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Distribution and conservation of threatened plants in China

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ABSTRACT

China is very rich in biodiversity, however, it is also characterized by a long history of civilization. As a result, China has a large number of threatened species. Recently the Chinese government evaluated the living status of plants, and published the China Biodiversity Red List: Higher Plants. However, little is known about how threatened plants are distributed and conserved in China. In this study, we developed a fine resolution distribution database for 3244 threatened plants, explored richness patterns and evaluated the in situ conservation status of the threatened plants by overlapping the species distribution with terrestrial national and provincial nature reserves (NNRs and PNRs) in China. We found the greatest richness of threatened plants in the southwestern region of mainland China (mainly Yunnan, southeastern Xizang and western Sichuan), northwestern Guangxi, northern Guangdong, Hainan Island and the mountainous region of Taiwan, while the lowest richness was found in Qinghai, Hebei, Shandong, Jiangsu and Chongqing Provinces. On average, NNRs covered 18.8%, and NNRs and PNRs together covered 27.5%, of threatened plant distribution areas. However, 827 threatened plants (including 627 species endemic to China) were not covered by NNRs and 397 threatened plants (including 293 endemic to China) were not covered by either NNRs or PNRs. We proposed that nature reserves specifically designed for threatened plants need to be established in South China, especially in the Yunnan, Guizhou, Guangxi, Xinjiang Hainan, and Zhejiang Provinces.

1. Introduction

Biodiversity is fundamental for the health of global ecosystems and human well-being (Rands et al., 2010; Brugiere and Scholte, 2013). However, due to land use/land cover change, resource overexploitation, climate change, and environmental pollution, biodiversity is increasingly faced with habitat destruction and confronted with the risk of extinction worldwide (Millennium Ecosystem Assessment, 2005; Monastersky, 2014; Teller et al., 2015). The past century witnessed a loss of biodiversity at a rate far more rapid than natural processes (Balmford et al., 2003). Meanwhile, the global conservation network has been enhanced to protect biodiversity across the world (Rabb and Sullivan, 1995; Kullberg and Moilanen, 2014). However, the coverage of the network is considered to be inadequate, and efforts need to be spent to optimize it step by step (Rodrigues et al., 2004; Grenyer et al., 2006; Wu et al., 2013b).

To efficiently allocate limited resources to the species most needed to be conserved, conservation scientists have paid enormous efforts setting priorities for biodiversity conservation (Roberts et al., 2002; Trizzino et al., 2015). One of the most successful steps is the evaluation of the Red List of Threatened Species initiated by the International Union for Conservation of Nature (IUCN), which provides information on population size and trends, geographic range as well as habitat needs for global biodiversity (IUCN, 1994; Rodrigues et al., 2006). The most recent evaluation of the threatened status of global biodiversity showed that, 10,896 plant species are threatened, including 2205 critically endangered (CR), 3381 endangered (EN), and 5310 vulnerable (VU) (www.iucnredlist.org). As defined, these threatened species face a higher risk of extinction, and are worthy of more conservation efforts (Orme et al., 2005; Schipper et al., 2008). In fact, threatened species have become one of the most effective surrogates for the identification and evaluation of conservation priority areas (Myers et al., 2000; Grenyer et al., 2006; Clough et al., 2010; Huang, 2011; Neel and Che-Castaldo, 2013).

China is exceptionally rich in biodiversity, due partly to its unique geographical and ecological characteristics (Chen, 1993; Tang et al., 2006; Wang et al., 2011; Ma, 2015). Moreover, China harbors more threatened species than other regions in the world, due to geographic and climatic variation as well as a long history of cultivation, etc. (Chen, 1997; Chen et al., 2002; Tang et al., 2006; Zhang and Ma, 2008b; Lenzen et al., 2009). As a result, the study of threatened plants in China is of great significance in conservation biology worldwide. Indeed, a recent biodiversity mapping study shows that China has

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exceptionally high species richness of threatened vertebrate animals, even after taking into consideration the high overall species richness (Jenkins et al., 2013). Consensus has been reached among the government, academics, and the public that in situ conservation is the most feasible way to conserve biodiversity in China (Heywood and Dulloo, 2005; Huang, 2011; Wu et al., 2013a; Zhang et al., 2015). By the end of 2012, China has established more than 2600 (this number increased to 2729 at the end of 2014) nature reserves to protect its megabiodiversity, including 363 national nature reserves (NNRs) (this number increased to 427 at the end of 2014) and 872 provincial nature reserves (PNRs) (Zhao et al., 2013). However, the effectiveness and efficiency of those reserves in protecting threatened species have being challenged in the past decades (Wan et al., 2014; Ng et al., 2015). Based on the distribution of 302 threatened plant species (a preliminary checklist of the Chinese Species Red List, Wang and Xie, 2004), Zhang and Ma (2008a) found large conservation gaps between the distribution and conservation of threatened plant species in China. The fact that some gaps still exist among these nature reserves implies that the protection of threatened plants is facing tough challenges in China.

Recently, the Ministry of Environment Protection of the People's Republic of China (2013) assessed the living status of 34,450 plants in China and published the China Biodiversity Red List: Higher Plants. According to the assessment, 3767 species from 176 families were identified as threatened plants, including 583 CR species, 1297 EN species and 1887 VU species, which is a ten-fold increase from previous reports (Wang and Xie, 2004). It is, therefore, of critical importance to re-evaluate the status of the in situ conservation of the threatened plants in China (Rodrigues et al., 2004; Wu et al., 2014; Zhang et al., 2015).

