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CONSERVATION ISSUES

Report in Brief: Assessing Botanical Capacity to Address Grand Challenges in the United States

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ABSTRACT: Botanical capacity 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. Yet critical components of botanical education, research, and management are lacking across government, academic, and private sectors. A recent nationwide survey 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. Private sector organizations are helping to fill identified gaps in capacity, but need to work strategically with all sectors to ensure their sustainability into the future. If botanical capacity continues to erode at its current rate, the nation's science, sustainability, and land management agenda will suffer, opportunities to economically and efficiently solve environmental challenges will be lost, and our public and private lands will continue to degrade.

Index terms: botanical education and training, botanical management, botanical research, plant science

BOTANY IS NOT OPTIONAL

Plants are essential to life and central to the future of human well-being, the sustainable use and preservation of the world's resources, and scientific discovery. In addition to delivering ecosystem services necessary to human health—such as water purification, food, and climate modulation—our plant landscapes provide habitat for myriad fish and wildlife species across the United States. This rich legacy of biodiversity is an invaluable component of American heritage.

The nation's botanical sector plays a mission-critical role by studying, effectively managing, and guiding the sustainable use of the nation's plant resources. Botanical capacity, therefore, is a fundamental component of strategic planning and action to address today's grand challenges (Table 1), particularly challenges surrounding climate change. Investments in this truly green sector will yield a high rate of return in environmental services and scientific advances while benefiting the health and well-being of American people and the nation's wildlife.

If We Do Not Invest in Botanical Capacity, the United States Will:

- Lose nearly half of its federal workforce with botanical expertise within the next decade (Figure 1). Without botanists, public lands and the nation's natural heritage cannot be efficiently or effectively managed.
- Lack critical expertise needed to strategically plan and successfully implement projects to mitigate the effects of climate change on habitats, biological diversity, and ecosystem services. This will lead to significant and unnecessary costs while exposing the nation's natural heritage to dramatic losses.
- Be unable to address critical challenges such as prevention and control of invasive species—adding to the billions of dollars already spent.
- Continue to lose its international scientific competitive status.
- Lose future opportunities to improve food security, cure disease, naturally sequester carbon, and produce carbon-neutral biofuel.

WHAT IS BOTANICAL CAPACITY?

Botanical capacity encompasses the human, scientific, technological, organizational, institutional, and resource capabilities that support botanical education, research, and management (Figure 2). Botanical capacity is necessary to guide the sustainable use and effective management of the nation's critical life resources, as it provides a fundamental understanding of the processes that affect ecosystems, the natural and managed environment, wildlife, and human health and well-being. A lack of botanical capacity will severely compromise progress in solving the nation's grand challenges (Table 1).

Botanical Expertise: An Urgent Need

Despite the economic and environmental importance of botanical expertise in the United States (Figure 3), a comprehensive

Table 1. Five grand challenges identified by the US National Research Council (in Grand Challenges in Environmental Sciences (2001) and A new biology for the 21st Century: ensuring the United States leads the coming biology revolution (2009)) and the National Economic Council (in A strategy for American innovation: driving towards sustainable growth and quality jobs (2009)) requiring botanical capacity.

