1-2014

Getting Plant Conservation Right (or Not): The Case of the United States

Kayri Havens
Chicago Botanic Garden

Andrea T. Kramer
Chicago Botanic Garden

Edward O. Guerrant Jr.
Portland State University, guerran@pdx.edu

Citation Details

Havens, K., Kramer, A. T., & Guerrant Jr., E. O. (2014). Getting Plant Conservation Right (or Not): The Case of the United States. International Journal Of Plant Sciences, 175(1), 3-10. doi:10.1086/674103

Int. J. Plant Sci. 175(1):3–10. 2014.

1058-5893/2014/17501-0002$15.00 DOI: 10.1086/674103

GETTING PLANT CONSERVATION RIGHT (OR NOT): THE CASE OF THE UNITED STATES

Kayri Havens,[1,*] Andrea T. Kramer,* and Edward O. Guerrant Jr.†

*Chicago Botanic Garden, 1000 Lake Cook Road, Glencoe, Illinois 60022, USA; and †Portland State University, P.O. Box 751-ESM, Portland, Oregon 97207, USA

Editor: Patrick S. Herendeen

Effective plant conservation includes addressing basic needs such as information about species distribution and rarity; research, management, education, and training capacity to mitigate threats facing threatened species; policy and funding to support continued capacity and conservation; and, ultimately, a public that understands and supports the importance of plants and the need for their conservation. Coordination of plant conservation efforts is also needed to ensure that resources and expertise are used in a strategic, efficient, and effective manner. We argue that no country is currently getting plant conservation right; plants are becoming increasingly rare around the world. Plants are often not fully protected by policy, their conservation is underfunded, and their importance is underappreciated. However, some countries have progressed further than others. Here we outline areas where the United States is strong and highlight components that need work to meet the country's plant conservation needs.

Keywords: botanical capacity, Global Strategy for Plant Conservation, policy and funding.

Introduction

There is no one formula for effective nationwide plant conservation, but there are elementary needs that need to be addressed. These include (1) accessible, up-to-date information on species distribution and rarity; (2) the ability to mitigate threats making plants rare (including policy, as well as in situ and ex situ conservation and research); (3) education and training to make sure everyone involved in actions that affect plant conservation are informed and able to make the best decisions; (4) funding to maintain and grow the infrastructure for plant conservation; and (5) effective communications so that plants (and their conservation) are valued and supported by the public. There is also a more subtle, overarching need for coordination and a framework for action for all of these efforts so that they can be strategic, efficient, and effective. We argue that no country has the recipe for plant conservation figured out, as plants are becoming increasingly rare around the world, threatened by habitat loss, fragmentation, climate change, and the continued introduction of new invasive species. However, some countries have progressed further than others. Here we outline areas where the United States is strong and can provide a model for other countries as well as areas where it needs work in order to meet its plant conservation needs.

[1] Author for correspondence; e-mail: khavens@chicagobotanic.org.

Manuscript received July 2013; revised manuscript received September 2013; electronically published December 6, 2013.

The Setting and Players

In the United States, there are more than 17,000 species of native vascular plants. In addition, more than 4000 nonnative plant species are found outside cultivation, many of which are weedy or invasive. Approximately one-third of the US native flora is considered threatened (query of NatureServe 2012) and may require conservation action to recover and persist. Plant conservation in the United States involves a large array of federal, state, and local agencies; nongovernmental organizations (NGOs); and academic institutions. These organizations work independently and (ideally) collaboratively, each playing a different role and holding different responsibilities but all supporting important capacity needed to preserve the nation's natural heritage. A recent project assessed current and future botanical capacity (both human and financial resources) in the United States, in order to understand the resources available to conserve and manage native plant species and habitat, identify gaps, and recommend ways to address gaps in the future. The Botanical Capacity Assessment Project (available at http://www.bgci.org/usa/bcap/), carried out by Botanic Gardens Conservation International US and Chicago Botanic Garden, found that many important components of botanical education, research, and management are lacking across government, academic, and private sectors. Surveys revealed severe shortages of botanists at government agencies, a wave of upcoming retirements, and an alarming decline in botanical degree programs and course offerings at the nation's colleges and universities. In addition, plant conservation is woefully underresourced in comparison with animal conservation efforts. Private-sector organizations, especially botanic gardens, are helping to fill some of

Table 1

Comparison between the Six Strategies (A–F) of the US Plant Conservation Alliance's (PCA) National Framework for Progress and Targets 1–16 of the Global Strategy for Plant Conservation (GSPC)

