Impacts of Climate Change on the Distribution of Staple Bamboo and Habitat of Giant Pandas in the Qionglai Mountains (Postprint)

Authors: Yan Tingting, Ran Jianghong, Zhao Chenhao, Zhong Xue, Liang Minyi

Date: 2017-04-18T00:00:00+00:00

Abstract

The impacts of climate change on biodiversity, particularly on rare and endangered species, constitute a current research focus. The effects of global climate change on giant pandas have garnered widespread attention. Based on field survey data of giant panda activity trace points, bamboo distribution points, and staple bamboo dispersal distances, we employed the Maxent model incorporating vegetation, topography, climate, and other factors to analyze the distribution trends of staple bamboo and habitat changes for giant pandas in the Qionglai Mountains under RCP8.5 for 2050 and 2070. The results indicate: (1) The area of suitable habitat for giant pandas and climatically suitable zones for staple bamboo will both decrease in the future, declining by 37.2% and 4.7%, respectively, by 2070; (2) The distribution range of staple bamboo will generally shift toward higher elevations in the future, but its area will continue to decrease, with the distribution area reduced by 8.3% compared to the present by 2070; (3) Giant panda habitat will exhibit a trend of expansion toward higher altitudes in the future, with significant contraction in lower elevation areas, decreasing by 27.2% compared to the present by 2070; however, by 2070, the combined area of giant panda habitat and staple bamboo distribution in non-habitat areas will be 1.5% larger than the existing giant panda habitat area; (4) The regions more severely impacted by climate change are the southern part of the Qionglai Mountains and lower elevation areas, while impacts on other regions are relatively minor; (5) Future efforts should strengthen monitoring and protection of regions severely affected by climate change, particularly the concentrated distribution areas of giant pandas in the central Qionglai Mountains.

Full Text

Preamble

Climate-Change Impacts on Bamboo Distribution and Giant Panda Habitat in the Qionglai Mountains

YAN Tingting, RAN Jianghong*, ZHAO Chenhao, ZHONG Xue, LIANG Minyi
Key Laboratory of Bio-Resources and Eco-Environment of Ministry of Education, College of Life Sciences, Sichuan University, Chengdu, China 610064

*Corresponding author. E-mail: rjhong-01@163.com

DOI: 10.5846/stxb201512032424

Abstract

The effects of climate change on biodiversity, particularly on rare and endangered species, are at the forefront of contemporary scientific research. As an ancient, highly specialized, and extremely rare species, the effect of global climate change on the giant panda (*Ailuropoda melanoleuca*) has received much attention. Due to climate change, giant panda habitats are generally becoming warmer and drier, reducing the total suitable area and thereby causing giant pandas to migrate to higher latitudes and altitudes. Climate change not only directly affects species distribution, but also indirectly alters the size and distribution of herbivore populations by influencing the growth of staple food plants. Bamboo comprises >99% of the giant panda' s diet. This strong dependence couples the distribution of the giant panda with that of bamboo growth.

Based on current locality and distributional data of giant pandas and bamboo species, respectively, from field surveys, we predicted distributional shifts of bamboo and giant panda habitats for the years 2050 and 2070 using a Maxent model with topography factors (altitude, slope and aspect), climate change data, river, road, resident community and land cover. We obtained current and future climate projections (for the years 2050 and 2070) from the WorldClim database at 30 resolution. The model was constrained by the conditions outlined in the representative concentration pathway 8.5 of the IPCC AR5. We assessed the accuracy of predictions using the area under the ROC curve (AUC), establishing acceptable predictions of Maxent.

The results show that the climatically suitable areas of bamboo and habitat for giant pandas might decrease by 4.7% and 37.2% in 2070, respectively. The northern and lower elevation limits of current suitable habitat for giant pandas would decrease, whereas suitable habitat would primarily expand to higher elevations. Lower elevations of climatically suitable areas of bamboo would also decrease; however, the distribution of bamboo would primarily expand to higher elevations. Therefore, the area of giant panda habitat will decrease by 27.2% and giant pandas would move to higher altitudes. Although bamboo will spread to higher elevations, and the total proportion of bamboo distribution will decrease by 8.3% in 2070, there will be sufficient food resources for nearly all giant pandas in this region. This suggests that climate change has limited impacts on giant pandas in the Qionglai Mountains. The southern area of the Qionglai Mountains and low-altitude regions are more sensitive to climate change, which may require additional management, research, and conservation in the future. The main habitats of giant panda (Wenchuan, Baoxing, Lushan, Dayi, Chongzhou and Tianquan counties) will also require additional focus in future studies.