Grand Challenge Identified	Botanical Capacity (Research) Required to Address Grand Challenges	Botanical Capacity (Management) Required to Address Grand Challenges
Biological Diversity and Ecosystem Functioning in a Changing Climate Challenge: To understand factors affecting biological diversity and ecosystem structure and function so habitat can be managed to sustain biological diversity, humans and wildlife in the face of rapid climate change.	• Improve tools for rapid assessment of plant diversity at all scales • Produce quantitative theory of spatial and temporal plant diversity • Elucidate relationship between plant diversity and ecosystem function • Understand how human activities and climate change affect plants and, as a result, ecosystem function, and develop interventions to minimize harmful effects	• Work with researchers to develop, test, and implement techniques to modify, create, and manage native plant habitats that support biological diversity and ecosystem functioning • Identify and monitor plants and ecosystems at risk due to climate change, invasive species or pathogens • Monitor ecosystem function and its relationship to plant species diversity and habitat composition
Sustainable Food Production Challenge: To generate *food plants* to adapt and grow sustainably in changing environments. This is a critical contribution toward making it possible to feed people around the world with abundant, healthy food, adapted to grow efficiently in many different and ever-changing local environments.	• Advance knowledge of how genetic background of crop plants confers adaptation to local conditions • Use genetic and breeding tools and techniques to develop crop plant varieties adapted to different local conditions • Use horticultural and agronomic techniques to understand how to sustainably and efficiently grow plant varieties adapted to different local conditions	• Monitor and manage native habitat to ensure wild genetic diversity of current and future crop wild relatives is not lost • Bank seeds of current and future wild crop relatives to ensure the range of genetic diversity is accessible for research and future use
Biogeochemical Cycles Challenge: To further understand the Earth's major biogeochemical cycles, evaluate how they are being perturbed by human activities, and determine how they might better be stabilized.	• Quantify plant-based sources and sinks of key nutrients, including carbon and nitrogen, an understand factors regulating transformations among them • Understand how changes in plant habitat diversity and composition caused by human activities alters biogeochemical cycling and impact ecosystem function	• Work with researchers to develop, test, and implement techniques to manage, modify, and re-create native plant habitats that can support ecosystem functioning and help stabilize biogeochemical cycle perturbations
Climate Variability Challenge: To increase our ability to predict climate variations, to understand how this variability may change in the future, and to assess realistically the resulting impacts.	• Improve tools to observe and record impacts of climate variability on plant species, plant habitat, and the wildlife that depends on it • More effectively incorporate impacts of climate variability on plants into comprehensive climate change models assessing future effects	• Work with researchers to develop, test, and implement techniques to observe and record impacts of climate variability on native plant habitats, including resulting impacts on biodiversity and ecosystem functioning • Take steps to mitigate impacts of climate variability on native plants and the wildlife and ecosystem functions that they support • Bank seeds of native plant populations to ensure genetic diversity is available for research and future use

Table 1. (*Continued*) **Five grand challenges identified by the US National Research Council (in Grand Challenges in Environmental Sciences (2001) and A new biology for the 21st Century: ensuring the United States leads the coming biology revolution (2009)) and the National Economic Council (in A strategy for American innovation: driving towards sustainable growth and quality jobs (2009)) requiring botanical capacity.**

Grand Challenge Identified	Botanical Capacity (Research) Required to Address Grand Challenges	Botanical Capacity (Management) Required to Address Grand Challenges
Optimized, Ultimately Carbon-Neutral Fuel Production Challenge: To expand sustainable alternatives to fossil fuels and ultimately develop biological systems that can turn sunlight into carbon-neutral fuel	• Identify which plants produce the most useful form of cellulose • Determine how alternative biofuel crops can be developed and grown efficiently and sustainably • Identify how alternative biofuel crop species, selected and produced in different regions, can be utilized to ensure carbon-neutrality and maintain ecosystem function	• Monitor and manage native habitat to ensure wild genetic diversity of current and future biofuel crops is not lost • Bank seeds of current and future biofuel crops, to ensure the range of genetic diversity is accessible for research and future use

assessment of national botanical capacity had not been conducted until now. This project was initiated in 2009 to evaluate critical gaps in botanical capacity across the government, academic, and private (including nonprofit) sectors. A survey targeting scientists, graduate students, administrators, educators, and land managers involved in natural resource management, education, and research across the United States was carried out, and in 2010 results were summarized in this Report in Brief and detailed in an accompanying report (Kramer et al. 2010).