Objective	PCA National Framework for Progress (developed 1995)	GSPC (agreed 2002; updated 2010)
Grow partnerships and resources	A. Build partnerships to cooperatively share resources and talents	15. Increase trained plant conservation staff and facilities 16. Strengthen plant conservation networks (national, regional, international)
Connect people and plants	B. Raise awareness about the importance of plant diversity and the need to conserve it	14. Promote education and awareness about plant diversity and the need for its conservation
Conserve natural resources	C. Promote ecosystem management to conserve and restore native plant communities	4. World's ecological regions secured (15%) 5. High plant diversity areas protected (75%) 7. Threatened species conserved in situ (75%) 8. Threatened species in ex situ (75%) and available for recovery programs (20%) 10. Manage invasive species to prevent and mitigate damage
Encourage research	D. Encourage scientific research and technological development	3. Develop and share information, research, and methods necessary to implement the strategy
Promote sustainability	E. Determine and encourage appropriate and sustainable use of native plants; document indigenous knowledge	6. Production lands managed sustainably (75%) 9. Conserve crop genetic diversity (70%) 11. No endangerment from international trade 12. All wild-harvested plant-based products sustainable 13. Maintain/increase indigenous knowledge and practices
Gather, maintain, and share data	F. Coordinate and promote data sharing and compatible, economical, and efficient databases	1. Online flora of all known plants 2. Assess conservation status of all known species

Note. Adapted from Kramer (2010).

these gaps but need to work strategically with all NGO, community, government, and industry sectors to ensure their sustainability into the future and to build capacity (Kramer et al. 2010).

Coordination and Strategic Framework

On a global level, a framework for plant conservation is provided by the Global Strategy for Plant Conservation (GSPC), a program of the Convention on Biological Diversity (CBD), which was originally adopted in 2002 and updated in 2010 (Sharrock 2012). The adoption of the GSPC was groundbreaking because it was the first time plant conservation received detailed attention by the governments of the world (193 countries are party to the CBD). The national priorities for plant conservation in the United States, as outlined by the Plant Conservation Alliance (PCA), align well with the GSPC's goals and objectives (table 1; Kramer 2010). The PCA is a consortium of 10 federal government member agencies and ~300 nonfederal cooperators representing various disciplines within plant conservation. In 1995, the National Framework for Progress in Plant Conservation was developed collaboratively by the PCA and more than 90 participants from all sectors across the United States (http://www.nps.gov/plants/strategy.htm).

The national framework consists of six broad strategies with 30 supporting goals for implementing plant conservation at national, regional, and local levels. Developing metrics and methods to measure progress toward the goals outlined in the national framework has proved challenging, as plant conservation work takes place in a wide range of sectors and government agencies. Coordination and communication often occurs on a species-by-species or region-by-region basis, with the full nationwide picture difficult to assess. In an attempt to resolve this, a nationwide survey was carried out in 2011 to help identify the most significant gaps in capacity to carry out the national framework's goals and to determine how well the national framework and other PCA resources incorporate and support current plant conservation activities in the United States. Nearly 400 individuals, representing all sectors, responded to the survey. Results revealed the important and unique role the PCA plays in facilitating communication and coordination and identified significant gaps in capacity to communicate via the media, document and protect indigenous knowledge and collection sites, and share data (Kramer 2011).

Documentation of Plant Abundance and Diversity

Fundamental to plant conservation activities is knowledge about where plant species occur and how rare they are. There are a variety of ranking systems used to assess the rarity of plant and animal species. In the United States, NatureServe (an NGO that represents a consortium of biological inventory programs active in all US states, Canada, Latin America, and the Caribbean) undertakes much of this work. NatureServe provides location information and conservation rankings for both plants and animals, and this information is online and searchable (http://www.natureserve.org). NatureServe's global ranks range from critically imperiled (G1) to demonstrably secure (G5), based on rarity, trend, and threat(s). This status is assessed at three geographic scales: global (G), national (N), and state/province (S). The NatureServe ranking system is sim-

ilar in concept but has some differences from the International Union for Conservation of Nature (IUCN) red-listing procedure used in global assessments. IUCN Red List categories are "extinct" (EX), "extinct in the wild" (EW), "critically endangered" (CR), "endangered" (EN), "vulnerable" (VU), "near threatened," and "least concern." NatureServe is working with IUCN to standardize rating criteria where appropriate in order to facilitate data sharing (NatureServe 2012). NatureServe and IUCN ranks do not mandate any legal protections for threatened species in the United States.

For US native flora, NatureServe provides exponentially better data on species abundance and threat status than does the IUCN Red List. In 2012, 5935 species (32% of the US native flora) were identified as threatened by NatureServe (labeled either GX, "presumed extinct or extirpated"; GH, "possibly extinct or extirpated"; or G1–3), while only 5% of these (273 species) had been identified as threatened on the IUCN Red List (EX, EW, EN, CR, or VU; IUCN 2012*a*). This disparity between the number of country-identified threatened species and red-listed species is not unique to the United States (fig. 1). Due in large part to the work of NatureServe, the United States has a better understanding of the threat status of its flora than most other countries. Unfortunately, even the NatureServe data are not as robust as they need to be and in fact are likely becoming less robust over time, with element occurrences often out-of-date, missing, or incorrectly geocoded. This is largely a function of increasingly limited resources at the state natural heritage program level (Stein and Gravuer 2008; Kramer et al. 2010).