Keywords: climate change; giant panda; qionglai mountains; bamboo; conservation

1. Introduction

Extensive terrestrial and marine observational evidence indicates that many natural systems on Earth are being affected by regional climate change, particularly temperature increases. Climate warming may cause tremendous impacts on global ecosystems and biodiversity [1]. The giant panda (*Ailuropoda melanoleuca*) is a globally rare and endangered wild animal and a flagship species for biodiversity conservation [2-3]. Against the backdrop of global climate warming, the climate in giant panda habitats is generally trending toward warmer and drier conditions [4]. Some studies have predicted that climate change will cause the giant panda habitat in the Minshan Mountains to shift to higher altitudes and latitudes, with a reduction in suitable habitat area [6-7]. The suitable habitat for giant pandas is fragmented and severely degraded [8-9]. It has been predicted that by 2050, giant pandas may lose 16.3% of their suitable habitat, and the minimum altitude of suitable habitat will rise [5]. However, only 1.5% of existing giant panda reserves contain suitable habitat.

As the Qionglai Mountains have severely fragmented giant panda habitat, research on climate change impacts on giant panda habitat and staple bamboo remains blank. Climate change not only directly affects species distribution but also influences plant growth and distribution, thereby affecting the size and distribution of herbivore populations [10]. Within the Qinling giant panda habitat, the distribution area of three staple bamboo species will decrease substantially [12]. If bamboo species cannot disperse beyond their current distribution under climate change, almost all giant panda habitat in the Qinling region may disappear [12]. Giant pandas have a monotonous diet, with subalpine bamboo comprising over 99% of their food composition [11], making their distribution highly dependent on bamboo distribution and living conditions [13-15].

From the perspective of giant pandas' current and historical distribution altitudes, pandas should have some adaptability to climate change. However, bamboo is highly susceptible to climate change impacts. Therefore, climate change affects giant pandas primarily by influencing bamboo distribution, with climate warming itself being secondary. Thus, predicting climate change impacts on giant pandas requires actual bamboo distribution data and its dispersal capacity. Previous studies on climate change impacts on giant panda habitat mainly used climate factors and panda field trace distribution points for prediction [4, 6-9], with few comprehensively utilizing climate, bamboo distribution (including dispersal capacity), and panda trace points for prediction [12]. This study uses the latest completed fourth Sichuan Province giant panda field survey bamboo distribution point data, measured dispersal data for each bamboo species, combined with third giant panda field survey trace point data, and comprehensively utilizes vegetation, topography and other factors to predict changes in giant panda suitable habitat and staple bamboo distribution in the Qionglai Mountains for 2050 and 2070 under RCP8.5, aiming to better understand potential climate change impacts on giant pandas and provide references for regional giant panda and biodiversity conservation.

2. Study Area

The study area includes the main current distribution areas of giant pandas in the Qionglai and Daxiangling mountain systems. As there are no natural barriers between the giant panda habitats of Daxiangling and Qionglai mountain systems, they were analyzed as an integrated whole. Administratively, the area involves Chengdu, Ya' an, and parts of Aba and Ganzi prefectures in Sichuan Province, specifically including Wenchuan, Lixian, Baoxing, Tianquan, Mingshan, Yingjing, Hanyuan, Luding, and Kangding. The region lies between 102°1 45.9 -103°49 10.4 E and 29°16 35.3 -31°55 6 N. The highest elevation in the region is 6250 m. The area contains Wolong and Fengtongzhai National Nature Reserves, and the Giant Panda Habitat World Heritage Site is also located here.

