APPLYING LESSONS FROM THE U.S. BOTANICAL CAPACITY ASSESSMENT PROJECT TO ACHIEVE 2020 GLOBAL STRATEGY FOR PLANT CONSERVATION TARGETS[1]

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ABSTRACT

Despite the fundamental role plant science plays in addressing global environmental issues, a recent survey of nearly 1600 members of the botanical community in the United States revealed a severe shortage in the nation's botanical capacity or resource capabilities that support the advancement of plant science. The survey and a subsequent published report detailed 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 filling gaps in botanical capacity created by declines in academic and government sectors. While this survey was carried out in the United States, its results are internationally relevant and applicable. These declines occur as the need for botanical capacity increases globally to address important plant conservation needs. Recognizing the critical situation facing the world's flora, the Convention on Biological Diversity (CBD) adopted the Global Strategy for Plant Conservation (GSPC) to halt the continuing loss of plant diversity. Our results illustrate the necessity of working across public and private sectors to ensure that botanical capacity is valued, supported, and utilized to achieve all 16 targets of the GSPC by 2020.

Key words: Botanical capacity, Global Partnership for Plant Conservation, Global Strategy for Plant Conservation, plant science education, research, and management, U.S.A.

The botanical community plays a critical role in researching, conserving, and sustainably managing the world's plant diversity and resources. Botanical capacity is the human, scientific, technological, organizational, institutional, and resource capabilities that support plant-based education and training, basic and applied research, and environmental monitoring and management. It is a critical component of efforts to address current and future challenges, such as climate change mitigation, land management and habitat restoration, invasive species control, and the conservation of rare species. Increased botanical capacity is necessary globally for achieving all 16 targets of the Global Strategy for Plant Conservation (GSPC) with the larger goal of halting the loss of plant diversity (Convention on Biological Diversity [CBD], 2010).

Despite the fundamental role botanical capacity plays in addressing key environmental challenges, it is often lacking in countries where plant diversity is highest (CBD, 2010). This includes developing tropical countries like Madagascar and Laos, where botanic gardens such as Missouri Botanical Garden and Royal Botanical Gardens, Kew, are working to build on-the-ground botanical capacity. Botanical capacity also appears to be eroding in many countries where it has historically been strongest, most notably the United Kingdom (Drea, 2011). This includes shortages of trained botanists at government agencies and declines in botanical degree programs and course offerings at colleges and universities. There is a clear need to better quantify and monitor botanical capacity in countries around the world because available information is largely anecdotal and often outdated. Without this information, it will be difficult to track trends in increasing or declining capacity and nearly impossible to achieve the GSPC targets by its 2020 deadline. This paper presents results from the first formal botanical capacity survey of government, academic, and private sectors across the United States, and connects findings and recommen-

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dations with ongoing efforts to reach the GSPC 2020 targets.

Assessing Botanical Capacity in the United States

To assess current botanical capacity as it applies to plant science research, education, and application in the United States, the Botanical Capacity Assessment Project was initiated in 2009 by the Chicago Botanic Garden, in partnership with Botanic Gardens Conservation International (BGCI) U.S. This cross-sector approach identified current strengths and areas where growth is needed by polling botanical professionals employed by universities, businesses, nonprofit organizations, and federal, state, and local governments.

We conducted an initial search of published and gray literature to synthesize all previous efforts to assess botanical capacity (education, training, research, application, and infrastructure) in the United States. Project staff then worked in consultation with members of an established advisory board and other individuals in the botanical community to develop, test, and carry out seven online surveys designed to capture information not available in the literature. Survey participants were from (1) federal government agencies; (2) state Natural Heritage Programs; (3) regional, state, county, or city government; (4) nonprofit organizations; (5) self-employed and for-profit sectors; (6) graduate students (master's and doctorate level); and (7) academic faculty.