Herbaria are also excellent sources of plant location information; a recent trend has been to make specimen data available online, either singly, such as the New York Botanical Garden C. V. Starr Virtual Herbarium, or as consortia, such as the Consortium of Pacific Northwest Herbaria, the Consortium of California Herbaria, or vPlants, a virtual herbarium of the Chicago region. Many online herbaria have mapping capabilities and provide scanned images of herbarium sheets. In addition to location data, records from all of the above sources often provide population size, phenology information, associated species lists, and site information that can be helpful for ecological studies. Some virtual herbaria also provide species profiles and pictures of plants in their native habitats.

Mitigating Threats

Policy

In the United States, the Endangered Species Act (ESA) is arguably the most powerful piece of conservation legislation that aims to protect imperiled species and the habitats on which they depend. Nevertheless, plants and animals receive different protection under this law, dating back to a legal distinction in England, which considered animals to be property of the king and plants to be property of the landowner. Under the ESA, this distinction remains; plants, considered property of the landowner, are protected from "take" only on federal lands, whereas animals, considered property of the state, are protected on both public and private lands. Plant protection on state lands varies widely, and only 32 of 50 states have enacted any type of legal protection for plants (Stein and Gravuer 2008). In order to be legally protected by the ESA, a plant species must be listed as "endangered" or "threatened" by the US Fish and Wildlife Service or the National Marine Fisheries Service for marine plants. There are 796 plant species on the endangered species list that are protected from being harmed or killed on federal lands and from interstate or international trade. The ultimate goal of the law is to recover imperiled species to a point where they no longer need legal protection. Funding for species recovery is provided by the US Fish and Wildlife Service under the ESA, but the vast majority of funding goes to mammals, birds, and fishes and is therefore insufficient for virtually all plant species and less charismatic animal species.

In Situ Plant Conservation

In the United States, in situ plant protection varies depending on land ownership. Federal lands, including those managed by the Bureau of Land Management (BLM), US Fish and Wildlife Service, Forest Service, National Park Service, and Department of Defense, make up approximately one-third of the United States, and most are managed for "multiple use," including conservation, recreation, and in many cases extractive uses such as timber sales, oil and gas development, alternative energy development, and grazing. It is not uncommon for conflicts to arise between these multiple uses. Within federal

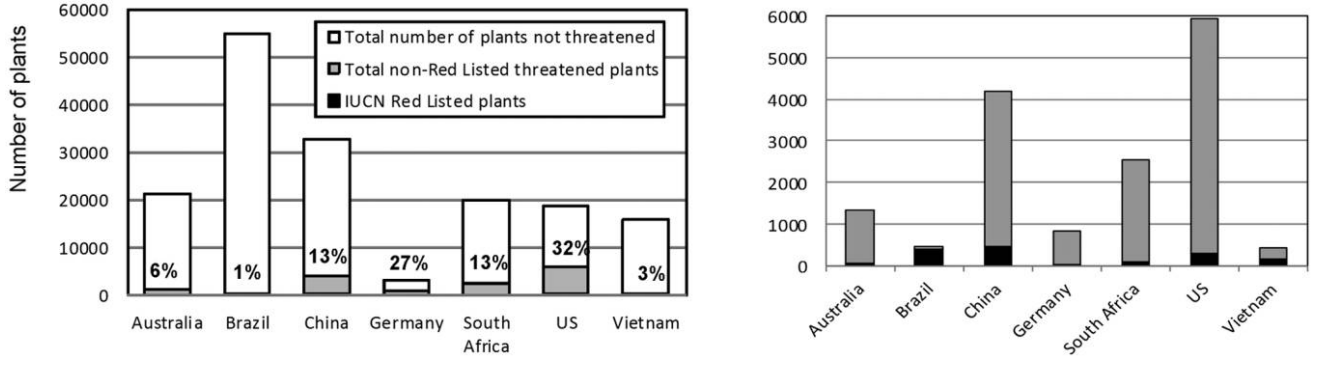

Fig. 1 Threatened flora of the United States in comparison with threatened flora of other countries. Percentages indicate the total number of identified threatened species.

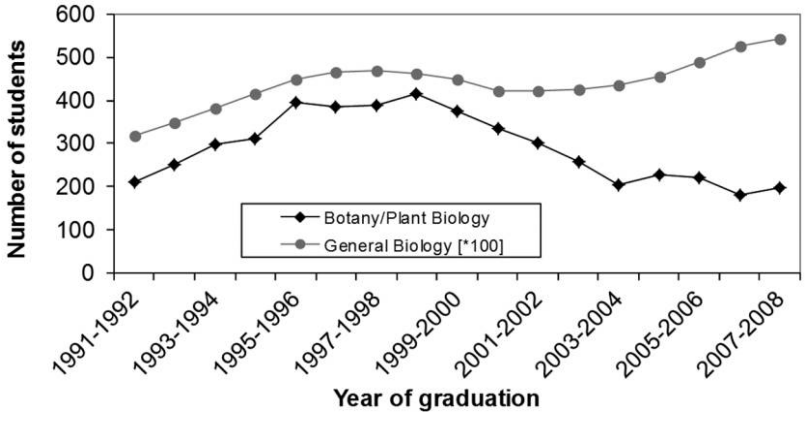

Fig. 2 Recent trends in botanical education in the United States, revealing a steady decline in botany majors and increase in general biology majors from 1991 to 2008.

agency land holdings, there are a subset of properties that are set aside specifically for conservation and compatible activities, such as the BLM's National Landscape Conservation System, the National Preserves of the National Park System, or the interagency National Wilderness Preservation System. State and local governments also maintain parks and other protected areas, as do some NGOs such as the Nature Conservancy and various land trust organizations.