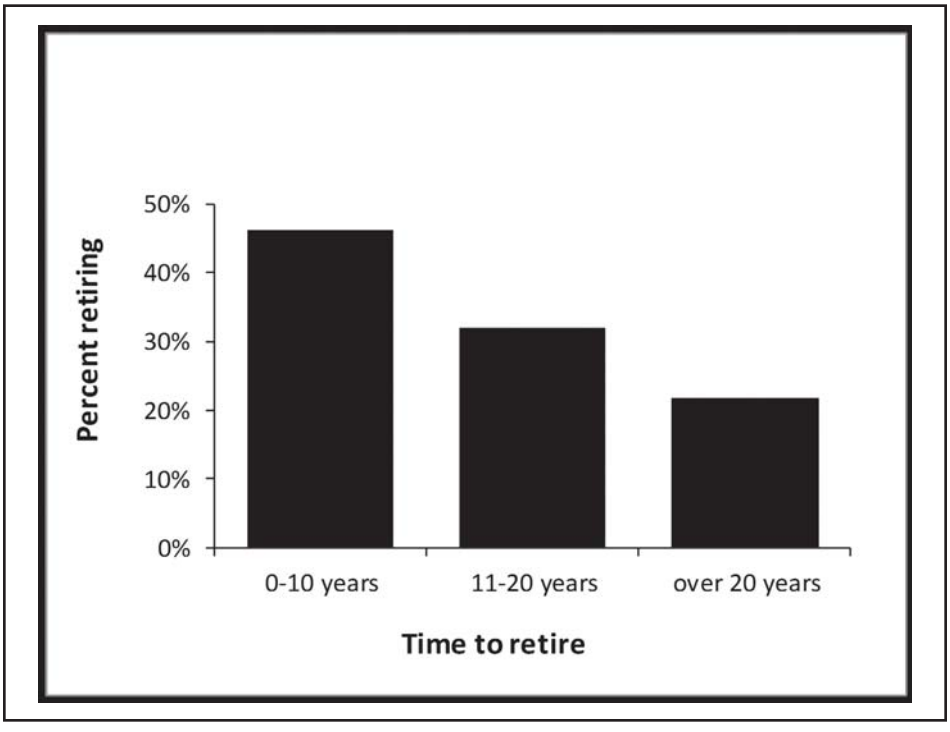

Figure 1. Survey results show that nearly 50% of federal botanists surveyed (n = 147) will retire within 10 years.

Identified: Current Gaps in Botanical Capacity

Federal and state agencies currently lack the botanical capacity required to guide efficient and effective management of the nation's most critical biological resources. Survey results document severe shortages of management and research staff with botanical degrees throughout all federal and state government agencies (Table 2), with some of the most significant shortages found in agencies directly responsible for managing public lands (Table 3).

Over half of all respondents from federal agencies indicated that individuals with botanical expertise are rarely, if ever, included in efforts to address topics like climate change effects on habitat, invasive plant and animal species, habitat monitoring, plant selection for restoration, or rare plant and animal species recovery. Investing in botanical capacity at government agencies will ensure that botanical expertise is available to inform these efforts, leading to more efficient management of the nation's biological resources and ultimately greater success and significant cost savings.

Identified: Future Shortfalls in Botanical Capacity

Already critically lacking, botanical ex-

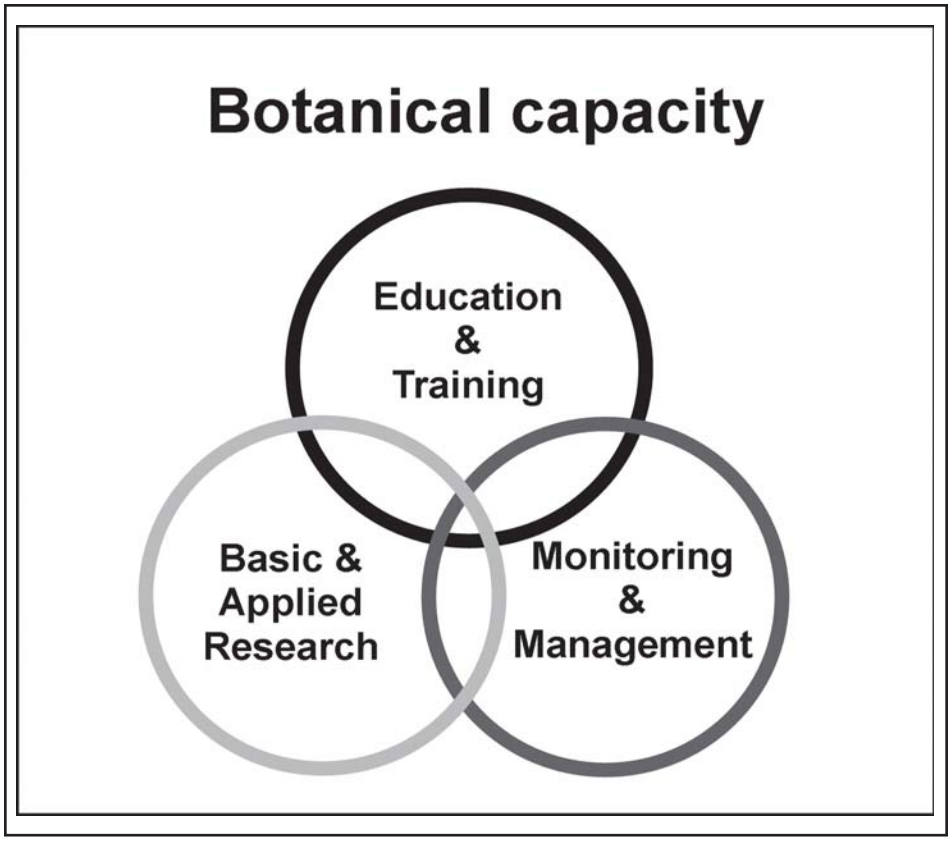

Figure 2. Components of botanical capacity: (1) Education and Training, (2) Monitoring and Management, and (3) Basic and Applied Research.

