climate change are particularly evident in the mountainous areas of southwestern China that support the last remaining populations of giant pandas (*Ailuropoda melanoleuca*). However, very few studies to date have assessed the likely impact of climate change on the distribution and abundance of giant panda habitat. In this paper, we developed a mechanistic model that uses climatic variables (rather than biotic variables) to (i) examine how variation in landscape scale climate influences the spatial distribution of panda habitat in China's Qinling Mountains, and (ii) evaluate how the distribution and extent of panda habitat will change in the future under forecast climate change scenarios. We found that there was substantial variation in temperature throughout the study area that correlated with variation in altitude. Under climate change scenarios, the future climate in this region (during the period 2070–2100) would be far warmer and wetter than the current climate (for the period 1990–2007). Our model results revealed that this predicted climate change could reduce the extent of a suitable habitat for giant pandas by up to 62% (under IPCC SRES A2 scenarios; and 37% under IPCC SRES B2 scenarios). We also showed that as a result of this predicted climate change, the minimum elevation of panda habitat would rise by 500 m. Accordingly, our model showed that on the basis of predicted climate change, a new suitable giant panda habitat would likely become available in areas further north of their current range (at higher latitudes, in the northwest part of the study region). Finally, and most importantly, we showed that the established network of nature reserves within this study region does not adequately protect the current distribution of suitable panda habitat, nor will it protect suitable panda habitat in the future.

1. Introduction

Qinling Mountains provide a habitat for approximately 273 wild giant pandas (*Ailuropoda melanoleuca*), possessing a unique history of population development and harboring the highest population density in China (State Forestry Administration, 2006). Meanwhile, this region also constitutes a geographic climate division within the country. Although the Qinling Mountains offer arguably the best habitat conditions and level of protection for pandas across their current range (Viña et al., 2010), pandas within this region are geographically and genetically isolated from other populations (Pan et al., 2001). In addition, this population faces the threat of habitat loss and fragmentation caused by encroaching anthropogenic developments (primarily infrastructure developments such as increasing road networks and hydropower schemes; Fan et al., 2011). Furthermore, climate change presents a serious potential threat to the maintenance of global biodiversity, and entails impacts that are both hysteretic and irreversible (Parmesan and Yohe, 2003; Wilfnied, 2007). Tuanmu et al. (2013) have revealed substantial reductions in the distributions of the three dominant bamboo species throughout the Qinling Mountains as a result of the impact of climate change, which could lead to a potential shortage of food for the resident panda population.

Whereas, previous studies and field investigations indicate that the panda habitat quality is impacted by multiple factors (Xu et al., 2006a,b). Vegetation and bamboo distribution, elevation and slope, distance from sites of human activities are the key factors influencing the large-scale spatial distribution of giant panda (Ouyang et al., 2001). As a result of the combined effects from these factors, the actual panda habitat range is much smaller than the distribution of bamboo. Therefore, the impact of climate change maybe more severe on panda habitat than on bamboo distribution.

Numerous empirical monitoring and theoretical modeling studies conducted in the past to investigate panda population dynamics (Zhou and Pan, 1997), their relationships to bamboo dynamics (Reid et al., 1989; Wu et al., 1996; Carter et al., 1999), and the

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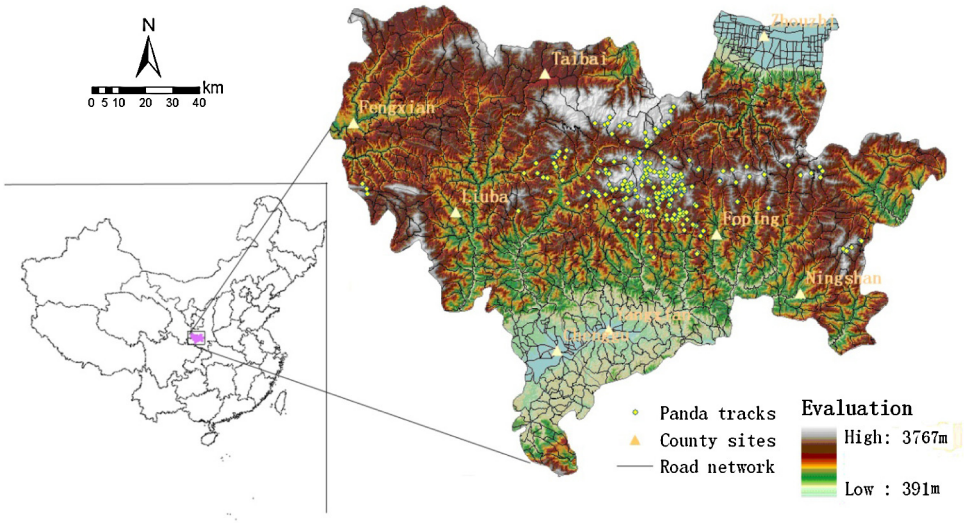

