

Rescuing *Magnolia sinica* (Magnoliaceae), a Critically Endangered species endemic to Yunnan, China

BIN WANG, YONGPENG MA, GAO CHEN, CONGREN LI
ZHILING DAO and WEIBANG SUN

Abstract *Magnolia sinica*, a Critically Endangered tree endemic to Yunnan, China, is one of the 20 plant species with extremely small populations approved by the Yunnan government for urgent rescue action before 2015. Information on the geographical distribution and population size of this species had not previously been reported, hindering effective conservation. We therefore carried out a survey of the literature and of herbarium specimens, followed by a detailed field survey and morphological measurements and observations of surviving individuals. We located 52 individuals in the wild, in eight localities. Two distinguishing morphological characters (tepal colour and tepal number) were revised based on observations of all remaining wild individuals that produced flowers and on one 30-year-old flowering plant in Kunming Botanical Garden. The survival rate of individuals propagated from seed for ex situ conservation at the Garden was 100% over 5 years; of 100 individuals transplanted to each of two reinforcement sites, 20 and 18, respectively, were alive after 6 years. We propose two groups of measures to protect *M. sinica*: (1) in situ conservation, population monitoring, and public engagement, and (2) ex situ conservation with reinforcement or reintroduction.

Keywords Ex situ conservation, extremely small populations, in situ conservation, *Magnolia sinica*, morphological revision, reinforcement, species distribution

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/S0030605315000435>

Magnolia sinica (Law) Noot. (Magnoliaceae), a tree endemic to China, was first described as *Manglietiastrum sinicum* Law (Law, 1979); the type locality is in broadleaved evergreen forest near Fadou village, Xichou County, in south-east Yunnan Province. Most

Chinese botanists refer to the species as *M. sinicum* and also use its common name *huagaimu* (Sun et al., 2012). The species is categorized as Critically Endangered on the IUCN Red List, based on limited data suggesting a population of < 10 mature individuals (Wang & Xie, 2004; Cicuzza et al., 2007; Zheng et al., 2008). The term 'plant species with extremely small populations' is used to describe species that are restricted to a narrow geographical distribution, have been subjected to disturbance and other external stress factors over a long period of time, and whose population size has decreased below a critical threshold necessary to prevent extinction (Ren et al., 2012; State Forestry Administration of China, 2012; Ma et al., 2013). *Magnolia sinica* is one such species, and it has been targeted as one of the 20 such species approved by the Yunnan government for urgent rescue action before 2015. Here we (1) update distribution data for *M. sinica* and reassess the number of wild individuals, (2) revise the species' main floral characteristics, and (3) examine the conservation of the species.

We firstly gathered information covering most of Yunnan Province, with a focus on the south-east (including almost all counties in Wenshan, Honghe: Maguan, Xichou, Malipo, Jinping and Hekou/Pingbian prefectures). We reviewed *Flora Reipublicae Popularis Sinicae* (Law, 1996), *Flora Yunnanica* (Law, 2006) and *Flora of China* (Xia et al., 2008) for information on the species, and examined all *M. sinica* specimens in the three major herbaria of the Chinese Academy of Sciences (KUN, IBSC, PE) to identify potential sites for field verification. We then surveyed for *M. sinica* during 2004–2014, using field measurements and participatory rural appraisal (Chambers, 1994, 2007; Upjohn et al., 2013). We interviewed 20 people (five members of staff at each of four reserves), in particular regarding factors affecting the vulnerability of the species. During the field surveys several previously unrecorded individuals of *M. sinica* were discovered, bringing the total number of known individuals in the wild to 52, scattered throughout the prefectures of Wenshan and Honghe in Yunnan (Fig. 1) at altitudes of 1,339–1,707 m. Thirty-six of the remaining individuals are in Wenshan prefecture (Table 1).