Simply protecting land where threatened plant species occur is not sufficient for their long-term conservation. Even protected lands face the ever-present threats of climate change, invasive species, and often habitat fragmentation. Community-level management activities to address these threats can include removal of invasive species, prescribed fire, altering grazing regimes, seeding in native species to increase genetic and/or species diversity, and acquiring land to create corridors or stepping-stones between fragmented patches of habitat.

Invasive plant pests have also had an increased impact in recent years. In part due to increased global trade and in part due to climate change, plant pests are increasingly moving into new regions. From emerald ash borer (*Agrilus planipennis*) that is decimating ash (*Fraxinus*) species in the eastern and midwestern United States and Canada to sudden oak death (*Phytophthora ramorum*) impacting oaks (*Quercus* spp.), tanoaks (*Lithocarpus densiflorus*), and other taxa in the western states, these new pests are changing plant community structure and dynamics. The agency charged with managing these threats is the US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS), whose Plant Protection and Quarantine program safeguards agriculture and natural resources from the risks associated with the entry, establishment, or spread of animal and plant pests and noxious weeds (USDA APHIS 2012).

In terms of caring for the most imperiled plant species, federal agencies and state natural heritage programs have historically monitored the threatened species on their lands and continue to do so as staffing levels allow. However, a trend has emerged in recent years for citizen science groups, often organized and trained by botanic gardens, to assist in rare-plant monitoring efforts. One of the first such groups to do so is the New England Plant Conservation Program, led by the New England Wild Flower Society. This group, active since 1998, engages hundreds of plant conservation volunteers to monitor and manage rare plants in six states. Similar programs include Plants of Concern, managed by the Chicago Botanic Garden, and Rare Care, managed by the University of Washington Botanic Garden. With straightforward protocols and appropriate quality-control mechanisms, data quality from citizen science projects has been shown to be remarkably robust (Bonney and Dickinson 2012; Havens et al. 2012). Botanic gardens have also been extremely active in restoring threatened plant species declining in or lost from wild landscapes, typically in partnership with a land-managing agency. Rare-plant reintroductions have been carried out by many botanic gardens in the Center for Plant Conservation (CPC) network, a consortium of 38 gardens and arboreta dedicated to seed banking and reintroduction of rare plants. The CPC's work on reintroduction has resulted in two published volumes (Falk et al. 1996; Maschinski and Haskins 2012), which have contributed greatly to this young and evolving field.

Ex Situ Plant Conservation

Ex situ plant conservation can serve as an important supplement to in situ protection and management. The most common type of ex situ plant conservation is seed banking that has been practiced in an informal way, saving seeds of food plants, since the dawn of agriculture. Modern seed banks can trace their origins to the pioneering work of Vavilov (1926), who recognized the importance of crop landraces and their wild relatives for agriculture. To this day, most seed banks continue to focus on crops and crop wild relatives. However, the role of seed banking as a conservation tool for threatened plants was recognized only in the mid-1900s, shortly after anthropogenic threats to plant diversity were acknowledged (Maunder et al. 2004). Today, seed banking is undertaken for many purposes (Guerrant et al. 2014), including the conservation of economically important species, rare species, and whole floras. A recent report found that more than 21% of 9496 extinct, endangered, or vulnerable plant species native

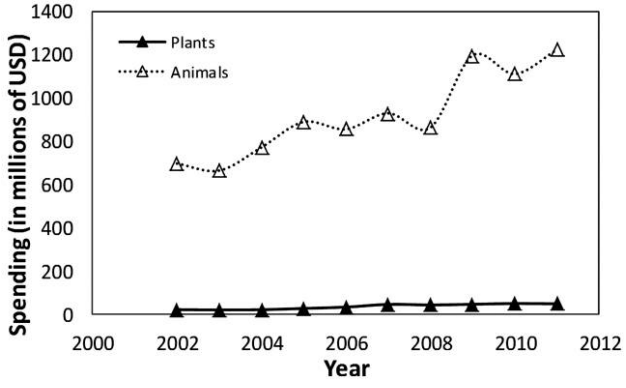

Fig. 3 Comparison of total endangered species spending, excluding land acquisition, from US federal and state governments for plants (filled triangles) versus animals (open triangles). Compiled from federal and state endangered and threatened species expenditure reports for 2002–2011 available at http://www.fws.gov/endangered/esa-library/index.html.

to North America (the United States, Mexico, and Canada) are maintained in ex situ seed bank collections in these countries (Kramer et al. 2011). In the United States, the largest seed bank is maintained by the US Department of Agriculture's National Center for Genetic Resources Preservation (NCGRP). Holding nearly a half million accessions, the NCGRP focuses on species of agronomic value. It also provides primary or backup storage facilities for the two national seed-banking networks focusing on native plant collections, Seeds of Success (SOS) and the CPC.