According to the fourth Sichuan Province giant panda survey results, there are 296 wild giant pandas in the region, accounting for 29.9% of Sichuan' s wild giant panda population and 40.2% of the national population [16]. The region is rich in bamboo resources, with seven staple bamboo species distributed, among which the most widely distributed are *Fargesia* spp., *Yushania brevipaniculata*, *Chimonobambusa robusta*, and *Bashania faberi*, collectively accounting for over 90% of the bamboo distribution area in the region' s giant panda habitat [16].

3. Methods

3.1 Giant Panda Trace Points and Bamboo Distribution Data

Giant panda trace point data and staple bamboo distribution data were obtained from the third and fourth Sichuan Province giant panda surveys. There were 517 giant panda trace point data and 364 staple bamboo distribution point data.

3.2 Climate Factor Data

Climate data were downloaded from the WorldClim database (http://www.worldclim.org/) for current (1950-2000) and future years (2050, 2070) at 30 arc-seconds spatial resolution. Previous studies have shown that the BCC-CSM1-1 model performs well in simulating climate in China [17]. Due to the special terrain of the Hengduan Mountains region, the RCP8.5 scenario is closer to China' s possible future CO2 concentration equivalent [8]. Therefore, this study selected the RCP8.5 scenario (the strongest intensity level in IPCC AR5) [18] from the BCC-CSM1-1 model.

3.3 Other Environmental Factor Data

Topographic data including altitude, slope, and aspect were extracted from the Chinese Academy of Sciences database (1km×1km). River, road, and residential point distribution data were obtained from 1:250,000 electronic maps of Sichuan Province. Land cover data were obtained through unsupervised classification and validated using vegetation data from the fourth Sichuan Province giant panda survey.

3.4 Bamboo Dispersal Data

From 2013-2015, we investigated and measured the dispersal capacity of three bamboo species: *Chimonobambusa robusta* in Yingjing Longcanggou (elevation 1900-2200m), *Bashania faberi* in Dujiangyan Longchi (elevation 2400-2800m), and *Yushania brevipaniculata* in Baoxing Fengtongzhai (elevation 1900-2200m). Within each bamboo forest, we randomly established 1m×1m plots and measured the distance from current-year bamboo shoots to the nearest mature bamboo. Each bamboo species had no fewer than 30 measurements. The mean dispersal distances were: *Chimonobambusa robusta* (21.3±0.71) cm/a, *Bashania faberi* (11.4±0.57) cm/a, and *Yushania brevipaniculata* (10.1±0.52) cm/a. The predicted dispersal distances for target years were calculated from these measurements.

3.5 Model Introduction

The Maxent model is software developed based on maximum entropy theory [19]. It uses species' actual distribution points and environmental variables from distribution areas to generate predictions, which are then used to simulate potential species distributions under target conditions [20]. It is now widely used for species habitat evaluation and prediction, demonstrating good predictive capability. This study used AUC (Area Under the ROC Curve) values generated by Maxent software to evaluate prediction quality, with evaluation criteria of: 0.5-0.6 (poor), 0.6-0.7 (fair), 0.7-0.8 (good), 0.8-0.9 (very good), and 0.9-1 (excellent) [21]. In this study, the AUC values for giant panda training and test sets were 0.894 and 0.963; for *Fargesia* spp. were 0.944 and 0.950; for

Yushania brevipaniculata were 0.911 and 0.915; for *Chimonobambusa robusta* were 0.899 and 0.885; and for *Bashania faberi* were 0.936 and 0.873.

3.6 Data Analysis

Giant panda suitable habitat: Giant panda trace point data and climate, vegetation, and other environmental factor data were input into Maxent. Panda trace points were used for model training and validation, with other parameters set to default values. Model output results were imported into ArcGIS 10.1 and reclassified based on thresholds calculated by the model to obtain giant panda suitable habitat.

Bamboo climate suitable area (CSAs): Each bamboo species' distribution point data and climate, vegetation, and other environmental factor data were input into Maxent. Distribution points for each species were used for model training and validation, with other parameters set to default values. Model output results were reclassified based on thresholds to obtain each species' climate suitable area. The CSAs of the four bamboo species were summed to obtain the overall staple bamboo CSA.