We collected morphological data for each of the 52 individuals, and grouped them into eight categories, based on height (H) for smaller individuals and diameter at breast height (DBH) for larger individuals: I (H < 33 cm), II (H ≥ 33 cm, and individuals for which DBH can be measured with DBH

BIN WANG*, YONGPENG MA, GAO CHEN, CONGREN LI, ZHILING DAO (Corresponding author) and WEIBANG SUN (Corresponding author) Kunming Botanical Garden, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, 650201 Yunnan, China. E-mail daozh@mail.kib.ac.cn, wbsun@mail.kib.ac.cn

*Also at: University of Chinese Academy of Sciences, 100049 Beijing, China

Received 10 November 2014. Revision requested 10 December 2014.

Accepted 16 March 2015. First published online 22 May 2015.

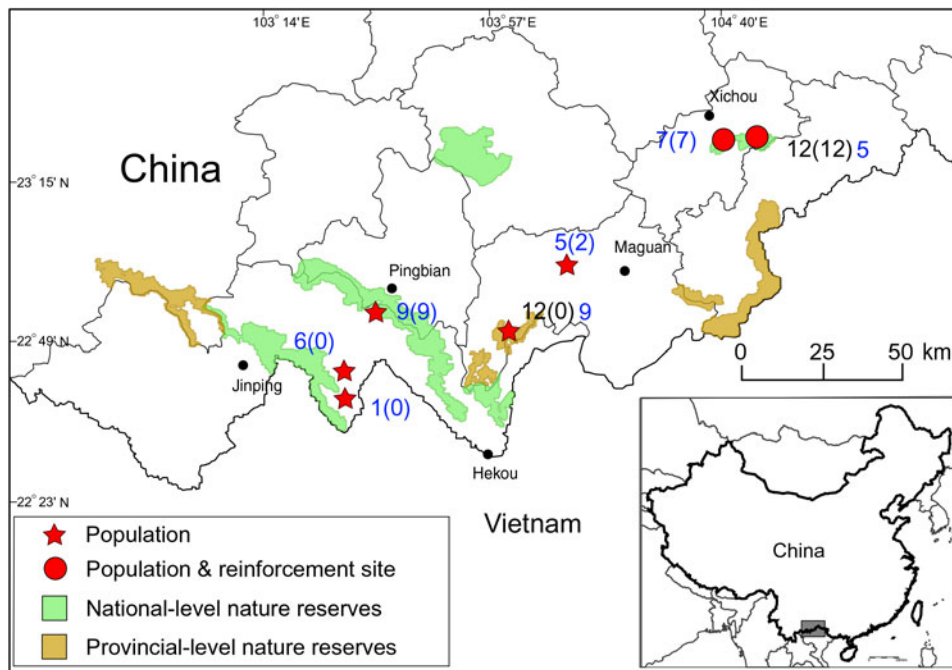


FIG. 1 Known locations of *Magnolia sinica* in China, with the total number of individuals at each location and, in parentheses, the number of these that are within nature reserves. New records are indicated in blue, and previously known populations in black. The shaded rectangle on the inset shows the location of the main map in China.

<2.5 cm), III (DBH 2.5–7.5 cm), IV (DBH 7.5–22.5 cm), V (DBH 22.5–45 cm), VI (DBH 45–67.5 cm), VII (DBH 67.5–100 cm) and VIII (DBH \geq 100 cm). There was considerable variation in size, implying differences in age. There were no seedlings near those adult trees that could have produced seeds (Fig. 2). The height of adult trees (V–VIII) was 13–42.6 m, and DBH was 25.5–127 cm; the height of immature trees (III–IV) was 4–15 m, and DBH was 5–20 cm. Our revision of the floral traits of *M. sinica* is provided in Supplementary Material 1.