pertise at federal agencies will continue to decline over the next 15 years as more than half of the current workforce retires. This decay in critical botanical infrastructure at government agencies is occurring in tandem with declines in botanical education and training opportunities at the nation's colleges and universities. While the private sector is filling many gaps in botanical education and research, there is a need for more sustainable support and partnerships amongst the academic, private, and government sectors to ensure the private sector is able to continue filling these gaps in the future.

Survey respondents reported an inability to find appropriately trained botanists to fill currently open positions within government agencies, and they were generally dissatisfied with the botanical training of incoming employees. At the current rate of decline in botany programs at colleges and universities (Table 3, section b), and as agencies hire more botanists to fill current gaps in capacity and refill positions following retirement, there will not be an appropriately trained workforce to fill vacancies when they are needed most.

Recommendations to Fill Critical Gaps in Botanical Capacity

Education and Training

1. Faculty and administration involved in college and university biology education should ensure plant science is appropriately incorporated in annual course offerings for undergraduate and graduate students to ensure they are employable both within and outside the academic sector. This includes offering courses that meet requirements for employment as a federal botanist (such as botany, plant anatomy, morphology, taxonomy and systematics, mycology, ethnobotany, and other plant-specific courses), and encouraging interdisciplinary research programs to train students in both basic research and applied science.

2. Faculty and administration at the nation's academic institutions should ensure plant science, including basic organismal expertise, is strongly represented within interdisciplinary departments, particularly as staff with botanical expertise retires in the coming decade. Accreditation bodies should develop recommendations and criteria for monitoring and evaluation to support adequate representation of botanical disciplines in biology departments and interdisciplinary study programs nationally.

3. Nonprofit organizations play an increasingly critical role in filling gaps in botanical education and training. They contribute to course development and classroom education while providing amplification and practical experience, particularly for subjects that are most in demand for the nation's botanical workforce outside of academia. Because demand will likely only increase in this area, nonprofit organizations should take strategic steps to increase their ability to fill this gap in capacity in this area. Leadership to recognize, support, and sustain the ability of nonprofit organizations to fill this role is needed from private foundations as well as academic and government sectors.

4. A full-time liaison position should be established between the Botanical Society of America and federal land management and research agencies to ensure botanical education and practical training needs for expert resource management are met. Similar to the current liaison position between the Bureau of Land Management and the Society for Range Management, this position would strengthen collaboration and workforce building through avenues such as quick-hire programs as well as the Office of Personnel Management's Student Educational Employment Program and Presidential Management Fellows Program.

5. Academic, government, and private sectors should work collaboratively to strategically strengthen botanical education and training at all age levels. This includes curriculum development that