SOS, led by the BLM in partnership with six botanic gardens, zoos, and municipalities, has a mission to "collect, conserve, and develop native plant materials for stabilizing, rehabilitating and restoring lands in the United States" (http://www.blm.gov/wo/st/en/prog/more/fish__wildlife_and/plants/1.print.html). SOS members share a common collection protocol and work together to prioritize target species. To date, members have made more than 15,000 collections across the United States. A portion of each collection goes into long-term storage; the remainder is released as needed for research and development into crops to provide seeds for restoration efforts through the BLM's Native Plant Materials Development Program (NPMDP). The program was created by Congress in 2001 after a series of bad wildfire years, "to ensure a stable and economical supply of native plant materials ... for restoration and rehabilitation efforts on public lands" (NPMDP 2009, p. 9). Part of the NPMDP's goals included building sufficient capacity among federal agencies and private-sector partners to produce plants for at least 1000 native species important in restoration and to have sufficient quantities of these native seeds to provide for emergency stabilization following a 15-million-acre fire season. The BLM is the largest seed purchaser in the Western Hemisphere, often buying upward of 5 million pounds of seed each year (NPMDP 2009). At present, there are insufficient quantities of native species seed available, forcing agencies to use nonnative species in some cases. The NPMDP is also a private-sector enhancement program that benefits local growers and farmers who bulk up the seed for sale back to federal agencies and the restoration community in general.

The CPC is a network of botanic gardens focused on the ex situ conservation of nearly 800 of the nation's most imperiled species. It maintains the National Collection of Endangered Plants. Holdings are primarily in the form of banked seeds but also include living collections and tissue culture collections of species that are not amenable to seed banking. Some of the CPC's member institutions, most notably the Cincinnati Zoo and Botanical Garden and the University of Hawaii's Lyon Arboretum and Botanical Garden, have developed extensive expertise in micropropagation and cryopreservation of species difficult to seed bank. The CPC's member institutions conduct research on species in the national collection, including demographic, genetic, ecological, and horticultural studies. As mentioned earlier, many of the species have been reintroduced to the wild, and the CPC's work has contributed much to the science of rare-plant reintroductions.

Rare-plant reintroductions are most successful when areas of appropriate habitat exist. Increasingly, plant communities are degraded, invaded, or highly fragmented, and ecological restoration is necessary to provide a long-term sustainable context for threatened species. In recent years, the ever-increasing need for restoration has been recognized globally and has become a focus of land-managing agencies and botanic gardens alike. For instance, the US Forest Service recently pledged to restore 15 million hectares of forest and grassland habitat by 2020, and many other countries are making similar pledges (International Union for Conservation of Nature 2012*b*). The Ecological Restoration Alliance of Botanic Gardens, led by Botanic Gardens Conservation International, was launched in 2012 with a goal of restoring 100 sites on six continents in 20 years. Large-scale restoration goals such as these will require strategic partnerships between land-managing agencies; native-seed providers; botanic gardens with their core competencies in floristics, plant propagation, and ecology; and scientists who study ecological restoration.

Research

The need for research related to plant conservation has never been greater. From conserving and managing biodiversity and restoring ecosystems to addressing threats of climate change and invasive species, the need for botanical research is increasing. These critical needs coincide with a continuing loss or reduction of botany programs at many universities (Eshbaugh and Wilson 1969; Affolter 2003; Sundberg 2004). Botanical gardens are helping to partially fill this need, conducting research ranging from traditional systematics and floristics to applied conservation research. Many gardens are developing new techniques for seed banking, plant propagation and reintroduction, and habitat management and restoration. Botanical garden networks such as Botanic Gardens Conservation International and the CPC help coordinate activities between gardens (Wyse Jackson and Sutherland 2000). The federal government, particularly research departments in the US Geological Survey and the US Department of Agriculture Forest Service, also contributes significantly to plant conservation research, particularly in regard to issues related to large-scale habitat management and restoration, including seed transfer zone research. Recent surveys conducted by the Botanical Capacity Assessment Project identified the following botanical

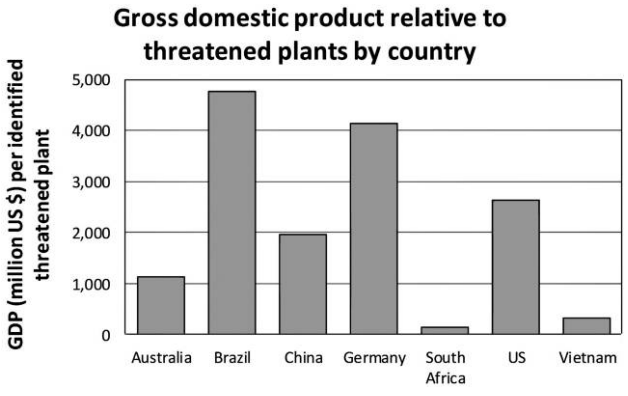

Fig. 4 Number of threatened plant species divided by gross domestic product (GDP) for several countries as an indicator of capacity to afford plant conservation efforts.

research priorities: threatened species conservation and recovery, invasive species management, use of native plants in ecological restoration, and climate change effects on plants/ecosystems. Respondents also noted that incorporating the results of plant research into policy documents and decisions was lacking (Kramer et al. 2010).