Online surveys were widely advertised via print and electronic means, including through the Botanical Society of America and a range of plant science, conservation, and education listservs. The survey was open and publicly available during the summer of 2009. A total of 1569 individual survey responses were recorded, representing a diverse cross-section of the botanical community (Table 1). To our knowledge, it was the first time multiple sectors of the botanical community in the United States have been surveyed simultaneously. A workshop involving 30 stakeholders from government, academic, and private sectors was held at Chicago Botanic Garden in autumn 2009 to evaluate survey results and make recommendations for addressing critical gaps in botanical capacity. Key report findings are detailed below, and a full report (Kramer et al., 2010), including survey results and workshop recommendations, is available through the BGCI website, <http://www.bgci.org/usa/bcap>.

Education and Training

Botanical capacity in education and training is fundamental to achieving all targets of the GSPC, but is specifically related to Objective V and Targets 15 and 16 (CBD, 2010). The main task of Objective V and Targets 15 and 16 is to develop the capacities and public engagement necessary for halting the continuing loss of plant diversity, which involves increasing the number of trained people (Target 15), and strengthening the relationships among institutions, networks, and partnerships for plant conservation at national, regional, and international levels (Target 16). Unless we are able to build botanical capacity in education and training and ensure mechanisms are in place to monitor and sustain it over the long term, we will ultimately be unable to address the challenges posed by threats to plant diversity.

As early as 1952, a general decline in botany/plant-based curricula relative to general biology curricula at U.S. universities and colleges was noted (Greenfield, 1955), and by all indications, this trend continues today. This may be due in part to the widely recognized decline in organismal biology and taxonomy, including a decline in the support of natural history collections for both plants and animals (Gropp, 2003; Schwenk et al., 2009; Yoon, 2009) and is likely amplified by the phenomenon of what is termed as plant blindness, or a lack of awareness of plants in one's own environment (Wandersee & Schussler, 1999; Hershey, 2002). Research has shown that students have better recall for animals than plants (Schussler & Olzak, 2008), and science textbooks do little to help change this, as they describe and detail animals more so than plants in general (Link-Pérez et al., 2009). Much has been written about the need to update botanical curricula and education programs from pre-college (Daisey, 1996; Hershey, 1996; Goins, 2004; Enger, 2006; Hoot, 2009) to post-secondary education (Greenfield, 1955; Uno, 1988, 1994, 2002, 2007, 2009; Ewers, 2000; Cantino, 2004; Carter, 2004; Curtis & Bell, 2004; Sundberg, 2004; Senchina, 2008). Yet declines are ongoing and much remains to be done to ensure plant science is more broadly and effectively incorporated into the science and management curriculum of the United States.

It is possible to quantify some of the declines in botanical capacity in the academic sector using data from the National Science Foundation (Chaney et al., 1990; NSF, 1999, 2009). These data show that in 1988, 72% of the nation's top 50 most-funded universities offered advanced degree programs in botany. By 2009, more than half of these universities had eliminated their botany programs and many, if not all, had eliminated related courses. Likewise, data from the U.S. Department of Education, National

Center for Education Statistics (U.S. Department of Education, NCES, 2008) revealed that undergraduate degrees earned in botany declined by 50% between 2000 and 2008, whereas degrees awarded in general biology rose nearly 17% (Fig. 1).

In the United States, little quantitative information on the botanical capacity of the private sector is available, particularly with respect to for-profit businesses and self-employed and contracted individuals. In contrast, information on how botanic gardens and arboreta in the nonprofit sector contribute to botanical capacity through education and training is found in GardenSearch, the online database of the world's botanic gardens maintained by BGCI (2011). In the past century, GardenSearch reveals the number of botanic gardens in the United States has grown from fewer than 40 institutions to more than 450 (BGCI, 2011). This database identifies education programs at 152 U.S. botanical gardens, with more than 495 staff implementing these programs (at 92 botanic gardens that provided detailed employment statistics; see Table 2 for additional information on education efforts at botanic gardens).