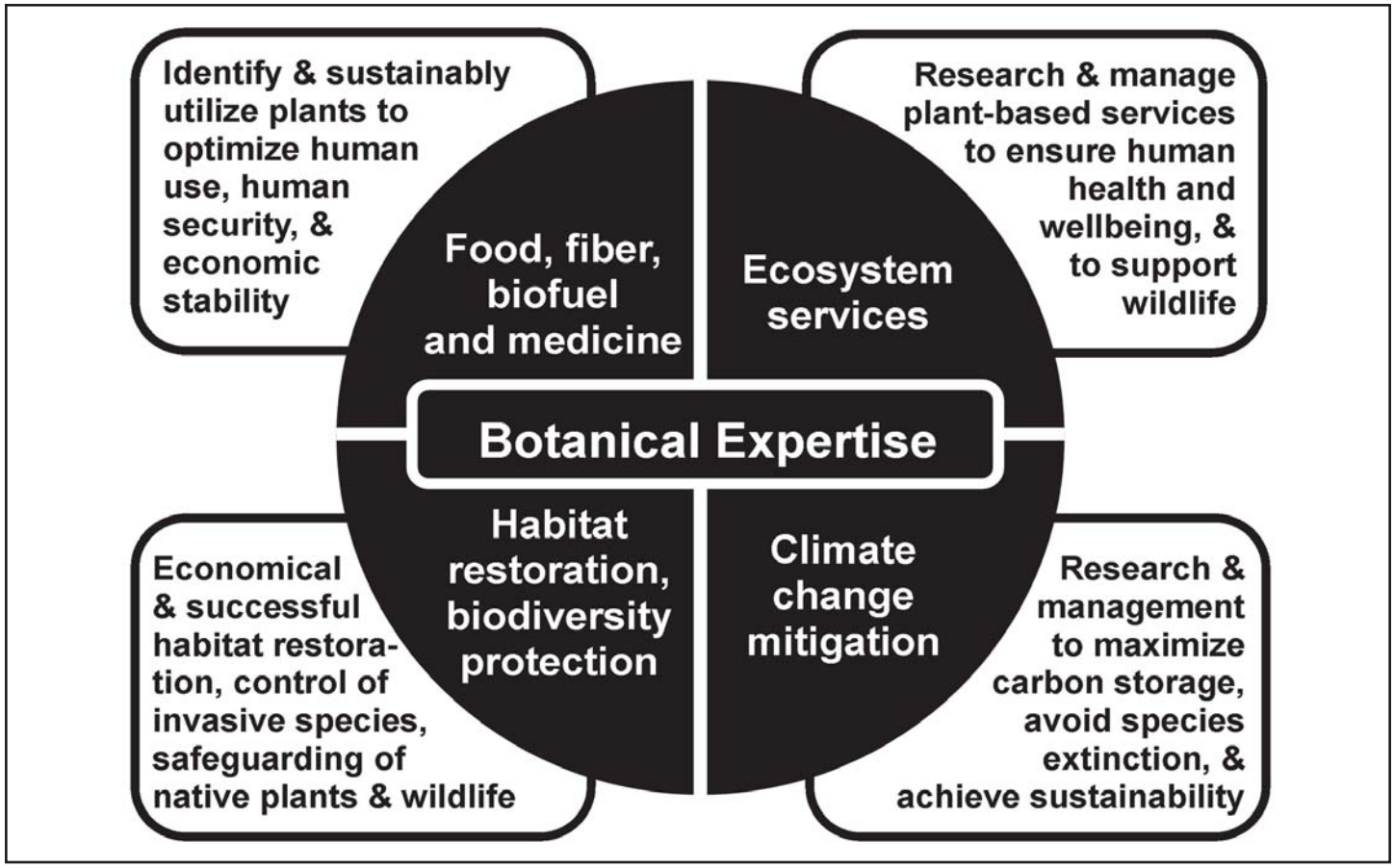

Figure 3. Four areas requiring botanical expertise (within circle) and the contributions botanists make to them (adjacent boxes).

recognizes the central role plants play in biological systems and human life, and better integration of plant science into biology standards and textbooks. Work through the STEM (Science, Technology, Engineering, and Mathematics) Education Coalition as well as organizations like the Botanical Society of America, the American Institute of Biological Sciences, and the National Association of Biology Teachers is needed to build support for and better integration of plant science education and training in biology coursework.

Communications and Outreach

6. All sectors should work both individually and collaboratively to strategically increase outreach efforts to different audiences, and to monitor the effectiveness of this work. Action is needed to create appropriate materials and deliver information that increases the level of botanical literacy and appreciation among policy makers, other scientific disciplines, and the general public. The private sector should build on current outreach efforts to the government and general public, the government sector should ensure outreach efforts to the public effectively include plants as well as the wildlife that depends upon them, and the academic sector should make a commitment to increase outreach efforts beyond the academic sector.

Table 2. Summary of survey responses to the question "Do you think your agency has enough botanically trained staff to meet its current management/research needs?" for federal agency staff and state natural heritage program staff.

Responses by sector	Response = No
Federal government agencies [a]	94% (n = 358)
State natural heritage programs	84% (n = 32)

[a] Represents respondents from twelve federal agencies. See full report for details.

Research and Management

7. The significant impacts of climate change on plants, as well as the people, wildlife, and ecosystem services that are dependent upon plants for survival and well-being, should be recognized. Appropriate botanical expertise should be incorporated into climate change planning and policy efforts in all sectors to ensure

Table 3. Summary of survey results demonstrating: a) Evidence of current gaps in botanical capacity in research and management, and b) Evidence of future shortfalls in botanical capacity in education and training.

a) Evidence of current gaps in botanical capacity in research and management

Bureau of Land Management (BLM) **:** Charged with managing biological resources on 40% of all public land, but employ just over one botanist per 4 million acres (equivalent to having one person responsible for all plants in Connecticut). Of 105 BLM survey respondents, 94% said their agency did not have enough botanically trained staff to meet current needs.