Despite the decline of botany programs in universities, much of the basic plant biology research is still carried out by the academic sector. Factors limiting progress in academic plant research include insufficient financial support, shortages of botanically trained scientists, heavy teaching loads, and, sadly, lack of student interest (Kramer et al. 2010). It is imperative that scientific research be focused and fast-tracked and adapt to needs. Scientists need to link with stewardship communities to ensure that adaptive management is an integrated component of all research programs on species conservation.

Education and Outreach

The key to better management of our natural areas, more sound ecological decision making, and an environmentally literate society is science education. Botanical knowledge plays a fundamental role in solving the grand challenges of the next century, including climate change, sustainability, food security, preservation of ecosystem services, conservation of threatened species, and control of invasive species. However, a decline in botanical curricula at universities has been evident for more than 50 years and continues today (fig. 2; Kramer et al. 2010). For example, in 1988, 72% of the top 50 highest-funded US universities offered advanced degree programs in botany. By 2009 more than one-half of these universities had eliminated their botany programs and most or all related courses; only a few universities retained the majority of their botanical course work in an integrated biology department (National Science Foundation 1990, 1999, 2009). This decline may be exacerbated by the phenomenon of plant blindness, which is "the inability to see or notice the plants in one's own environment," which leads "to the inability to recognize the importance of plants in the biosphere and in human affairs" (Wandersee and Schussler 1999, p. 82).

Improved education efforts not only are needed to ensure that the next generation of plant scientists is ready to address grand challenges but also extend beyond our community. It is critical that land managers are able to identify, monitor, and manage plant species and communities under their control. It is equally critical that policy makers understand that botanical input is necessary to solve environmental problems, for instance, understanding that climate change is related to the carbon cycle (which involves plants) or that endangered animals require habitat (which involves plants). Last, without public support, there cannot exist the political will to make difficult decisions that put natural capital on an even playing field with financial capital.

Funding

Funding for plant conservation comes from a wide variety of sources, from federal, state, and local governments and federal grant programs such as the National Science Foundation to private foundations and individuals. Unfortunately, the disparity between plant and animal protections extends to funding as well. Despite plants comprising the majority of the federal endangered species list (57%), in 2011 they received less than 3.86% of federal endangered species expenditures (US Fish and Wildlife Service 2011; fig. 3). In a ranked list of endangered species and amount of spending they received, the first plant (*Astragalus holmgreniorum*) was 114th on the list (US Fish and Wildlife Service 2011). If state and federal expenditures are totaled, plants receive only 3.82% of the funding for endangered species nationwide (US Fish and Wildlife Service 2011). Fundamental plant science is similarly underresourced, receiving just 2% of extramural spending for life sciences research in the United States (McCormick and Tjian 2010).

To consider potential ability to pay for threatened plant species conservation, we compared annual gross domestic product (GDP; World Bank 2012) with the number of known threatened plants identified for each country in figure 1. Results of this comparison (fig. 4) show that the United States has an intermediate ability to pay (a result of having both the highest GDP and the highest number of identified threatened plants), while Brazil has the highest ability to pay and South Africa the lowest. Of course, the ability to pay does not necessarily translate into funding for plant conservation, as amply evidenced by the dismal state of plant funding in many developed countries, including the United States.

These results are highly influenced by the number of plants that have been identified as threatened by individual countries. In the case of Brazil, only 472 plants are listed as threatened on their current red list, which is incredibly conservative: the first draft of the list identified 1495 plants as threatened and an additional 2513 as in need of more information to determine threat status (Scarano and Martinelli 2010). If all 1495 species had been listed as threatened, then the GDP versus identified threatened plant ratio in Brazil would be only slightly higher than in Australia ($1.507 billion of GDP/threatened species instead of the current $4.773 billion of GDP/threatened species).