Magnolia sinica in Kunming Botanical Garden can be traced to a single introduction event in 1983. Of the 10 individuals introduced to the garden in 1983 for ex situ conservation the first flowering (of an individual 13 m in height) occurred in March 2013. During the flowering period (March–April) in 2013 we performed bagged pollination treatments to assess seed-set from self-pollination ($n = 6$ flowers) and outcrossing (cross-pollination with pollen from a wild tree in Jinping County, $n = 2$ flowers); as a control 10 flowers were untreated and accessible to natural pollinators. None of the flowers open to pollinators produced any fruit, whereas all hand-pollination experiments showed seed-set of 14.29–60.42% (calculated as the number of successfully fertilized ovules producing seed relative to the total number of ovules per flower). The eight follicles that resulted from the pollination experiments contained a total of 154 seeds. At least some of these seeds were viable, as several germinated after incubation in humid sand for 6 months.

Seeds were collected for ex situ conservation and propagation from four trees at the type locality in Fadou village, Xichou County, in 2004 (Batch 1) and in 2005 (Batch 2; Zhang et al., 2014). Both batches of seeds were sown in a

nursery affiliated with Kunming Botanical Garden. After 2 years of nursery growth 100 saplings of each batch were transplanted to Shangchang (SC1 and SC2) and another 100 saplings of each batch to Xiaoqiaogou (XQG1 and XQG2). These two reinforcements were monitored by local rangers, who recorded the height, basal diameter and crown breadth of the saplings. Saplings were also transplanted to Kunming Botanical Garden, batch 1 (KBG1) after 3 years of nursery growth and batch 2 (KBG2) after 6 years of nursery growth, and both batches were monitored to record annual growth. Beginning in June 2012 we measured the growth of batches KBG1 (45 individuals) and KBG2 (22) annually. In June 2013 the survival rate of both batches was 100%. In 2013 the numbers of surviving individuals at the reinforcement sites were 20 (SC1) and 18 (XQG1) after 6 years, and 21 (SC2) and 23 (XQG2) after 5 years. We believe that the low survival rate of these two batches of reintroduced seedlings is attributable to inappropriate handling of the saplings during transplanting (c. 48% of the saplings were planted directly without removing the plastic bags in which they had been grown, thus hindering the young plants from taking root). The annual increments of height, basal diameter and crown breadth are in Supplementary Table S1.

Although the species is protected at the national level as well as locally in Yunnan, it is on the brink of extinction in the wild. The low number of saplings and young trees is limiting the potential for regeneration, and the surviving individuals all occur in remnant populations that are fragmented and comprise too few individuals for natural recovery. As *M. sinica* is unlikely to recover naturally, effective conservation of this species requires intervention.

TABLE 1 Records of *Magnolia sinica* in the wild, with locality, geographical coordinates, altitude, and number of individuals in categories III–IV (DBH 2.5–7.5 cm and 7.5–22.5 cm, respectively) and V–VIII (DBH 22.5–45 cm, 45–67.5 cm, 67.5–100 cm and ≥ 100 cm, respectively).

Localities (village/reserve, county) ¹	Geographical coordinates	Altitude (m)	No. of individuals	
			Category III–IV	Category V–VIII
Wenshan Zhuang & Miao Autonomous Prefecture				
Fadou, Xichou ³	23°21'37"–23°22'43"N, 104°45'59"–104°47'16"E	1,490–1,573	4	6
Pingzhai, Xichou ²	23°21'17"–23°21'18"N, 104°46'46"–104°46'47"E	1,366	1	1
Xiaoqiaogou, Xichou ²	23°21'43"–23°21'44"N, 104°41'57"–104°42'02"E	1,528–1,584	1	4
Heba, Xichou ²	23°21'24"–23°21'37"N, 104°41'28"–104°41'58"E	1,572–1,639	0	2
Dalishu, Maguan ²	23°01'54"–23°02'44"N, 104°12'21"–104°13'30"E	1,605–1,707	1	4
Miechang, Maguan ⁴	22°51'15"–22°51'48"N, 104°01'19"–104°02'38"E	1,420–1,509	2	8 + 2 ⁵
Honghe Hani & Yi Autonomous Prefecture				
Daweshan, Hekou/ Pingbian ²	22°54'00"–22°55'41"N, 103°37'51"–103°40'52"E	1,403–1,570	0	5 + 4 ⁵
Maandi, Jinping ²	22°40'27"–22°46'32"N, 103°29'50"–103°32'26"E	1,339–1,437	0	7

¹The individuals in Xichou are all in nature reserves. Two individuals in Dalishu, Maguan are in state-owned forest. The individuals in Hekou are all in non-commercial forest.

