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Delineating the ecological conservation redline based on the persistence of key species: Giant pandas (*Ailuropoda melanoleuca*) inhabiting the Qinling Mountains

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ABSTRACT

To effectively resolve conflicts between natural resources and environmental protection and guarantee ecological safety, the Chinese government has proposed a national strategy to delineate ecological conservation redlines (ECRs). The ECR is defined as the least amount of area needed to guarantee the national and regional ecological safety of ecosystem services and implementation of strict mandatory protection policy. Because this was piloted by government and theoretical study has lagged, there remains no fully accepted ECR delineation framework. Being neglected in the current delineating guidelines for ECR, we focused on ECR delineation of the Qinling Mountains based on the sustainable survival needs of giant pandas (*Ailuropoda melanoleuca*) to explore the ECR delineation approach with species persistence. We define the concepts of basic, current and future ECR, and set the principals and procedures for ECR delineation based on the historical and current giant panda population range, current and future habitat modeling with data from national giant panda surveys, and the impacts of climate change. Our results indicate that the basic ECR is 369,531 ha; the current ECR is 422,149 ha with 33,498 ha of suitable and sub-suitable habitat from the basic ECR covering 67% of current giant panda reserves. The future ECR in 2050 is 516,838 ha with 109,990 ha future suitable and sub-suitable habitat based on current ECR and covers 84% of current reserves. As the foundation of an ecosystem, species deserve to be an important basis when delineating ECR. Concentrating on the needs of long-term species survival, rich and powerful study of target species' biology makes ECR delineation feasible and operational, while strengthening theoretical and scientific support at better temporal and spatial scales. The approach and index system employed here is a scientific framework for ECR delineation, especially given the temporal scale of population and habitat, and the main driving factors for future habitat dynamics. This method avoids the complicated process of ecological assessment. We hope our methods and reasoning can be incorporated into national guidelines and applied to ECR delineation across China.

1. Introduction

To address the conflict between natural resources and environmental protection, and to resolve spatial mismatches and management gaps in current ecological conservation policy, the Chinese government has proposed a national environmental policy based on ecological conservation redlines (ECRs) (Gao, 2015; Xu et al., 2015; Zheng and Ouyang, 2014). The ECR is defined as the least amount of area needed to guarantee the national and regional ecological safety of ecosystem services and implementation of strict mandatory protection policy. Due to its significance to economic and social sustainable development, this policy was approved by the Central Committee of the Communist Party of China in 2013 and included in revised environmental protection law in 2014 (Bai et al., 2015; Liu et al., 2015; Yang et al., 2014). As a policy for ecological protection, the ECR needs to be delineated according to specific areas and boundaries before it can be put into conservation practice. The Chinese Ministry of Environmental Protection, the key ministry sponsoring ECR policy, released a recommended standard technical guide (hereafter, the guide) for identifying ECRs based on previous zoning of eco-function areas, eco-fragile hotspots and biodiversity hotspots in 2015 (Chinese Ministry of Environmental

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Protection, 2015). With methodological support, some provinces and cities launched a delineation of their ECR, including Hunan, Jilin and Jiangsu (Lin et al., 2016; Liao et al., 2015; Yan et al., 2014).

The ECR is a policy piloted by government and remains ahead of the current state of ecological research. There is a lack, and lag, of theoretical and technical support, and this has resulted in operational challenges when implementing ECR delineation. The main theories initially reflected in ECR delineation were those around landscape ecology and system ecology (Lin et al., 2016; Si et al., 2013; Xu et al., 2015) such as hotspots, gap analysis and systematic conservation planning (Jørgensen, 2001; Jantke et al., 2011). Other theories, especially population ecology and conservation ecology, are seldom incorporated into the recommended techniques for operational implementation. The assessment of ecological value is an important process in ECR delineation, but the valuation models in national guidelines require a great number of parameter settings and scenario assumptions. Without clear identification of the main function for a given area in the guide, confusion about which function can be used to evaluate ecological value and parameters persists (e.g. water storage, biodiversity protection or landscape value) (Lin et al., 2016), and it remains difficult to construct a more convenient model for ECR. Thus we now have a situation where ecological value assessments are only completed at provincial scales during ECR delineation (e.g. in Jilin and Jiangsu). In addition, the ECR guidelines rely heavily on the results of previous zoning of ecological function, major function and conservation networks, and lack response strategies to faults in this zoning (Lin et al., 2016). All zoning has defects caused by topographic isolation, landscape fragmentation and administrative boundaries that remain unresolved (Xu et al., 2015). Further, the main basis for ECR delineation was based on the current requirements of economic development projects at the expense of ecological function and system dynamics, and the historical and future conditions affecting ecological conservation needs are rarely included. In combination, these factors have impeded the development of a fully accepted technical, scientific and index system for delineating ECR in China.

