The role of The New York Botanical Garden in plant and fungal conservation

Brian M. Boom

Center for Conservation Strategy, New York Botanical Garden, 2900 Southern Blvd., Bronx, NY 10458-5126, USA; e-mail: bboom@nybg.org

Abstract. The New York Botanical Garden has had an institutional focus on global plant and fungal conservation, both explicitly and implicitly, throughout its 125 year history of botanical research, education and publication. Research has laid the underpinnings for species and habitat conservation. Education, formal and informal, has built human capacity for understanding and saving plants and fungi. Publications, in print and online, have disseminated authoritative results and science-based recommendations for enabling the conservation of biodiversity, from the Bronx to Brazil. This paper reviews the broad conservation themes pursued by the institution over this period, providing examples of specific projects, and concludes with the latest conservation initiative launched in 2015, the creation of the Center for Conservation Strategy.

Key Words: Conservation, Global Strategy for Plant Conservation.

From its founding in 1891, The New York Botanical Garden has had a three-fold mission of research, horticulture, and education. Embedded in all three of these areas has always been, and continues to be, a deep concern and commitment for promoting the conservation of plants and fungi and their habitats around the world. The Botanical Garden's conservation efforts span the gamut from protecting and caring for precious natural areas, such as its own native 50-acre Thain Family Forest, to enhancing conservation policies, such as trying to catalyze cooperation between the governments of Cuba and the United States on environmental issues of mutual concern (Boom, 2012).

Most of the Garden's influence on plant and fungal conservation derives from its track-record of exploring, documenting, and disseminating information about biodiversity. This authority is enabled by the Garden's outstanding collections in its William and Lynda Steere Herbarium and LuEsther T. Mertz Library, and its consistent and persistent efforts over the past 125 years to use these resources in a concerted research, education, and publication program. Without knowing the names of species, in addition to where they occur, what are their important traits, and how they are interrelated with other ecosystem components, there is no substantive basis for making decisions about conservation goals. Numerous publications have documented this linkage (e.g., McNeely, 2002).

Some conservation themes span the entirety of the Garden's existence, such as publications providing accounts of plants of protected natural areas, for example Yellowstone National Park in the first volume of the series *Memoirs of The New York Botanical Garden* (Rydberg, 1900). Other themes were developed more recently, such as assessments of the utility of plant and fungal resources and indigenous knowledge of them as a rationale for conserving natural habitats; Ghillean Prance et al. (1987) wrote a pioneering paper on the origins of quantitative ethnobotany and the case for conservation in Amazonia. In this paper, the Garden's conservation activities will be reviewed within the context of the Global Strategy for Plant Conservation (GSPC).

Conservation and the Early Years of The New York Botanical Garden

Nathaniel Lord Britton, Founding Director-in-Chief of The New York Botanical Garden, was vitally important in setting the direction of the

Brittonia 68(3): 305–316 (2016), DOI 10.1007/s12228-016-9421-9
ISSN: 0007-196X (print) ISSN: 1938-436X (electronic)

Published Online: 12 April 2016

institution in all of its programmatic areas, including conservation. He was entrepreneurial in building the Garden physically and in positioning it intellectually during the rapid growth of the young organization in the late 19th and early 20th centuries. His wife, Elizabeth Gertrude Knight Britton, a noted bryologist, was instrumental in this period of the Garden's history in many respects. Mickulas (2007: 145) wrote the best general reference on the Britton era, in which several conservation initiatives are discussed, among the earliest pertaining to the Garden's grounds themselves:

> One of [N. L.] Britton's earliest efforts to use this landscape to educate a broader audience than professional botanists was undertaken as part of a larger project of his wife's, the protection of native wildflowers. Elizabeth Britton was one of the founding members of the Wildflower Preservation Society of America, organized in 1902. In her later years, involvement with this organization would actually demand more attention than her own botanical research. Using $3200 donated by a pair of concerned New York sisters, Caroline and Olivia Phelps Stokes, the Brittons inaugurated an essay contest in which three prizes were awarded annually to the best pieces submitted for publication in the Garden *Journal* that advocated protection of native plants of the Northeast. The cash prizes were derived from the income of the invested gift of the Stokes sisters. He then distributed copies of these essays to various other botanical periodicals and newspapers. By doing so, Britton claimed, the victorious writers reached a nationwide audience of 'many thousands' and provided valuable pedagogic materials to American schoolteachers (many of whom had also received copies) [Britton, 1902]. Among the earliest winners were students conducting research at the Garden, including MA candidate Mary P. Anderson, who took her message of plant conservation directly to her students in the Bronx public schools.