Table 2

Recommendations to Improve Plant Conservation Efforts in the United States

Need	Recommendation
Document plant abundance and diversity	Complete crosswalk of NatureServe ranks and International Union for Conservation of Nature (IUCN) Red List ranks so all US plants are globally assessed for threat; maintain or increase support to monitor rare species and feed results into NatureServe/IUCN ranks; federally list and legally protect all threatened plants identified above
Mitigating threats	Increase monitoring efforts for invasive plants, animals, and pathogens, including by citizen scientists; seed bank all native species with orthodox seed, prioritizing species used for restoration and those that are rare and utilizing alternative methods such as cryopreservation for rare, recalcitrant-seeded species; expand the scale, scope, and coordination of reintroduction and restoration programs
Research	Address critical botanical research needs in areas of climate change mitigation and adaptation, invasive species control, habitat restoration, and preservation of ecosystem services; ensure research results inform policy and management decisions
Education and outreach	Strengthen botanical education and outreach at all age levels; offer enough botanical course work to meet standards for a federal botanist (24 credit hours) at one or more universities in each state; develop more effective ways to communicate the importance of plants and the need for their conservation to the public and policy makers
Funding and staffing	Have funding for plant conservation commensurate with animal conservation across all sectors; have dedicated funding lines for plant conservation at all land-managing agencies; increase botanical staffing to a minimum of one botanist per office at all land-managing agencies; improve cross-sector collaborations to maximize efficiency and fill gaps in botanical capacity

Note. Some recommendations have been adapted from Kramer et al. (2010).

Conclusions

Many plant conservation accomplishments in the United States can serve as models for other countries. The country's flora is well documented, and conservation assessments have been completed for essentially all plant species, at least at a preliminary level. The United States has excellent infrastructure through the US Department of Agriculture for long-term seed storage, and many botanic gardens are contributing significantly to ex situ conservation efforts. Many of the rarest members of the US flora are safely seed banked, and progress is being made to bank most native species. More than one-third of the country is composed of publicly managed land, where if conservation is not a high priority, it is at least balanced (in most cases) with other uses. Finally, we can celebrate the successful recovery of five formerly listed plant species, including Robbins' cinquefoil (*Potentilla robbinsiana*) and Tennessee coneflower (*Echinacea tennesseensis*), both of which were brought back from the brink of extinction by strong public/private collaborative efforts.

Nevertheless, US plant conservation has a long way to go to reach its full potential (see table 2). Although the ESA is considered a very strong piece of conservation legislation, legal protections for plant species are far less than those for animals. Capacity for plant conservation is declining as botanical degree programs decrease, botanists in both agencies and academia retire, and positions are not refilled. Funding for plants is only a very small fraction of what is spent on conservation generally. Communications between government, academic, and NGO sectors could improve to make better use of limited funding and to ensure that the next generation of botanical professionals is receiving the training needed to address future conservation challenges. Research is needed to understand and mitigate threats to plants and to improve success of reintroduction and restoration projects. Most critically, the problem of plant blindness must be addressed if future generations are going to value plant diversity and the services it provides, because ultimately it is US citizens who, through their voices and choices of conservation-minded representatives, will determine whether plant conservation is a priority in the years to come. Only when people value plants will plants receive the attention and funding necessary to adequately conserve them.

Other countries have addressed plant conservation challenges differently and in some cases more efficiently than the United States. For example, Australia has strong legislation to protect threatened species and threatened ecological communities at both the federal level (Environment Protection and Biodiversity Conservation Act; EPBC) and state levels, though there is considerable discrepancy between the federal and various state assessment processes. A benefit of the two-tier approach to conservation of threatened species is that developments that impact threatened species or threatened ecological communities have to be justified first at the state level and then at the federal level. Importantly, animals listed on the EPBC threatened lists can result in protection of vegetation and species that support forage, breeding, and habitat for threatened animals. However, as in the United States, funding for threatened species conservation, let alone the science to underpin informed conservation decisions (in situ and ex situ), has dwindled, while the size of the threatened flora is increasing. Despite the lack of long-term funding security for rare flora conservation, significant strides have been made, particularly in seed banking. The cryogenic conservation program at Kings Park and Botanic Garden has resulted in the largest somatic tissue culture collection of rare species in the world, with more than 80 threatened and extinct-in-the-wild species in long-term storage in liquid nitrogen (K. Dixon, personal communication).

Over the past several decades, botanists and conservation

professionals have made great strides in documenting and conserving plant diversity and understanding the benefits of resilient plant communities, and yet we have only scratched the surface of what needs to be accomplished. The Earth's ecosystems continue to be destroyed and degraded at unprecedented rates, and the capacity to restore them is extremely limited. But we must begin to address this need if we want to maintain biodiversity and ecosystem services into the future. Ecosystem services are the benefits people obtain from ecosystems, including provisioning of food and water; regulation of atmosphere, floods, drought, land degradation, and disease; support for soil formation and nutrient cycling; pollution filtering; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits (Millennium Ecosystem Assessment 2005), and plants serve as the foundation of ecosystems. Plants are not optional; they are essential to life and central to the future of human well-being. Plants provide habitat—food, cover, nesting areas, and more—for the planet's wildlife. This rich legacy of biodiversity is an invaluable and irreplaceable component of our natural heritage and deserves our protection.

Acknowledgments

This article is based on a talk given in Taiwan in September 2012. We appreciate the efforts of C.-H. Chen, P. Raven, and the Taiwan Endemic Species Research Institute for organizing the conference and facilitating the participation of K. Havens and E. O. Guerrant. We also thank K. Dixon, P. Olwell, and two anonymous reviewers for their comments, which improved the manuscript.

