Conserving our global botanical heritage: The PSESP plant conservation program

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Abstract

It is a fundamental truth of ecology that most species are rare. And this rarity extends beyond measures of abundance to geographic distribution. In a global context, very few species are truly abundant, and most are more or less restricted geographically. In the world of plants, where there are several hundred thousand species, the number of species with especially small population sizes and small fragmentary ranges is extremely large. One recent assessment, the most exhaustive undertaken so far, based on 200 million observations taken from herbarium records, ecological surveys and other sources, suggests that of the more than 400,000 species of land plants, ca. 36% are “exceedingly rare” (Enquist et al., 2019). In the very long “tail” of plant species with increasingly small range sizes, many species persist as only a very small number of individuals. As such, in a rapidly changing world, those species are at great risk of extinction. An entire population, perhaps the only population of the species, could be wiped out by a single detrimental event. The risks of such events come not only from direct human-induced habitat destruction or degradation, but also from more subtle effects, often driven or exacerbated by indirect human influences: for example, forest fires, the spread of new pathogens, and of course, climate change. Species with extremely small populations are precisely the ones most in need of urgent conservation action, and in China it is these species that are the focus of the “Plant Species with Extremely Small Populations” (PSESP) program. The goal of the PSESP program, first developed and implemented in 2005 in Yunnan Province, is to try to secure a long-term future for these plants in peril (Ma et al., 2013; Sun, 2013; Sun, 2016; Sun et al., 2019a, b; Yang et al., 2020).

Conservation biology is a discipline replete with difficult choices. How much emphasis should be devoted to influencing policy, rather than conservation action on the ground? What should be the balance between habitat conservation, and species conservation? What are the relative merits of in situ and ex situ approaches to conservation? The answer, of course, is that all these approaches are necessary, have different advantages and disadvantages, and the pursuit of one does not preclude the vital importance of attending to the others. The PSESP program shows how these approaches can be integrated, while also ensuring that high-quality research can be melded with practical conservation action. Too often, conservation research that is elegant in theory has a little practical value, while much well-meaning conservation action is not informed by the best science. The PSESP program breaks down these barriers in seeking to balance and pursue a range of conservation interventions, while adopting best practices in research and conservation action, to create more successful conservation outcomes.

Close integration of in situ and ex situ approaches to plant species conservation is a hallmark of the PSESP program. The program has a robust ex situ component, that builds on and extends the pioneering work of Kunming Institute of Botany in germplasm banking of wild species (Cai, 2015). However, this ex situ effort is an adjunct to, rather than a replacement for, in situ conservation. The highest priority of the PSESP program is to ensure that the target species are protected in their native habitats as part of ecological communities that are as intact as possible and that can continue to provide diverse ecosystem services. The intimate connections of these plant species with other organisms, from microbes and insects to birds and mammals, are very incompletely understood. It is therefore vital that everything should be done to ensure the survival of plant species with extremely small populations in the wild.
Effective in situ plant conservation cannot be done from the laboratory, it requires more than genetic profiles and sophisticated models. It must be based fundamentally on detailed field-based knowledge of the plants, and the ecological conditions where they grow. Fieldwork is therefore an important component of the PSESP program. Active field research is a prerequisite for assessing and understanding the condition of plant species in the wild, including, for example, the effectiveness of seed set and natural recruitment. Field observations also allow the basic features of population structure to be assessed, to inform the conservation genetics of recovery programs as well as the design of sampling strategies for ex situ conservation.

At the same time, creation of ex situ collections is vital to bring living specimens into cultivated safe havens, most often botanical gardens, where their future can be assured and where they can be available for research, public outreach and educational programs at all levels. It is also critical to understand whether long term storage as seed is possible, or whether alternative strategies are needed. Research on seed biology also facilitates the development of appropriate germination and propagation protocols: crucial information for successful re-introduction and restoration programs. Bringing rare plants into cultivation is also important for exploring appropriate germination and propagation protocols: crucial information for successful re-introduction and restoration programs.

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and understanding the condition of plant species in the wild, includ-

As an evolutionary biologist and plant paleontologist it is also

significant for me, and I believe important for all of us, that among

the species that are the focus of the PSESP program are several for

which there is clear paleobotanical evidence of a long history

measured in many millions of years (e.g., Crane, 2013; Dong et al.,

2020) and the plant communities of which they are part also

appear to have deep geological roots, including in southwest China

(Linnemann et al., 2018). Many of the species that are the focus of

PSESP program are probably of relatively recent origin, may never

have been native outside eastern Asia, and perhaps were never

abundant. Such species are nevertheless important from multiple

perspectives. But species that have survived for thousands of

millennia, were once widespread across the Northern Hemisphere,

and survive today only in China, are a special part of the shared

natural heritage of humankind. In such instances, the attention that

the PSESP program brings to these species is especially important.