Species form the basic component of biodiversity, ecosystems and ecological services, but have been neglected from the ECR process. The current ECR definition and guidelines have biodiversity as the main target, but the sustainable survival needs of species are not reflected. The theories of population ecology and conservation ecology, closely related to species, have not been incorporated into the scientific basis of ECR and these omissions represent an important technical gap in the delineation of ECR. In order to address this gap, here we focused on ECR delineation based on the survival of one species. We used the Qinling Mountains as a case study and delineated its ECR according to the sustainable needs of giant pandas (*Ailuropoda melanoleuca*). Giant pandas are a global icon of biodiversity conservation and the Qinling Mountains form their northernmost stronghold (State Forestry Administration, 2014). This case study provides an opportunity (1) to explore ECR delineation based on species sustainability and survival; (2) strengthen and build theoretical support of ECR; and (3) develop a case study for ECR delineation using giant pandas and their long-term survival based on biological characteristics, and current and future habitat dynamics. Our overall aim is that a species approach is incorporated into ECR delineation in order to facilitate better zoning and ECR implementation across China.

2. Materials and methods

2.1. Study area

The Qinling Mountains run west to east across Shanxi in central China. The highest peak is Taibai Mountain at 3767 m above sea level in southern Shanxi (Fig. 1). The Qinling Mountains are of great importance to China because they form a watershed between the Yangtze and Yellow Rivers, and a natural climatic and cultural boundary between southern and northern China. This area is a biodiversity hotspot and a global conservation priority area (Mittermeier et al., 2009; Olson and Dinerstein, 1998) containing many rare, endangered and endemic species such giant panda, golden monkey (*Rhinopithecus*), takin (*Budorcas taxicolor*) and ibis (*Nipponia nippon*). Fourteen nature reserves have been established here (Fig. 1). The Qinling Mountains are a stronghold for giant pandas and contain 18.6% of all giant pandas in China according to the Fourth National Giant Panda Survey (FNGPS) conducted by the State Forestry Administration of China. The Qinling Mountains are the focus of nature forest protection projects and provide water for Beijing and Xian. The mountains have been designated an important ecological function area and area of water resource conservation by the Chinese Ministry of Environmental Protection, and a major function-oriented area by the Chinese National Development and Reform Commission (Fan et al., 2010; Yue et al., 2012). Delineating ECR is of real significance to the eco-functioning and ecoservices of the Qinling Mountains.

2.2. Giant panda presence and habitat data

The State Forestry Administration conducted national surveys of giant pandas in 2000 and 2012. During each survey, line transect methods were applied within pre-defined 2 km^2 survey grid cells (the side length of a cell is close to the average radius of a giant panda's home range) (State Forestry Administration 2006, 2014) that covered the entire giant panda range and potential habitat. All signs for the presence of giant pandas such as feces, dens, sleeping sites and footprints were collected; latitude, longitude, elevation, slope and vegetation at each sign point were recorded. We derived elevation and slope data of habitat and GIS layers from a digital elevation model based on 1:50,000 topographic maps obtained from the Chinese Academy of Sciences (www.gscloud.cn). In addition, vegetation and bamboo data and GIS layers were obtained from the two surveys and satellite images from Landsat 5 in 2000 and Spot5 in 2012 using the maximum likelihood classification algorithm in supervised classification by Erdas 8.7 (Leica Geosystems GIS and Mapping, 2003, LLC, Atlanta, GA, USA). All data were obtained and approved by the State Forestry Administration.

Given global change, we also included climatic variables as habitat factors using current and future bioclimatic variables at a 30 s resolution from the WorldClim database (WorldClim.com) (Hijmans et al., 2005). As the main human-induced threat to giant panda habitat (Zhu et al., 2013), the latest road data, including national roads, highways and high-speed railways were taken from previous studies and field surveys (Fig. 1). All geospatial data were based on the UTM WGS 84 coordinate system. The raster data resolution was 30×30 m and data were analyzed using ArcGIS10.0 (Esri, Redlands, USA).

2.3. ECR modeling

2.3.1. The principles and definition of ECR

To identify a scientific ECR for the Qinling Mountains based on the long-term survival of giant pandas we set the principal criteria for ECR delineation and modeling as follows: (1) ECR should include the area that current giant pandas possibly inhabit, taking historical distributions into consideration; (2) ECR should be dynamic and include current and future high quality habitat to ensure species long term survival; (3) ECR should meet the integrity and connectivity of landscapes for ecosystem function and biodiversity conservation needs referring to expert knowledge; and (4) the size of ECR should be appropriate considering land resource