Current bamboo distribution area: Current CSAs of each bamboo species were overlaid with each species' field measurement points. Overlapping portions were smoothed along elevation gradients to form each species' current distribution. The current distribution areas of all species were summed to obtain the current staple bamboo distribution area. Since the main bamboo species in Lixian and Xiaojin counties were not among the four studied species, these counties were excluded from bamboo distribution and panda habitat analysis.

Future bamboo distribution area: Current distribution areas of each bamboo species were buffered by their dispersal distances and overlaid with future CSAs. Future distributions of each species were summed to obtain future staple bamboo distribution.

Current giant panda habitat: Current giant panda suitable habitat and current bamboo distribution area layers were overlaid. Overlapping areas were designated as current giant panda habitat range.

Future giant panda habitat: Future giant panda habitat was defined as the overlapping area between future giant panda suitable habitat and future bamboo distribution area.

4. Results

4.1 Predicted Changes in Giant Panda Suitable Habitat and Bamboo Climate Suitable Areas

Compared with current conditions, new giant panda suitable habitat will emerge in the high-altitude areas of central and southern Qionglai Mountains, while suitable habitat in northern and low-altitude areas will decrease. The total suitable habitat area will decrease by 25.7% in 2050 and 37.2% in 2070 compared with current area. Current giant panda suitable habitat area is 9219 km^2.

Future staple bamboo climate suitable area will also continue to decrease, but with a smaller magnitude than giant panda suitable habitat. Current bamboo CSA is 12,764 km^2. In 2050, CSA will decrease by 3.2% compared with current area, and in 2070, CSA will decrease by 4.7% compared with current area. Decreases will be concentrated in low-altitude areas, while new climate suitable areas will emerge in central and northern high-altitude areas. Overall, both giant panda suitable habitat and bamboo climate suitable areas show a trend of expansion to higher altitudes.

4.2 Predicted Changes in Bamboo Distribution

Current giant panda staple bamboo distribution area is 7353 km^2. Future bamboo distribution will decrease slightly: by 8.3% in 2050 and continuing to decrease in 2070 compared with current area. Combined with changes in bamboo CSA, bamboo distribution shows a trend of expansion to higher altitudes under climate change. However, due to limited bamboo dispersal capacity, newly added distribution area is minimal, while low-altitude areas show obvious decreases. Therefore, staple bamboo distribution is continuously decreasing, which may reduce giant panda habitat area.

4.3 Predicted Changes in Giant Panda Habitat

Excluding Lixian and Xiaojin counties, current giant panda habitat area is 6648 km^2. With climate change, both giant panda suitable habitat and bamboo distribution show trends of expansion to higher altitudes. However, due to limitations in bamboo dispersal capacity, although giant panda habitat shows an overall trend of expansion to higher altitudes, newly added habitat area is far smaller than decreased habitat area. Therefore, the final predicted habitat area shows continuous decrease: 1194 km^2 decrease in 2050 (18% of current habitat area), and 27.2% decrease in 2070 compared with current habitat. Future giant panda habitat expansion will be mainly located in southern mountain areas, while habitat in northern and low-altitude areas will continue to decrease.

5. Discussion

From the perspective of topography and vegetation conditions, new giant panda suitable habitat will emerge in central and southern high-altitude areas of the Qionglai Mountains under climate change, while suitable habitat in northern and low-altitude areas will decrease. The Qionglai Mountains' giant panda suitable habitat shows a continuous decreasing trend with expansion to higher altitudes, similar to conclusions from previous studies, but the proportion of suitable habitat area reduction varies significantly. This may be due to different mountain systems experiencing different climate impacts and having different existing panda population distributions, and also due to different authors' selection of models and scenario patterns, leading to different baseline parameters.