Survey results helped quantify a growing gap in botanical capacity at the university level, specifically related to declines in botanical course offerings. Nearly 40% of the over 400 university faculty who completed the survey said botany courses in their department had been cut in the past five to 10 years. Those courses eliminated tended to be from among those required for employment as a botanist in the federal government. A majority of faculty and graduate student respondents were dissatisfied with botany courses offered by their college or university; field botany was identified as the most in-demand course to add to curricula (Fig. 2). Survey respondents also reported an inability to find adequately trained botanists to fill current open positions within government and nonprofit agencies, and they were generally dissatisfied with the botanical training of candidates and new hires (Sundberg et al., 2011). The elimination of botany degrees and courses across U.S. universities has a direct and severe impact on the scientific community's ability to meet the GSPC Targets 15 and 16.

Research and Management

Botanical capacity in research and management is also critical for achieving Objectives I and II of the GSPC, which ensures plant diversity is well understood, documented, and recognized (Objective I) and plant diversity is urgently and effectively conserved (Objective II; CBD, 2010). Specifically, Objective I, Target 3 develops information, research, and the associated outputs necessary to implement the strategy. Objective II, Targets 4, 5, and 10 focus on conservation with at least 15% of each ecological region or vegetation type secured through effective management and/or restoration (Target 4); at least 75% of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity (Target 5); and effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded (Target 10).

Table 1. Percent of survey respondents (n = 1569 total respondents) shown by self-identified sector in which they work.

Sector	Percent of respondents
Federal government staff	34%
Academic faculty or administration	26%
Nonprofit organization staff	15%
Graduate students (Master's or Ph.D.)	13%
State or local government staff	6%
For-profit/self-employed staff	4%
State Natural Heritage Program staff	2%

Nearly one third of all land in the United States is managed by the federal government, and in 2008, 1520 species (831 vascular plants, 374 vertebrates, 313 invertebrates, and two lichens) protected under the U.S. Endangered Species Act were found on federal lands in the United States. An additional 3069 species on federal lands were considered imperiled (2686 plants, 383 vertebrate taxa; Stein et al., 2008). Given these high numbers, it is important that botanists with specific botanical training and expertise are employed to help manage public lands and the threatened plants they support. However, it is currently not possible to identify the actual number of individuals with sufficient botanical training that are in place at federal government agencies. We do know that the workload and responsibilities of a federal botanist are often much greater than for federal wildlife biologists. For example, on California's National Forests each plant specialist is responsible for an average of 14 sensitive plant species, while animal specialists are each responsible for an average of only one sensitive animal species (Roberson, 2002). However, botanists are not compensated for this greater workload. In fact, they are paid much less than their counterparts: in March 2009, the U.S. Bureau of Labor Statistics (BLS) reported that federal government ecologists earned an average annual salary of $84,283;

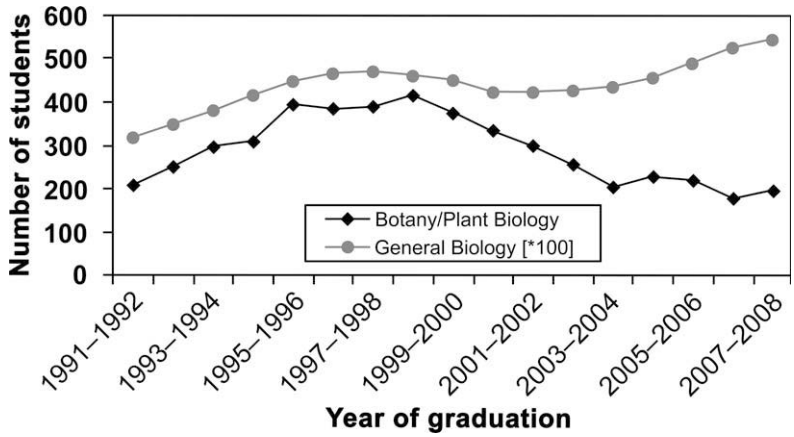

Figure 1. Comparison of undergraduate students graduating with a bachelor's degree in botany/plant biology versus a degree in general biology (data from the U.S. Department of Education, NCES, 2009). Note that numbers for general biology graduates are divided by 100 to facilitate viewing on a single graph.

zoologists, $116,908; and botanists, $72,792 (BLS, 2010).