²New records

³Records include seven previously known individuals

⁴Records include three previously known individuals

⁵Based on information provided by local people

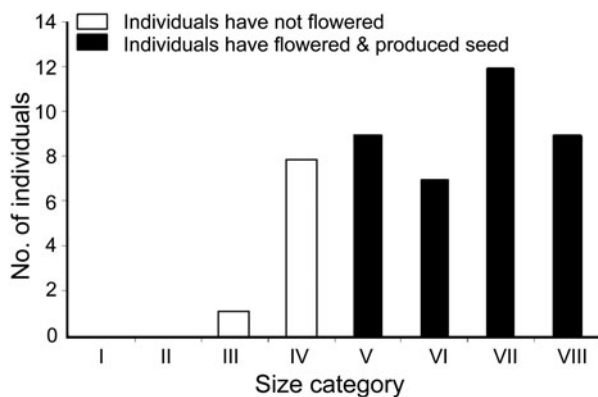


FIG. 2 Numbers of wild *M. sinica* individuals in each of eight size categories, defined in the text. Information provided by local people about six individuals is not included.

We therefore propose two groups of measures to protect *M. sinica*: (1) in situ conservation, population monitoring, and public engagement, and (2) ex situ conservation with reinforcement or reintroduction.

(1) Many of the individuals remaining in the wild (22 of 52, in three populations) are outside protected areas, and therefore expansion of reserves or establishment of new sites for in situ conservation is necessary (Shen et al., 2013). Local governments and nature reserves could limit any further habitat destruction by reducing cultivation of amomum, rubber and banana, which are grown in former *M. sinica* habitat, and renaturalization of farmland could create new habitat for reinforcement or reintroduction. To bridge the gap between scientific research and public

education, establishing better cooperation between local governments and research institutes, including universities and environmental organizations, is needed for long-term monitoring and research and to develop strategies for the conservation of *M. sinica*.

(2) The seeds cultivated in Kunming Botanical Garden and used for reinforcement of wild populations were from only one site (Xichou). It is essential to collect seeds from other sites and individuals to increase the genetic diversity of the seed pool for further ex situ conservation and for reinforcement or reintroduction (Ren et al., 2014). One of the criteria for judging the success of ex situ conservation is whether the transplanted plants can produce offspring (Law et al., 1997), and *M. sinica* has done so in Kunming Botanical Garden.

Acknowledgements

We gratefully acknowledge Yuan Zhou, Jing Yang, Tiancai Bo, Wulong Jiang, Guoyun Li, Hongliang Liu, Li Ma, Enjun Wang, Yongjun Wang, Ziqing Yuan, Xiangyuan Zeng and Yingliang Zhao for their help during fieldwork, Fauna & Flora International, Botanic Gardens Conservation International, and the State Forestry Administration of China for their support for this study, the local forestry authorities (including Maguan, Xichou, Hekou and Jinping) for assistance in field work, all interviewees for their valuable information about the distribution of *M. sinica*, Drs Tobias and Jane Marczewski for reviewing the text and for drafting Fig. 1, two anonymous reviewers for their invaluable comments and suggestions, and Xingfeng Zhao for providing

photographs. This study was supported by the National Science Foundation of China–Yunnan (Grant no. U1302262 to WS).