The PSESP program underpins China’s role as the global guarantor

of the long-term future of plant species that were here long before

people came to dominate this planet. Reflecting on these ancient

species should engender a degree of humility while encouraging us
to think more carefully about calibrating our impacts on the natural

world (Crane, 2013).

There are many plant species in China that once had more widespread distributions and that were no doubt once much more abundant. Among the 595 genera that are endemic to East Asia, critical review reveals 54 that are known reliably from the fossil record outside East Asia. Almost all are woody plants (Manchester et al., 2009), reflecting the pervasive taphonomic bias toward woody plants in the fossil record. The number would likely be higher if equivalent paleobotanical knowledge were available for herbaceous species endemic to East Asia. Many of the 54 genera are mono- or oligotypic reflecting their systematic and evolutionary distinctiveness. About a quarter of these ancient plants are gymnosperms, such as Ammonitaxus, Cathaya, Cephalotaxus, Cryptomeria, Cunninghamia, Glyptostrobus, Ginkgo, Metasequoia, Pseudolarix, Sciadopitys, and Taiwania, but the remainder are angiosperms, such as Ceridiphyllum, Craugia, Cyclocarya, Davidia, Dipelta, Dipteronia, Eucommia, Koelreuteria, Paulownia, Platycarya, Sargentodoxa, Tapiscia, Tetracentron, Trapella, and Trochodendron. Some of these genera, for example Cunninghamia, are reasonably common, even in habitats with considerable human impacts, and are of little conservation concern. Others, such as Ginkgo biloba and Metasequoia glyptostroboids are rare or endangered in the wild but widely cultivated, including as street trees in urban settings. As such they are buffered, at least in part, from the risk of total extinction.

While the future of both Ginkgo and Metasequoia is assured, at least as cultivated plants, other “living fossils” that were once widespread have a much more uncertain future. With very restricted distributions, and extremely small populations, several are now receiving much needed attention as part of the PSESP program. For example, among the China’s National List of 120 PSESP species of most concern (Sun, 2013) are the monocot conifers Cathaya argyrophylla and Glyptostrobus pensilis, as well as the angiosperms Craugia yunnanensis and Dipteronia dyerana. All have a fossil record that clearly documents their formerly widespread distribution in the Northern Hemisphere and an evolutionary history of several tens of millions of years. The PSESP program highlights the perilous situation of these species (Sun, 2013).

C. argyrophylla (Pinaceae) is among China’s most endangered plant species (Wang et al., 2012). Now restricted to small scattered populations in the mountains of Guangxi, Chongqing, Guizhou and Hunan, Cathaya once existed both in North America and Europe, where it is known not only by its distinctive fossil pollen grains but also well-preserved fossil cones and leaves (Manchester et al., 2009). Based on recent assessments, less than 4000 mature individuals of Cathaya survive in the wild and the remaining populations show low genetic variation and fertility, as well as poor germination and recruitment rates (Xie and Chen, 1999). Only discovered in 1955, Cathaya is also not well represented in ex situ collections. Work is underway to expand ex situ collections, as well as to protect and reinforce the remaining populations in the wild (Wang et al., 2012).

The Chinese swamp cypress, G. pensilis (Cupressaceae), was once common in the Pearl River Delta, but has undergone a dramatic decline over the past 50 years and is now critically endangered throughout China (Chen et al., 2016). During the Cenozoic, Glyptostrobus was common and widespread in the Northern Hemisphere, as documented by a very extensive and well-studied fossil record in both North America and Europe (LePage, 2007; Manchester et al., 2009). A recent assessment of living Glyptostrobus in southern China documented 42 wild occurrences, 17 of which were single individuals that were often in poor health (Chen et al., 2016, 2017b). Only five populations had more than 10 individuals. Current estates suggest that only around 350 individual trees of Glyptostrobus exist in China, with around 120 individuals in Vietnam and 300 individuals in Laos (Ruijiang Wang, personal communication). The major threat to Glyptostrobus is anthropogenic impacts on the wetlands in which it lives. So, in addition to efforts to improve the survival of the remaining individuals and better understand their conservation genetics, attempts to secure a long-term future for the species under the PSESP program include strengthened ex situ germplasm collections and raising large numbers of saplings for planting in urban wetlands (Chen et al., 2016).