US Geological Survey (USGS) **:** Provides the science to guide management of nearly 400 million acres of public lands. All USGS survey respondents said their agency did not have enough botanically trained staff to meet current needs. A preliminary assessment of USGS scientists at centers in the western United States, where most public lands are located, suggests that wildlife scientists outnumber botanical scientists by over 20 to 1.

b) Evidence of future shortfalls in botanical capacity in education and training

Loss of botanical degree programs **:** In 1988, 72% of the nation's top 50 most funded universities offered advanced degree programs in botany. Today, more than half of these universities have eliminated their botany programs and many, if not all, related courses. Advanced degrees earned in botany are down 41% in the last decade, while advanced biology degrees have grown by 11%

Decline in botanical course offerings **:** Nearly half of the over 400 university faculty who completed the survey said botany courses in their department had been cut in the past 5–10 years. A majority of faculty and graduate student respondents were dissatisfied with botany courses offered by their college or university.

appropriate proactive research efforts are initiated, and collaborative partnerships are encouraged to support effective, efficient, and economically defensible solutions. This includes ongoing work by the Department of Interior in developing and managing Climate Science Centers and Landscape Conservation Cooperatives, where botanical capacity is currently greatly underrepresented.

8. Public and private funding should be directed to help all sectors close key gaps identified in plant science research that are directly linked to top needs and applications identified by this survey. This includes identified research needs in invasive species control, climate change mitigation and adaptation, habitat restoration, and the preservation of ecosystem services.

9. The nation's five federal land management agencies* should increase the number of trained, full-time botanists on staff. At minimum, each agency should have at least (1) one full-time botanist working collaboratively at the national level to address critical climate change issues facing plants on public lands, and (2) one full-time botanist with appropriate training on staff at all regional, state, and field offices.

*Bureau of Land Management (BLM), Department of Defense (DOD), National Park Service (NPS), US Forest Service (USFS), and US Fish and Wildlife Service (USFWS) are collectively responsible for managing nearly 1/3 of the nation's landmass.

10. The US Geological Survey, responsible for carrying out research to guide management of Department of Interior lands** should have at least five full-time botanists with a range of appropriate training on staff at each of its regional science centers.

**US Geological Survey (USGS) is the research arm of the BLM, NPS, and USFWS National Wildlife Refuge system, therefore charged with research on the native plant communities comprising almost 400 million acres of public lands.

11. Administrators and decision-makers at federal and state land management and research agencies should engage full-time staff botanists and work collaboratively with academic and private sector expert advisors in developing land-use plans, and in planning and implementing responses to key challenges (including climate change mitigation planning, habitat restoration, and invasive species control strategies). This will lead to more successful, efficient, and economical outcomes.

12. Federal and state land management and research agencies should provide support for full-time staff botanists to identify and prioritize plant-related issues, and ensure these priorities are clearly and consistently communicated to the academic and private sector to allow for effective and efficient action. Once identified and communicated, management and funding decisions in the private and public sectors should ensure that capacity and resources are focused on the highest priority issues (such as invasive species) and/or taxa (such as those most critically threatened).

13. All federal land management and research agencies should ensure new hires have appropriate botanical training, and that monitoring and reporting mechanisms are in place to avoid a similar decay in botanical capacity in the future. Specifically, all new federal hires recommended here should be employed under the US Office of Personnel Management employment code 0430 (Botany), rather than the more general code of 0400 (Natural resource management / general biology), as it does

not effectively capture required botanical expertise.

14. Cross-sector communication and partnership should be enhanced to pool existing resources, maximize efficiency, and more rapidly address and fill critical gaps in botanical capacity. Additional resources are needed to facilitate partnerships among government, academic, and private sectors, ensuring long-term sustainability of programs necessary for science-driven management of the nation's biological resources. The Plant Conservation Alliance provides an effective vehicle for multi-sector partnerships, and examples of programs built around public-private partnerships include the national Seeds of Success program and regional programs such as the New England Plant Conservation Program and the Georgia Plant Conservation Alliance.

This Report in Brief is based on the full report available online from Botanic Gardens Conservation International. It is a slightly modified version of the Report in Brief also available at the same website. For more information, see Kramer, A.T., K. Havens, and B. Zorn-Arnold. 2010. Assessing botanical capacity to address grand challenges in the United States. Chicago Botanic Garden and Botanic Gardens Conservation International US, Glencoe, IL. Available at www.bgci.org/usa/bcap.

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