In this study, we compiled a 10 × 10 km resolution distribution database for nearly all threatened plants and then analyzed the distribution patterns of threatened plants and further evaluated the in situ conservation status of threatened plants in China. There are already several studies on the patterns of threatened plants based on county level distribution of previously defined threatened plants (Tang et al., 2006; Zhang and Ma, 2008a). However, the distribution of threatened plants is still unclear because of limited data availability. Specifically, our study has the following four characteristics. Firstly, the number of threatened plants in the China Biodiversity Red List has been widely expanded to 3767 species because of the larger number of plants that have been evaluated (Qin and Zhao, 2014). By comparison, Zhang and Ma (2008a) included 302 species and Tang et al. (2006) included 388. Secondly, we refined the distribution to a resolution of 10 × 10 km, which is much higher than the county level distribution used in previous studies (Tang et al., 2006; Zhang and Ma, 2008a). Thirdly, we compiled a distribution dataset based on all sources, compared to the local flora and specimen records in previous studies (Chen et al., 2002; Tang et al., 2006; Zhang and Ma, 2008a). Lastly and most importantly, we evaluated the conservation status of each of the threatened plants by comparing its distribution with the spatial database of the nature reserves, and therefore were able to calculate the coverage of nature reserves for each species. Two specific questions were posed here: (1) Where were the threatened plants distributed? and (2) How were these threatened plants conserved in China?

2. Material and methods

2.1. Threatened plant species in China

The threatened plant species used in this study are from the China Biodiversity Red List (Ministry of Environment Protection of the People's Republic of China, 2013; Qin and Zhao, 2014). The evaluation was conducted by 294 authoritative experts across China according to the IUCN Red List Categories and Criteria (Version 3.1, IUCN, 2001) and Application of the IUCN Red List Criteria at Regional Levels (Version 3.0, IUCN, 2003). The base list of the evaluation is from the "Catalogue of Life China" (http://www.sp2000.cn/joacn/), which covers almost all the wild higher plants in China. Finally, the Red List assessed the status of 34,450 species (including infrataxa) from 437 families, resulting in 3767 threatened species, including 583 critically endangered (CR), 1297 endangered (EN), and 1887 vulnerable (VU) species. The assessment is based on expert knowledge, specimen records (4,816,050 available specimens in total), and a literature review (more than 4000 sources). Please refer to Qin and Zhao (2014) for a more detailed description of the evaluation.

2.2. Distribution of the threatened plants in China

Our data on the distribution of the threatened plants are based on three sources. First, for the woody plants, we extracted the county level occurrences from the Atlas of Woody Plants in China (Fang et al., 2011). Second, for the herbaceous plants, we compiled the county level occurrence based on all available literatures, such as national, provincial and local floras, checklists of nature reserves, monographs of field investigation, and peer reviewed articles. Third, we further searched the specimen records from the China Virtual Herbarium (www.cvh.ac.cn) for all the threatened plants, and the locations (towns and villages) where the specimen was collected were digitalized for biodiversity mapping.

For the first two sources (county level distribution of woody and non-woody plants), the county level occurrence might over-estimate the distribution of each species, therefore, we also collected the upper and lower elevation records and habitat type of each species to refine the distribution. Then we overlapped the county level occurrence with a vegetation map of China (1:1,000,000) (Editorial Committee of Vegetation Map of China, 2007) and a digital elevation model (DEM) obtained from the United States Geological Survey (at a resolution of 30 m, available at http://reverb.echo.nasa.gov/reverb/redirect/wist). We defined the distribution as grids containing the habitat types and any elevation between the upper and lower limit of the county where the species occur. Finally, the distribution based on all three sources was transformed into grids at a resolution of 10 × 10 km, as this resolution is widely used for species distribution modeling at regional or country scales (Zhang et al., 2014; Irannezhad et al., 2015). In total, we compiled 888,596 distribution records for 3244 threaten species of higher plants (86% of the total threatened plants in China) from 176 families, of which 483 are CR species, 1112 EN are species and 1649 are VU species. It includes 2175 endemic and 1069 non-endemic species to China (Qin and Zhao, 2014).

In the analyses, we also equally grouped the threatened plants into four types (811 species in each types) according to their distribution ranges, including most narrowly distributed (Q1), narrowly distributed (Q2), widely distributed (Q3) and most widely distributed (Q4). Q1 species included one quarter of species with the narrowest distribution ranges; Q2 species included one quarter of species with the second narrowest distribution ranges; Q3 species included one quarter of species with the second widest distribution ranges; and Q4 species included one quarter of species with the widest distribution ranges.

2.3. Spatial database of nature reserves in China

Among the ~2600 nature reserves established before the end of 2012 in China, 319 NNRs and 835 PNRs are terrestrial (Zhao et al., 2013). To evaluate the representativeness of threatened plants in those nature reserves, we compiled the spatial database on NNRs and PNRs by digitalizing all terrestrial NNRs and PNRs using geographical information system techniques, using ArcGIS 10.2 software (ESRI, Redlands, US). We only included the terrestrial NNRs and PNRs because of the following facts, first, NNRs and PNRs covered >92% of the total area of terrestrial nature reserves in China (Zhao et al., 2013), second, most prefectural and county level nature reserves were not well managed (Quan et al., 2009); third, boundaries of these prefectural and county level were not well defined (Zhao, 2013).