Literature Cited

Affolter J 2003 Botanical gardens and the survival of traditional botany. Public Gard 18:17–19, 22.

Bonney R, JL Dickenson 2012 Overview of citizen science. Pages 19–26 *in* JL Dickinson, R Bonney, eds. Citizen science: public collaboration in environmental research. Cornell University Press, Ithaca, NY.

Eshbaugh WH, TK Wilson 1969 Departments of botany, passé? BioScience 19:1072–1074.

Falk DA, CI Millar, M Olwell, eds 1996 Restoring diversity: strategies for reintroduction of endangered plants. Island, Washington, DC.

Guerrant EO Jr, K Havens, P Vitt 2014 Sampling for effective ex situ plant conservation. Int J Plant Sci 175:11–20.

Havens K, P Vitt, S Masi 2012 Citizen science on a local scale: the Plants of Concern program undertakes rare plant monitoring. Front Ecol Environ 10:321–323.

IUCN 2012*a* International Union for Conservation of Nature red list of threatened species. Version 2012.1. http://www.iucnredlist.org.

——— 2012*b* USA and others to restore more than 18 million hectares of forest lands. http://www.iucn.org/?uNewsID=10172.

Kramer A 2010 Measuring botanic gardens contributions to plant conservation and education in the United States. BGjournal 7:24–28.

——— 2011 Assessment toward evolution of the Plant Conservation Alliance's national framework. Botanic Gardens Conservation International, Glencoe, IL. http://www.bgci.org/files/UnitedStates/PCA/assessment_toward_evolution_pca_national_framework_final.pdf.

Kramer A, A Hird, K Shaw, M Dosmann, R Mims 2011 Conserving North America's threatened plants: progress report on Target 8 of the Global Strategy for Plant Conservation. Botanic Gardens Conservation International, Glencoe, IL. http://www.bgci.org/usa/makeyourcollectionscount.

Kramer AT, B Zorn-Arnold, K Havens 2010 Assessing botanical capacity to address grand challenges in the United States. Botanic Gardens Conservation International, Glencoe, IL. http://www.bgci.org/usa/bcap.

Maschinski J, KE Haskins, eds 2012 Plant reintroduction in a changing climate: promises and perils. Island, Washington, DC.

Maunder M, K Havens, EO Guerrant, D Falk 2004 Ex situ methods: a vital but underused set of conservation resources. Pages 3–20 *in* EO Guerrant, K Havens, M Maunder, eds. Ex situ plant conservation: supporting species survival in the wild. Island, Washington DC.

McCormick SJ, R Tjian 2010 A new focus on plant sciences. Science 330:1021.

Millennium Ecosystem Assessment 2005 Ecosystems and human well-being: synthesis. Island, Washington, DC.

National Science Foundation 1990 Plant biology personnel and training at doctorate-granting institutions. National Science Foundation, Directorate for Biological, Behavioral, and Social Sciences, Washington, DC. http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/23/e0/3d.pdf.

——— 1999 Science and engineering doctorate awards: 1997 (NSF 99-323). National Science Foundation, Division of Science Resources Studies, Arlington, VA.

——— 2009 Federal science and engineering support to universities, colleges, and nonprofit institutions: FY 2006 (detailed statistical tables NSF 09-310). National Science Foundation, Division of Science Resource Statistics, Arlington, VA. http://www.nsf.gov/statistics/nsf09310/.

Native Plant Materials Development Program (NPMDP) 2009 Native Plant Materials Development Program progress report for FY2001–2007. Bureau of Land Management National Operations Center, Lakewood, CO.

NatureServe 2012 NatureServe conservation status. http://www.natureserve.org/explorer/ranking.htm.

Scarano FR, G Martinelli 2010 Brazilian list of threatened plant species: reconciling scientific uncertainty and political decision-making. Nat Conserv 8:13–18.

Sharrock S 2012 Global Strategy for Plant Conservation: a guide to the GSPC, all the targets, objectives and facts. Botanic Gardens Conservation International, Richmond, UK.

Stein BA, K Gravuer 2008 Hidden in plain sight: the role of plants in state wildlife action plans. NatureServe, Arlington, VA.

Sundberg MD 2004 Where is botany going? Plant Sci Bull 50:2–7.

US Fish and Wildlife Service 2011 Federal and state endangered and threatened species expenditures, fiscal year 2011. http://www.fws.gov/endangered/esa-library/pdf/2011.EXP.final.pdf.

US Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) 2012 Plant health. http://www.aphis.usda.gov/plant_health/index.shtml.

Vavilov NI 1926 Studies on the origin of cultivated plants. Bull Appl Bot Plant Breed 16:1–248.

Wandersee JH, EE Schussler 1999 Preventing plant blindness. Am Biol Teach 61:82–86.

World Bank 2012 Data catalog: GDP (current US$). http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

Wyse Jackson PS, LA Sutherland 2000 International agenda for botanic gardens in conservation. Botanic Gardens Conservation International, Richmond, UK.