Botanic gardens also provide important botanical research and management capacity, particularly when working in partnership with other sectors. For example, the Center for Plant Conservation (CPC) is a coordinated network of 38 botanical institutions dedicated to conserving and restoring imperiled native plants in the United States. The network collectively works with nearly 750 vulnerable species, including seed banking and restoration in the wild. Over the last 25 years, CPC participating institutions have banked nearly 22 million seeds of rare species, monitored ca. 2100 vulnerable plant sites, engaged in more than 202 reintroduction projects, are working to control invasive species at 94 wild sites, and conducted 47 other habitat restoration projects. Additional baseline data on botanical research and management capacity are provided by botanic gardens and arboreta in the United States in the BGCI's GardenSearch database. For example, in this database 41 gardens report an invasive species biology research program, and 73 report a plant conservation program (BGCI, 2011; Table 3).

Botanic gardens also amplify nationwide botanical capacity by working in partnership with other sectors. One example comes from the Seeds of Success program (SOS, 2010) led by the United States Department of the Interior, Bureau of Land Management. This national native seed collection and banking program is the result of a public-private collaboration involving numerous federal government agencies and private institutions (particularly botanic gardens) across the country. Since it began in 2001, this partnership has banked over 13,000 collections of native seeds at the Western Regional Plant Introduction Station (WRPIS) in Pullman, Washington, with back-up collections maintained by botanic gardens and partners across the country. This work is safeguarding native species against genetic erosion or even extinction, and providing opportunities for efficient and effective research and production of native plants in the United States.

Survey respondents were unanimous in selecting invasive plant species control as the top management issue requiring additional research, yet very few

Table 2. Education, training, and outreach summary statistics for U.S. botanic gardens and arboreta, as detailed in Botanic Gardens Conservation International's GardenSearch database (BGCI, 2011).

Education or training capacity	Summary for U.S. gardens (Nov. 2011)
Have an education program	152 gardens
Number of education staff	495 staff (n = 92 gardens reporting)
Education programs for K–12 students	64 gardens
Education programs at university level	45 gardens
Education programs for visitors	110 gardens
Number of volunteers engaged in activities	28,736 volunteers (n = 100 gardens reporting)

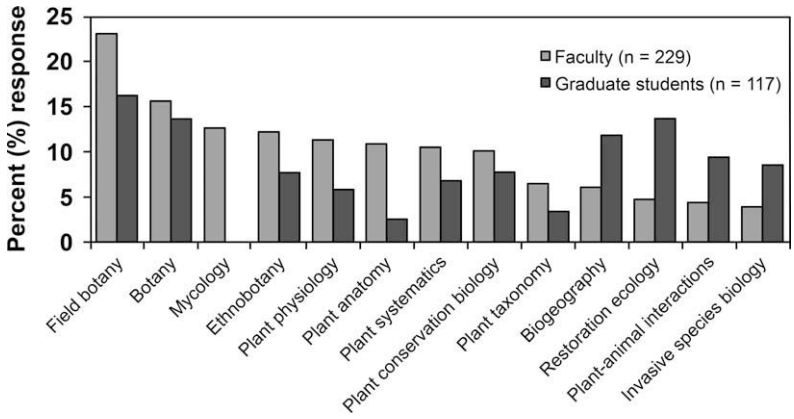

Figure 2. Plant science courses that faculty and graduate students responding to the survey felt should be added to their university's curriculum (Kramer et al., 2010).

faculty or graduate students reported undertaking research or offering courses that were applicable to invasive plant species control. This unmet demand for research on invasive species is a surprise, given that the United States currently spends more than $25 billion every year controlling invasive plant species (Pimentel et al., 2005; Pimentel, 2009), with costs expected to rise over the next decade.

Survey results documented severe shortages of management and research staff with botanical degrees, indicating government agencies currently lack the botanical capacity required to guide effective management of the nation's most critical biological resources. For example, in response to the question, "Do you think your agency has enough botanically trained staff to meet its current management/research needs?" Ninety-four percent of the 358 respondents in federal government agencies indicated that botany was the top employment area with shortages. These shortages occur throughout all federal and state government agencies, with some of the most significant found in agencies directly responsible for managing public lands.

