Threatened medicinal plants in China: Distributions and conservation priorities

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ABSTRACT

Medicinal plants are more vulnerable to threats than non-medicinal plants. In China, a large number of medicinal plants are threatened by human activities and climate change, which greatly affect the conservation of species diversity, genetic resources and sustainable development of the traditional Chinese medicine industry. In this study, we established the first database for the distributions of 535 threatened medicinal plant species in China at the county level. Using this database, we explored geographic patterns, identified biodiversity hotspots and determined the conservation gaps for these threatened medicinal plants. Threatened medicinal plants were widely distributed in 1709 counties across the whole country. The species richness was higher in southern than in northern China. Using the "top 5% richness algorithm" and the "complementary algorithm", we identified 213 counties as biodiversity hotspots for threatened medicinal plants in China. However, based on further conservation gap analysis, we found that 30 hotspot counties were not covered by any type of nature reserve (complete conservation gaps), and 27 more hotspot counties were not covered by national or provincial nature reserves in mainland China. We suggest that new nature reserves should be established for the 30 complete conservation gaps, while range, level or management strategies for the current nature reserves should be improved for the remaining 27 conservation gaps to promote the conservation of threatened medicinal plants in China.

1. Introduction

Medicinal plants are those containing compounds useful for human health and are used to treat or prevent diseases. China is one of the world's megadiverse countries (Tang et al., 2006), harboring more than 30, 000 higher plant species (Ma et al., 2016). Medicinal plants are an important part of biodiversity in China. According to the most recent census, there are 10, 608 medicinal higher plant species, accounting for 83.4% of all medicinal biological resources in China (12, 727 plant and animal species in total, China National Chinese Medicinal Material Corporation, 1994; Huang, L.Q. et al., 2012) and 30.3% of all medicinal plants in the world (approximately 35, 000 species, Kong et al., 2003).

The rich diversity of medicinal plants provides an important source of medicinal raw materials both for traditional medicine systems and the pharmaceutical industry (Shreekar and Virbala, 2011). The plants' seeds, berries, roots, leaves, bark, or flowers can be handled and prepared differently for different therapeutic results. The World Health Organization has indicated that approximately 80% of the worldwide population uses herbal medicine for primary health care (Kong et al., 2003). The traditional Chinese medicine (TCM) market has been developing rapidly since the late 1990s (Helmut Kaiser Consultancy Studies, 2017). It is estimated that the output value of TCM amounted to RMB 786.6 billion (approximately $124.9 billion, 28.6% of the overall output value of China's medical industry) and the gross export

value reached $3.72 billion in 2015 (The State Council Information Office of the People's Republic of China, 2016). TCM products are exported mainly to the markets of Asia, North America and Europe. Customs figures indicate that approximately 240,000 tons of medicines are exported annually, of which 200,000 tons are raw herbs, which account for 20% of the country's annual harvest (Helmut Kaiser Consultancy Studies, 2017). The rapid development of the TCM market has led to a rapid expansion in the cultivation of medicinal plants. However, 70% of the commonly used Chinese medicinal materials still depend on wild resources (Huang, L.Q. et al., 2012). Most wild medicinal plants, especially commercially viable and highly valuable species, are under threat of over-harvesting due to the ever-increasing market demand. Even more, habitat degradation, habitat loss (Huang, L.Q. et al., 2012) and climate change (Khanum et al., 2013), also threaten the survival of medicinal plants. For example, *Neopicrorhiza scrophulariiflora* (Pennell) D. Y. Hong and *Panax ginseng* C.A. Mey have a conservation status of endangered and critically endangered, respectively (Ministry of Environmental Protection of the People's Republic of China, 2013). The dried rhizomes of *Neopicrorhiza scrophulariiflora* are a traditional medication that has long been used to treat inflammatory diseases (He et al., 2009). *Neopicrorhiza scrophulariiflora* is threatened by large-scale exploitation for international trade, and the high financial importance of the species to rural harvesters increases the difficulty of protecting it (Olsen, 2005). The circumstances of *Panax ginseng*, which currently can hardly be found in the wild, are even worse (Yang et al., 2000). Hence, compared to non-medicinal plant species, medicinal plants are more vulnerable because of their commercial value, which leads to selective harvesting (Yang et al., 2000; Law and Salick, 2005; Huang, L.Q. et al., 2012). The loss of medicinal plant species has greatly affected both the conservation of genetic resources and the sustainable development of the TCM industry (Huang, L.Q. et al., 2012). Thus, conservation of medicinal plants has become extremely urgent.

