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A bird's view of new conservation hotspots in China

Ruocheng Hu[a,b,1], Cheng Wen[a,b,*,1], Yiyun Gu[b], Hao Wang[a], Lei Gu[b,c], Xiangying Shi[b], Jia Zhong[d], Ming Wei[d], Fenqi He[e], Zhi Lu[a]

[a] Center for Nature and Society, School of Life Sciences, Peking University, Beijing 100871, China
[b] Shan Shui Conservation Center, Beijing 100871, China
[c] School of Life Sciences, Capital Normal University, Beijing 100871, China
[d] Chinese Bird Watching Societies Network, Kunming, Yunnan 650224, China
[e] Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China

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ABSTRACT

Blooming citizen science in China creates opportunities to update distribution maps of threatened birds and contributes to decision making for conservation. 46,073 records submitted by over 7000 bird watchers from 1998 to 2013 in China cover 1195 of 1371 species and all provincial administrative districts in the country. We extracted 13,181 occurrence localities for 95 threatened species defined by the IUCN Red List and 239 national protected species in China. By applying these data in MaxEnt model, we identified new conservation hotspots for threatened birds in China in coastal regions of the Bohai Gulf and the Yellow Sea, the south of the North China Plain, and the lower reach of the Yangtze River. These new conservation hotpots are not included in the global biodiversity hotspots, and not all represented in the priority regions in National Biodiversity Strategy and Action Plan (NBSAP). These newly identified conservation hotspots are seriously under-protected: only less than 2% of them are in national nature reserves. There is a long way to go to meet the Aichi targets, a plan to halt the loss of biodiversity by 2020.

1. Introduction

Birds have been widely accepted as flagship taxa for conservation hotspot identification and conservation GAP analysis (Scott et al., 1993; Balmford, 1998; Reid, 1998; Lei et al., 2003a; Chape et al., 2005; Jenkins et al., 2013). China is home to 1371 bird species (Zheng, 2011), accounting for about 15% of the world's total bird species (del Hoyo et al., 2014), while it also holds the greatest human population and the second largest economy in the world. Over a decade ago, the Mountains of Southwest China, the Qinling Mountains, and the Dabashan Mountain Region were identified as China's priority regions for bird conservation based on the distribution of endemic species (Lei et al., 2003a; Lei et al., 2003b; Lei et al., 2006; Chen and Townsend Peterson, 2002). At the same time, six bird conservation hotspots were identified based on the distribution of 183 threatened species from *China Red Data Book of Endangered Animals*: *Aves* (Lei et al., 2006; Zheng and Wang, 1998), namely the west of Tianshan Mountains, the Qilian and Hengduan Mountains, southern Anhui Province-southern Jiangsu Province-the Zhejiang Hills, the Songliao Plain and the north of the North China Plain, and islands of Taiwan Province and Hainan Province. In 2009, Birdlife International published *Directory of Important Bird Areas in China* (*Mainland*), *Key Sites for Conservation*, which listed 512 Important Bird Areas (IBAs). 75% (384/512) of IBAs are protected areas, and 62.5% (320/512) of IBAs are nature reserves (Chan, 2009). However, the clear boundary of each IBA has not been offered (Chan, 2009).

Recently, the global richness pattern and hotspots of birds have been drawn according to breeding ranges (Jenkins et al., 2013). While in China, the umbrella protective effect of the Giant Panda *Ailuropoda melanoleuca* to endemic and sympatric species including birds in China's southwest forests has been assessed and new conservation hotspots have been identified based on endemic species distributions (Li and Pimm, 2016). Biodiversity hotspots of endemic and non-endemic avian diversity in the mountains of Southwest China have been identified (Wu et al., 2016). Endemic species of China need to be in a higher-threat category than the current IUCN Red List, and more attention need to be payed to these endemic species (Li et al., 2016; Ocampo-Peñuela et al., 2016). However, the hotspots of endemic species and threatened species do not necessarily overlap with each other (Orme et al., 2005). The blooming economy in China heavily affected the key

* Corresponding author at: Shan Shui Conservation Center, Beijing 100871, China.
E-mail address: wencheng@shanshui.org (C. Wen).
[1] These authors contributed equally to this work.

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stopover habitats of birds (Ma et al., 2014; Kamp et al., 2015), and this caused a notable decline of migratory bird population (Runge et al., 2015). Therefore, the analysis of conservation hotspots for birds, especially for the threatened migratory birds, should take into consideration the stopover sites along migrating routes.

The GAP analysis of China's nature reserves also needs to be updated. In past decades, China's rapid economic growth and large-scale urbanization resulted in significant habitat loss of a large array of species (Brooks et al., 2002; Güneralp et al., 2015), especially birds (Li and Wilcove, 2005). This is one of the main reasons why 23 species of bird including 13 migrants have been upgraded to "threatened" by IUCN Red list in the last ten years (Baillie et al., 2004; IUCN, 2015). This may lead to a change of spatial patterns of conservation hotspots. Furthermore, this rapid change has not been taken into consideration by China's Wildlife Protection Law, in which the National Protected Species (NPS) List has not been systematically updated since the law went into effect in 1988 (Ministry of Forestry in the People's Republic of China and Ministry of Agriculture of the People's Republic of China, 1988), leaving many threatened species out of legal protection, including those critically endangered and endangered ones. The GAP analysis of protected areas has been performed at global level (Rodrigues et al., 2004; Alexander and Armitage, 2015) as well as national level, e.g. in the United States (Jenkins et al., 2015), and in Southeast Asia including Yunnan Province, China (Li et al., 2016; Hughes, 2017). However, the national or regional analysis in China needs to be done. Such analysis is important for guiding conservation plans and actions on the ground through strategies and investment. All these plans and actions require more accuracy and need to be updated from time to time.