Like the Chinese endemics Cathaya, Metasequoia and Platycarya, the malaveaceous tree C. yunnanensis is among that group of plant species that were recognized as fossils before the living plants were known to western science. Craugia, recognized in the fossil record based on fruits with associated foliage, has an extensive record from both western North America and Europe (Kvacek et al., 2005). Today, however, Craugia survives only as an extremely rare tree confined to only 19 small populations in Yunnan (less than 250
individuals) and perhaps as remnant populations in adjacent northern Vietnam (Yang et al., 2016; Weibang Sun personal communication). The remaining populations are threatened by clearance for agriculture and in 2007 survey the smallest Yunnan population contained only six mature trees, while the largest contained 167 (Gao et al., 2010). Another survey reported broadly similar numbers in the six populations (11–173 individuals). A second species, Craigia kwangsiensis described from Guangxi (Hsu, 1975), is probably already extinct as result of deforestation (Kvacek et al., 2005; Tang et al., 2007). Integrated conservation under the PSESP program has involved clarifying the genetic structure of the remnant populations, establishing ex situ collections, and growing plants for reintroduction (Yang et al., 2016).

The maple relative, Dipteronia (Sapindaceae) includes two very similar living species that together comprise the monophyletic sister group to the much larger genus Acer that has over 150 species (Feng et al., 2019). Dipteronia sinensis is distributed relatively widely in central China and is regarded only as ‘near threatened’ according to China’s Species Red List (Wang and Xie, 2004). In contrast, Dipteronia dyeriana is restricted to an area of only ca. 6 km² in southeastern Yunnan, where it is known from only five natural populations (Chen et al., 2017a). It is apparently locally extinct elsewhere in Yunnan and nearby Guizhou (Zhang, 2000; Su et al., 2006). The distinctive schizocarpic winged fruits of Dipteronia are known as fossils from the Eocene of western North America, but not so far from Europe (McClain and Manchester, 2001; Manchester et al., 2009). The PSESP approach for D. dyeriana has been to establish ex situ living collections in the Kunning Botanical Garden (where the tree flowered and fruited in 2018) and to undertake population reinforcement, as well as reintroduction and restoration near the native populations (Sun et al., 2019b).

By their very nature, plant species like C. argrophylla, C. yunnanensis, D. dyeriana and G. pensilis, known from only a limited number of individuals, over a very narrow geographic range, are highly susceptible to rapid changes in their environment resulting from natural causes or from human interference. They need our help and they bring into sharp relief the similarly threatened future of other Chinese endemic plants in landscapes heavily altered by human activity. The analysis of “biodiversity hotspots by Myers et al. (2000), based partly on levels of threat but also to a very large extent on patterns of endemism of plant species, identified south-central China and Indo-Burma as a priority area for conservation. A more recent summary of the global distribution of plant species also identified Southwest China and adjacent areas as one of a dozen global hotspots where rare species are especially concentrated (Enquist et al., 2019).

The extent to which the rare plant species in the other hotspots around the world are recent local or regional novelties, or relictual, remains to be determined, but in the case of southern and central China there is clear evidence that a significant proportion of the woody endemics, like C. argrophylla, C. yunnanensis, D. dyeriana and G. pensilis, are survivors from populations and lineages that were once much more widespread. Long term climatic stability and regional habitat complexity, with the concomitant reduced risk of extinction, seems to have been important in facilitating their survival. The key question for the future is how these areas will fare as global climate change accelerates? By one estimate, these areas will experience rapid and significant change at a magnitude greater than that between the last glacial maximum and the present, adding further urgency to species conservation efforts (Enquist et al., 2019).

The situation for the long-term survival of these species is further complicated by more direct human impacts, and especially land use change, which is inimical to the long-term survival of plant species with extremely small populations. Intensifying anthropogenic activity facilitates increases in abundance and range size expansion of the weedy species that flourish in the disturbed habitats created by people. To a first approximation, all over the world, plant communities are “becoming dominated by the same species everywhere,” but “losing their distinctive, narrow-ranged species” (Newbold et al., 2018). In the inexorable homogenization of global biodiversity, biodiversity loss is manifested most obviously and most consistently by the disappearance of rare species. Against this background, conservation action in the world of plants, must have a focus on the long-term future of rare species, through programs such as PSESP. The goal should be to save these species wherever and whenever possible in the wild, and thereby preserve the full range of ecosystem services provided by the communities of which they are part, but it also makes sense to take out the insurance that ex situ conservation provides. Ensuring a secure long-term future for plants like C. argrophylla, C. yunnanensis, D. dyeriana and G. pensilis, will allow us to enjoy them, study them, understand them, and sometimes use them.
beyond this we will have done the right and moral thing. These plants have important intrinsic value. They encapsulate millions of years of evolutionary history, set against which the geological longevity of our own species is merely the blink of an eye. The long paleontological history of these and similar plants across the Northern Hemisphere underlines that in a very real sense, they are a gift of the world to China. By ensuring their continued survival, including through the work of the PSESP and similar efforts, China is making an equally real, tangible and important gift in return.

Declaration of Competing Interest

None.

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