Fig. 1. Map showing study area within Qinling Mountains, China.

dynamics of their habitat preferences and usage (An et al., 2001, 2002; Linderman et al., 2004). Kinds of habitat assessment models based on Geographical Information Systems (GIS) and Remote Sensing (RS) were developed to evaluate the panda habitat distribution, and the impacts of human disturbance on habitat quality at a large scale (Xiao et al., 2004; Xu et al., 2006a,b; Liu et al., 2001). To date, however, few studies have evaluated the extent to which climate change influences the spatial distribution of giant pandas and their preferred habitat by considering human disturbance and topographic features simultaneously in this region.

This study aims to (1) analyze the spatial patterns in climatic features over recent years and search for a spatial relationship with the observed distribution of giant pandas in the Qinling Mountains; (2) develop a habitat assessment model for the giant panda, which uses climatic features rather than biotic features to allow an explicit evaluation on how variation in climate influences the spatial distribution of panda habitat in the Qinling Mountains. Findings may provide an insight into giant panda habitat protection under the climate change scenarios in the Qinling Mountains.

2. Methods

2.1. Study area

The study area spans the main distribution of Qinling giant pandas (106°29′50″ to 108°47′57″ E and 32°50′18″ to 34°00′18″ N) and encompasses eight administrative counties (Foping, Yangxian, Taibai, Zhouzhi, Fengxian, Liuba, Ningshan, and Chenggu; Fig. 1). The area comprises both mid-elevation and sub-alpine areas and experiences temperatures and levels of rainfall that are suitable for the growth of the foraging bamboo species of the giant panda, namely Qinling arrow, *Fargesia qinlingensis*; dragon-head, *F. dracocephala;* and wooden, *Bashania fargesii*. These three bamboo species account for more than 90% of bamboo cover in this region (State Forestry Administration, 2006). Hydrothermal and climatic conditions in the Qinling Mountains vary with elevation. The elevation climate gradient comprises a lower warm-temperate zone, followed by a temperate zone, a cool-temperate zone, and finally a high elevation sub-frigid zone. Approximately 270 giant pandas are estimated to reside in this area, and most of these are concentrated on the southern mountain slopes occupying elevations from 390 m to 3800 m.

2.2. Data preparation

Several different data sources were used to calibrate and verify the model. A Digital Elevation Map (DEM 1:250,000) was interpolated from digitized 100-m contours. Abiotic information, such as elevation and slope, was derived from the DEM. Data on land use (roads, residents and farmland) were obtained from the classification of Landsat Thematic Mapper (TM) images acquired in 2000 (at a scale of 1:100,000, Liu et al., 2003). Satellite data and topographic maps of the study area were resampled to a pixel size corresponding to the landscape grid (The gird is employed to define the habitat suitability components of the landscape with a resolution of 100 m × 100 m).

Signs of panda presence such as droppings, feeding remnants, and footprints ($N = 287$) were acquired from information contained in the Third National Survey Report on Giant Panda in China (referred herein as the National Survey Report; State Forestry Administration, 2006), and used to (1) search for the relationship between climatic indices and panda presence; (2) validate model by analyzing the relationship between habitat characteristics and panda presence.

As stated above, there is an evident elevation gradient in climate characteristic in the Qinling Mountains, with the panda population concentrated at mid-elevations. Hence, climate data with high resolution are required in this study. The average monthly temperature and precipitation simulating data for the period 1990–2007 and 2071–2100 were obtained from the National Climate Centre (NCC) of China, with spatial resolution 0.25° × 0.25° (Appendix Table A1, Fig. 2, Gao et al., 2008). Furthermore, two spatial interpolation methods were applied to derive the spatial distribution of temperature in the panda's core range: (1) a gradient plus inverse distance weighting interpolation (GIDW) that considers the effects of altitude; and (2) an inverse distance weighting (IDW) interpolation. Observation data obtained from eight meteorological stations in this region were used to examine the results of GIDW and IDW.

2.3. Model description

A number of abiotic, biotic, and anthropogenic (human disturbance) factors can influence the quality and availability of giant panda habitat (Ouyang et al., 2001). Traditional abiotic factors considered when modeling panda habitat include topographic features such as elevation, slope, and aspect. The primary biotic factor that