In China, historical occurrence data of birds are mostly from specimen collection sites (Zheng and Wang, 1998). From 1998 to 2001 and from 2012 onwards, the State Forestry Administration organized two National Terrestrial Wildlife Resources Surveys. However, the occurrence data from the surveys is not publically available. On the other hand, the number of birdwatchers and bird reports has grown rapidly since birdwatchers established the first online bird record database, Bird Report, in 2002 (http://birdreport.cn/bird/). Up to 2013, the database covers 1195 of 1371 species and all provincial administrative districts, complementing the basic knowledge of bird distribution (Li et al., 2013). Citizen scientists can provide timely and expansive information for addressing fast-changing threats and prioritizing conservation (Todd et al., 2016).

In this paper, we chose to model 160 bird species of interest in MaxEnt 3.3.3k, including 43 threatened species, using the occurrence data accumulated over 16 years (from 1998 to 2013), the majority of which collected from Bird Report. We conducted the GAP analysis to identify new conservation hotspots and addressed the following questions: where are the conservation hotspots and critical regions for threatened bird species in China? To what extent are they protected legally, and how to improve the situation?

2. Methods

2.1. Species checklist and occurrence data

We selected 288 species from 1371 bird species in China according to two criteria: 1) Threatened bird species - Critically Endangered (CR, 10 species), Endangered (EN, 25 species) and Vulnerable (VU, 60 species) defined by the most recent IUCN Red List (IUCN, 2012, 2015); 2) NPS listed under the List of Key Protected Wildlife of the China Wildlife Protection Law (Ministry of Forestry in the People's Republic of China and Ministry of Agriculture of the People's Republic of China, 1988), including Class I (43 species) and Class II (196 species). The checklist of these species is in the Supporting information Appendix S1.

The sources of occurrence point data of the 288 species include: 1) Bird Report (http://birdreport.cn/bird/, from 1998 to 2013). We selected 33,174 bird records of 273 species, 13,181 independent localities from all 46,073 records collected by birdwatchers, which were checked by experienced birders on Bird Report to reduce errors (Kelling et al., 2015) and examined via spatial autocorrelation in MATLAB software (2009a, Mathworks, Natick, Massachusetts); 2) All peer-reviewed papers published since 2004 concerning the 288 species. These papers offered 295 different occurrence localities of 187 species. We verified the accurate coordinates of those points manually according to the place names using Google Maps (https://www.google.com/maps).

To reduce statistical errors associated with small sample size, we excluded species with fewer than 5 independent localities (Hernandez et al., 2006; Wisz et al., 2008). The remaining 158 species and 12,951 independent localities were applied to simulate species distribution maps, including 3 CR, 14 EN, 26 VU, 23 NPS-Class I and 120 NPS-Class II species; 230 localities of 115 species were used to make scatter plots; and 15 of the 288 species have no occurrence data.

2.2. Environmental variables and bioclimatic variables

We compiled a total of 22 environmental and bioclimatic variables for projection (Zhao et al., 2017): 19 bioclimatic variables (ESRI grids, bio 10 m) were downloaded from the WorldClim 1.4 (current conditions) database (Hijmans et al., 2005), distance to water from the IGRR (Institute of Geography and Resource Research, Chinese Academy of Sciences) by inter-agency letter of agreement, land cover type (GlobalLand 30) from the National Geomatics Centre of China (National Geomatics Center of China, 2013), and digital elevation model (G-TOPO30) from the United States Geological Survey (USGS) (USGS, 1996).

All bioclimatic variables were downscaled to a resolution of 30 arc-seconds (0.8421 km per pixel) using the Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climate Model version 3 (RegCM3) (Gao et al., 2012) and spline interpolation, and we used nearest neighbor for resampling land cover type (GlobalLand 30) to match the spatial resolution of other sets of data in ArcMap 10.2 (2010, ESRI, Red Land, California).

2.3. Ecological Niche Modeling

We created the Ecological Niche Modeling (ENM) of the selected species in the software MaxEnt 3.3.3k (Phillips et al., 2006). MaxEnt is a machine-learning method using a maximum entropy approach to estimate the most uniform distribution of a particular species across the study area, constrained by the provided environmental correlations represented by training presence-only data (Phillips et al., 2006; Elith et al., 2011). The number of occurrence localities collected for each species is usually small and highly variable (the average is 81.9, the median is 32.5, the mode is 9, and the standard deviation is 193.8,see Appendix S1). To reduce the influence of small sample size on forecasted accuracy (Stockwell and Peterson, 2002; Bean et al., 2012), we chose MaxEnt because it has been proven to work better than other approaches with limited presence-only occurrence data (Phillips and Dudík, 2008; Wisz et al., 2008; Merow and Silander, 2014; P Anderson et al., 2006). For each species, the model was run by 5 bootstrap replicates with randomly assigned 80% of the presence records as training data and the other 20% as testing data. We used the default settings of the software and logistic output format ranging from 0 to 1. The Area Under the Curve (AUC) was used to assess the accuracy of predict results (Lobo et al., 2008), and the average AUC value of 158 species is 0.956 (Appendix S1).

2.4. Distribution mapping and GAP analysis

For each species, the logistic outputs of models for forecasted distribution (FD) were converted to "presence/absence" binary maps