Setting up protected areas has been found to be one of the most effective ways to protect biodiversity in situ (Heywood and Dulloo, 2005). To better protect the TCM resources, the Chinese government launched the overall plan of Chinese medicinal materials protection and development (2015–2020) in 2015 (The State Council General Office of the People's Republic of China, 2015). Identifying conservation priority areas for threatened wild medicinal plants and animals is an important task of the plan. Currently, nature reserves in China are established mainly to protect representative natural ecosystems, rare wild animals and plants, or special significant natural sites, which cover approximately 14.8% of the country's total landmass (Natural Ecosystem Protection Office of Ministry of Environmental Protection of the People's Republic of China, 2014). However, protection of threatened medicinal plants has not been given sufficient consideration in the current conservation design. Thus, assessing the conservation status of threatened medicinal plants and identifying the conservation gaps of biodiversity hotspots will help optimize the existing protected areas system and thereby maximize the conservation outcomes.

A biodiversity hotspot is a region containing the highest (threatened/endemic) species richness and vulnerable to species loss (Myers et al., 2000; Tang et al., 2006; Huang et al., 2016). Identifying biodiversity hotspots helps to set biodiversity conservation priorities and thus improves the efficiency of protection with limited resources (Tang et al., 2006; Zhang et al., 2015a; Huang et al., 2016). In the past few decades, scientists around the world have paid much attention to identify diversity hotspots and conservation gaps for rare and endangered species (Dobson et al., 1997; Myers et al., 2000; Chen et al., 2002; Tang et al., 2006; Zhang and Ma, 2008; Zhang et al., 2015a, 2015b) and endemic species (Tang et al., 2006; Chen et al., 2011; Huang, J.H. et al., 2012, 2016). For example, Huang et al. (2016) first identified diversity hotspots of Chinese endemic seed plant species with five indices and then detected that 73.52% of the identified hotspots were conservation gaps by overlaying them with the current network of Chinese national

nature reserves. Chinese medicinal plants have received less attention, although people in China and elsewhere are highly dependent on them. Many studies have been carried out to explore the distribution and diversity of Chinese medicinal plants within specific regions (e.g., He et al., 2004; Zhou et al., 2005; Wan et al., 2014) or in specific taxonomic groups (e.g., Guo and Xiao, 1993; He et al., 2011, 2013). Some model based analysis has also been conducted to evaluate the conservation status at the local scale. For example, Wan et al. (2014) predicted the potential distribution of habitat, determined the diversity hotspots and evaluated the conservation status of 49 medicinal plants in northeastern China based on species distribution models. However, it is still unclear how the diversity of medicinal plants is distributed and how these plants are conserved.

In this study, we first complied a checklist of threatened medicinal plants in China based on their conservation status and medicinal properties. We then constructed a county-level distribution database of these plants based on recent field surveys and literatures. Using this database, we explored the distribution patterns of the diversity of threatened medicinal plants across China and identified hotspots of these plants using two different algorithms. We also overlapped the spatial distribution of the identified hotspots and the Chinese nature reserves network to detect the conservation gaps of the hotspots of threatened medicinal plants and further identified three different levels of conservation priority areas.

2. Materials and methods

2.1. Checklist of threatened medicinal plants in China

To better protect plant diversity in China, the Ministry of Environmental Protection of the People's Republic of China (2013) organized an evaluation of the conservation status of plant species in China based on the International Union for Conservation of Nature (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). In this evaluation, 3767 higher plant species (including species, subspecies, variety and form, the same hereinafter) are identified as threatened, including 583 critically endangered (CR), 1297 endangered (EN), and 1887 vulnerable (VU) species. We searched the medicinal uses for each of these 3767 threatened species using mainly (1) the Subject Database of China Plants: Medicinal Plants Database (http://www.plant.nsdc.cn/herb, accessed May 6, 2016) and (2) professional books (Yunnan Chinese Medicinal Materials Corporation, 1900; China National Chinese Medicinal Material Corporation, 1994; Xie and Yu, 1996; Jia and Li, 2005; Zhong and Qin, 2010). Species with medicinal uses described in these sources were defined as medicinal plants. As any species may be recorded by its accepted or an alternative synonym name in different category systems, we unified the species names from various resources by using the accepted names from the Species 2000 list (Ma et al., 2016). Ultimately, we identified 603 threatened medicinal plant species from 338 genera and 134 families in China, including 44 CR, 189 EN and 370 VU species (Table 1, Appendix A).

Table 1

Statistics of the distribution information of critically endangered (CR), endangered (EN) and vulnerable (VU) medicinal plants in China.

Items	CR	EN	VU	Total
No. of all species	44	189	370	603
No. of species with distribution information	37	164	334	535
No. of occurrence records	782	3540	10,543	14,865