References

- CHAMBERS, R. (1994) The origins and practice of participatory rural appraisal. *World Development*, 22, 953–969.
- CHAMBERS, R. (2007) *From PRA to PLA and Pluralism: Practice and Theory*. Working Paper 286. Institute of Development Studies, Brighton, UK.
- CICUZZA, D., NEWTON, A. & OLDFIELD, S. (2007) *The Red List of Magnoliaceae*. Fauna & Flora International, Cambridge, UK.
- LAW, Y.W. (1979) A new genus of Magnoliaceae from China. *Acta Phytotaxonomica Sinica*, 17, 72–74.
- LAW, Y.W. (1996) Magnoliaceae. In *Flora Reipublicae Popularis Sinicae*, pp. 106–108. Science Press, Beijing, China.
- LAW, Y.W. (2006) Magnoliaceae. In *Flora Yunnanica*, pp. 14–16. Science Press, Beijing, China.
- LAW, Y.W., ZHOU, R.Z. & ZENG, Q.W. (1997) Ex-situ conservation of Magnoliaceae including its rare and endangered species. *Journal of Tropical and Subtropical Botany*, 5, 1–12.
- MA, Y.P., CHEN, G., GRUMBINE, R.E., DAO, Z.L., SUN, W.B. & GUO, H.J. (2013) Conserving plant species with extremely small populations (PSESP) in China. *Biodiversity and Conservation*, 22, 803–809.
- REN, H., JIAN, S.G., CHEN, Y.J., LIU, H., ZHANG, Q.M., LIU, N. et al. (2014) Distribution, status, and conservation of *Camellia changii* Ye (Theaceae), a Critically Endangered plant endemic to southern China. *Oryx*, 48, 358–360.
- REN, H., ZHANG, Q.M., LU, H.F., LIU, H.X., GUO, Q.F., WANG, J. et al. (2012) Wild plant species with extremely small populations require conservation and reintroduction in China. *Ambio*, 41, 913–917.
- SHEN, S.K., WANG, Y.H., ZHANG, A.L., WU, F.Q., JIANG, L.J. & JIANG, L.N. (2013) Conservation and reintroduction of a Critically Endangered plant *Euryodendron excelsum*. *Oryx*, 47, 13–18.
- STATE FORESTRY ADMINISTRATION OF CHINA (2012) *The Saving and Conservation Program on Extremely Small Populations in China*. Unpublished report. State Forestry Administration of China, China. [In Chinese]
- SUN, W.B., ZHOU, Y., LI, X.Y., YANG, H.B. & TAO, P.Y. (2012) Population reinforcing program for *Magnolia sinica*, a critically endangered endemic tree in southeast Yunnan province, China. In *Plant Reintroduction in a Changing Climate* (eds J. Maschinski & K.E. Haskins), pp. 65–69. Island Press, Washington, DC, USA.
- UPJOHN, M.M., ATTWOOD, G.A., LEROTHOLI, T., PFEIFFER, D.U. & VERHEYEN, K.L.P. (2013) Quantitative versus qualitative approaches: a comparison of two research methods applied to identification of key health issues for working horses in Lesotho. *Preventive Veterinary Medicine*, 108, 313–320.
- WANG, S. & XIE, Y. (2004) *China Species Red List*. Volume 1. Higher Education Press, Beijing, China.
- XIA, N.H., LIU, Y.H. & NOOTEBOOM, H.P. (2008) Magnoliaceae. In *Flora of China*, pp. 48–91. Science Press, Beijing, China & Missouri Botanical Garden Press, St. Louis, USA.
- ZHANG, A.L., SHEN, S.K. & WANG, Y.H. (2014) Conservation and reintroduction of the Vulnerable plant *Apterosperma oblata* in China. *Oryx*, 48, 170.
- ZHENG, Y.L., SUN, W.B. & ZHAO, X.F. (2008) Seed dormancy and germination of *Manglietiastrum sinicum* Law, a globally critical endangered plant in China. *Plant Physiology Communications*, 44, 100–102.

Biographical sketches

BIN WANG has a particular interest in seed ecology and conservation of threatened endemic plants, especially of the family Magnoliaceae. YONGPENG MA's main research interest is the evolutionary significance of natural hybridization. GAO CHEN's main research interest is the relationships between plants and insects. CONGREN LI carries out field investigations that focus on introducing and cultivating seedlings of threatened endemic plants. ZHILING DAO and WEIBANG SUN's main research interests are in conservation biology.