Wu et al. [7] used classification and regression tree models to analyze climate change impacts on national giant panda suitable habitat, concluding that the eastern, northeastern and southern parts of current suitable habitat would decrease by 70%. Songer et al. [8] used Maxent to model climate change impacts on giant panda habitat, concluding that new suitable habitat would mainly expand to western regions and that current suitable habitat would decrease by 67% by 2080. Fan et al. [9] predicted that under CGCM3 and HadCM3 scenarios, giant panda habitat in the Qinling Mountains would decrease by 37%. Jian et al. [22] used species distribution models to analyze giant panda suitable habitat (excluding Qinling), finding that 3.43% of area would change from unsuitable to suitable habitat and 2.64% from suitable to unsuitable habitat between 2050-2099. Shen et al. [5] used Maxent to predict Minshan giant panda habitat changes, finding a 6.59% decrease by 2050 compared with current area. Our study found a 25.7% decrease by 2050 and 37.2% decrease by 2070 compared with current area.

The staple bamboo climate suitable area in Qionglai Mountains also shows a continuous decreasing trend in the future, with a 4.7% decrease by 2070 compared with current area. Bamboo distribution predictions show an 8.3% decrease by 2070, a greater reduction than bamboo CSA. Tuanmu et al. [12] studied bamboo in Qinling giant panda habitat, finding that three major bamboo species' climate suitable areas would decrease dramatically by 59%-100% under climate change, with new suitable areas far from current bamboo distribution and panda habitat. Our results show that Qionglai Mountains' bamboo CSA decreases to some extent, but far less than in Qinling region, possibly because Qionglai Mountains are geographically more southern with warmer and wetter climate.

This study comprehensively used climate, vegetation and food resources to predict Qionglai Mountains giant panda habitat changes. Giant panda habitat distribution area will decrease by 18% in 2050 and 27.2% in 2070 compared with current area. The reduction rate is between that of giant panda suitable habitat and bamboo distribution area. Decreases will be mainly in northern mountain areas and low-altitude regions, while the core central mountain area will have smaller reductions. Shen et al. [5] used the third national giant panda survey data (1999-2003) and Maxent to analyze Minshan habitat changes, predicting a (16.3±1.2)% decrease by 2050. Shen et al.' s study [5] treated bamboo distribution alongside climate and other environmental factors. However, this study considers that staple bamboo has greater influence on giant panda habitat distribution than other environmental factors. Therefore, when considering climate change impacts on giant pandas from a food resource perspective, overlaying giant panda habitat change layers with bamboo distribution change layers yields more accurate results.

If we calculate the area of giant panda habitat plus non-habitat areas with bamboo distribution, the future giant panda usable habitat area will be 4.9%

larger than current habitat area in 2050, and still larger than current habitat area in 2070. This suggests climate change has limited impact on the Qionglai Mountains. Although climate change impacts are relatively small, future giant panda habitat area in Qionglai Mountains will decrease. Reduced areas are mainly located in Yingjing and Hongya counties of Daxiangling Mountains and Wenchuan County in the north. Future habitat fragmentation will intensify, requiring strengthened protection and monitoring in these areas. Long-term climate monitoring stations should be established, and dynamic monitoring of giant pandas and staple bamboo should be enhanced to track climate impact trends. Protection efforts in high-altitude areas should also be strengthened, as these are future giant panda habitat expansion areas, particularly in high-altitude regions of Daxiangling Mountains.

The central Qionglai Mountains area is less affected by climate change and represents the core giant panda distribution area. This region' s Wenchuan, Baoxing, and Tianquan counties have 192 giant pandas [16], accounting for 64.9% of the study area' s panda population. Protection in this region should be further strengthened to ensure long-term survival of core populations, particularly through enhanced protection area construction in Wolong and Anzihe reserves.

Acknowledgments

We thank the Sichuan Forestry Department for providing data from the third and fourth Sichuan Province giant panda surveys, the Sichuan Province Fourth Giant Panda Survey Team for field investigations, and Wang Bin for assistance with field surveys and data analysis. Shane DuBay and Dr. Wu Yongjie provided writing assistance.

References

[1] Rosenzweig C, Karoly D, Vicarelli M, Neofotis P, Wu QG, Cassasa G, Menzel A, Root TL, Estrella N, Seguin B, Tryjanowski P, Liu CZ, Rawlins S, Imeson A. Attributing physical and biological impacts to anthropogenic climate change. Nature, 2008, 453(7193): 353-357.