Already critically lacking, botanical expertise at federal agencies will continue to decline over the next 15 years as more than half of the current workforce retires (Fig. 3). Because this decay in botanical infrastructure at government agencies is occurring in tandem with declines in botanical education and training opportunities at U.S. universities, it requires immediate attention. The private sector is filling many gaps in botanical education and research (for example, conducting research and teaching courses on invasive species biology and offering courses in field botany), but recommendations were made to support more sustainable partnerships among academic, private, and government sectors to ensure the private sector is able to continue filling these gaps in the future.

Recommendations to Address Gaps in Capacity

By filling gaps in education and training, and research and management, the botanical community will be better prepared to meet GSPC targets. Recommendations to address these gaps include the following seven (Kramer et al., 2010).

(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

Table 3. Plant research and management summary statistics for U.S. botanic gardens and arboreta, as detailed in Botanic Gardens Conservation International's GardenSearch database (BGCI, 2011).

Research or management capacity	Summary for U.S. gardens (Nov. 2011)
Herbarium	45 gardens
Micropropagation/Tissue culture facility	18 gardens
Seed bank	32 gardens
Plant conservation program	73 gardens
Plant ecology research program	31 gardens
Invasive species biology research program	41 gardens
Restoration ecology research program	32 gardens
Plant systematics/Taxonomy research program	19 gardens
Floristics research program	17 gardens
Urban environment research program	24 gardens

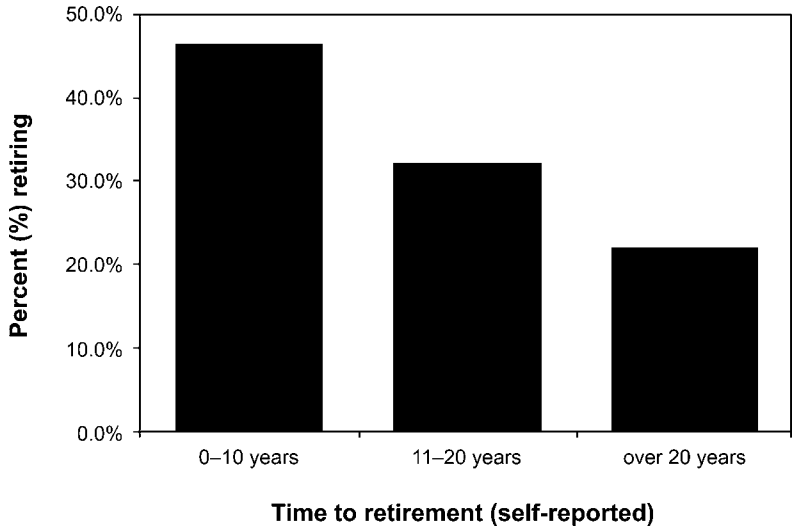

Figure 3. Retirement of survey respondents ($n = 147$) who are employed as federal botanists. There will be a significant need for a botanically trained workforce to fill the vacancies created by these retirements (Kramer et al., 2010).

offering courses that meet requirements for employment as a federal botanist (such as botany, plant anatomy, physiology, morphology, taxonomy and systematics, mycology, economic botany, 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 practical experience, particularly for subjects that are most in demand for the nation's botanical workforce outside of academia. Because demand will 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) 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.

(5) 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).

(6) 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).

(7) 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.

Application of Findings Outside the United States

Efforts to build botanical capacity in developing countries in support of the GSPC should consider identifying needs and monitoring botanical capacity so it can be built and sustained over the long term. Developed countries with established botanical capacity should develop processes to measure and monitor capacity over time, in order to define needs and take steps to prevent the loss of capacity or, in areas where capacity may already be lost, to rebuild it. All countries should work together to ensure that the need for public and private support of botanical capacity is widely understood and accepted.

Further Information

For full details on this assessment, and the results and recommendations that came from it, please visit <http://www.bgci.org/usa/bcap>, which contains free PDF copies of the full report (Kramer et al., 2010) executive summary, and recommendations.

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