[2] [Research progress on giant panda habitat quality evaluation. Guangdong Agricultural Science, 2012, 39(22): 193-198.]

[3] [Giant pandas past and present, 1981, (1): 6-7.]

[4] [Impacts of climate change on giant panda habitat in Sichuan. Plateau and Mountain Meteorology Research, 2010, 30(4): 57-60.]

[5] Shen GZ, Stuart L, Feng CY, Ren GF, Liu YP, Xu WT, Li JQ, Si XF, Xie ZQ. Climate-change challenges the current conservation strategy for the giant panda. Biological Conservation, 2015, 190: 43-50.

[6] [Impacts of climate change on giant pandas and habitat in Minshan Mountains.]

[7] [Potential impacts of climate change on giant panda distribution. Beijing Forestry University, 2012.]

[8] Songer M, Delion M, Biggs A, Huang QY. Modeling impacts of climate change on giant panda habitat. International Journal of Ecology, 2012, 2012: 108752.

[9] Fan JT, Li JS, Xia R, Hu LL, Wu XP, Li G. Assessing the impact of climate change on the habitat distribution of the giant panda in the Qinling Mountains of China. Ecological Modelling, 2014, 274: 12-20.

[10] Klanderud K. Climate-change effects on species interactions in an alpine plant community. Journal of Ecology, 2005, 93(1): 127-137.

[11] [Comparison of habitat selection between giant pandas and red pandas in Qionglai Mountains, 2002, 22(3): 161-168.]

[12] Tuanmu MN, Vina A, Winkler JA, Li Y, Xu WH, Ouyang ZY, Liu JG. Climate-change impacts on understory bamboo species and giant pandas in China' s Qinling Mountains. Nature Climate Change, 2013, 3(3): 249-253.

[13] [Research progress on ecological impacts of natural and anthropogenic disturbances on staple bamboo populations of giant pandas, 2015, 34(1): 1-9.]

[14] [Ecological niche factor analysis in giant panda (*Ailuropoda melanoleuca*) habitat evaluation, 2008, 28(2): 821-828.]

[15] [The rise and fall of giant pandas. Sichuan Forestry Department, 1983, 29(1): 93-104.]

[16] [Sichuan's giant pandas. Sichuan Science and Technology Press, 2015: 1-18.]

[17] [Evaluation and projection of multiple global climate models over China. Nanjing University of Information Science and Technology, 2012.]

[18] [Latest progress in research on new scenarios of greenhouse gas emissions and climate change. Chinese Agricultural Science, 2008, 41(6): 1700-1707.]

[19] [Application of MAXENT model in habitat evaluation of golden snub-nosed monkeys in Qinling Mountains, 2010, 26(2): 1-3, 26-26.]

[20] [MAXENT model-based potential habitat evaluation of black bears in Qinling Mountains. Biodiversity, 2011, 19(3): 343-352.]

[21] Liu Zhensheng, Teng Liwei, Wang Xiaoqin, Kong Fangyi. MAXENT model-based habitat suitability evaluation of blue sheep in Helan Mountains. Acta Ecologica Sinica, 2013, 33(22): 7243-7249.

[22] Jian J, Jiang H, Jiang ZS, Zhou GM, Yu SQ, Peng SL, Liu SY, Wang JX. Predicting giant panda habitat with climate data and calculated habitat suitability index (HSI) map. Meteorological Applications, 2014, 21(2): 210-217.

[23] [Investigation of giant panda population and habitat in Daxiangling, Sichuan. Journal of Sichuan University (Natural Science Edition), 2006, 43(4): 889-893.]

[24] [Habitat suitability evaluation of giant pandas on the northern slope of Daxiangling, 2007, 27(2): 146-152.]

[25] [Preliminary study on giant panda habitat conditions in Qionglai Mountains. Sichuan Forestry Science and Technology, 1993, 14(2): 74-76.]

Note: Figure translations are in progress. See original paper for figures.