Elizabeth Britton went on to champion the importance of protecting native plants through numerous publications (e.g., Britton, 1912a, 1912b, 1913, 1916). She even championed the rose as the United States' national floral emblem (V. B. Smocovitis, pers. comm.). Her efforts on behalf of plant conservation were recognized by a plaque placed on May 9, 1940, in what is today NYBG's Native Plant Garden by the New York Bird and Tree Club (Fig. 1). Gager (1940a) described the circumstances of the plaque dedication and Gager (1940b) discussed Elizabeth Britton's efforts to preserve native American wild flowers.

It was through ambitious floristic and monographic investigations launched during the Britton era that produced the Garden's earliest and most enduring most conservation-relevant scholarship. These titles are discussed in other papers in this volume (e.g., Thomas, 2016, this issue), but mention of some of them is warranted here. With respect to the flora of the Northeastern United States, Britton and Brown (1913) and Britton (1918) are noteworthy. The work on Cactaceae by Britton and Rose (1919–1923) is an outstanding example of an early, significant systematic monograph on a plant group of great conservation concern. Britton and Millspaugh (1920) and Britton and Wilson (1923–1930) exemplify the Garden's early documentation of the Caribbean flora. In the western United States, Curator of the Garden's Herbarium (1908–1931), Per Axel Rydberg, was active in documenting the flora (e.g., Rydberg, 1917), and

FIG. 1. Plaque dedicated May, 9, 1940, by the New York Bird and Tree Club, to remember Elizabeth Gertrude Knight Britton, "Lover of Wildflowers and Ardent Advocate for their Protection," as photographed in NYBG's Native Plant Garden in 2015. Photo by Lisa Vargues.

in the southeastern United States, John K. Small was similarly engaged (e.g., Small, 1933). North American ferns were popularized by the Garden's first pteridologist (Underwood, 1900). Mycology was also a very active field of study during the Britton era, and especially noteworthy in terms of conservation was the research by William A. Murrill on the isolation and description of the invasive fungus responsible for the devastating American chestnut blight (Rogerson & Samuels, 1996).

Internationally, during the Britton era the most important conservation focus was in the Caribbean region, and particularly in Puerto Rico, where Garden researchers, especially the Brittons, invested much time and effort to document the island's flora and advise about deforestation. For example, in a 1915 report entitled "The Forests of Puerto Rico," N. L. Britton presented as a speech to the U.S. National Academy of Sciences on the extensive deforestation of the island, in which he stated that the "remaining forests of Puerto Rico are quite insufficient for the needs of the island, either for forest products or for a satisfactory conservation of the rainfall." N. L. Britton frequently briefed the Garden's Board of Managers on the issue, and nine of his annual reports, published in the *Journal of The New York Botanical Garden* commented on Puerto Rico's deforestation problem.

As a testimony to the Brittons' influence in Puerto Rico, there is perhaps no better example than the naming of a mountain in the Luquillo Mountains in their honor because of their contributions to the study of the island's flora and their tireless conservation efforts, particularly concerning forestry. Dr. Juan Nolla, then Assistant Commissioner of Agriculture and Commerce in Puerto Rico wrote this in a letter to a colleague at the NYBG (Archives of Nathaniel and Elizabeth Britton, 1891–1934):

> We are very pleased that we have been able to name a mountain in the Luquillo [now "Caribbean"] National Forest in honor of the Brittons. I can assure you Mount Britton will be one of the most attractive places of the whole National Forest, and we are hoping that it may become a botanical shrine in the tropics. I have visited this region and find that it is as worthy an honor as Puerto Rico has to offer to her best botanist and friend.

One of N. L. Britton's graduate students at Columbia University went on to have a distinguished career in taxonomy and conservation. Otto Degener was appointed Collaborator in Hawaiian Botany by The New York Botanical Garden in 1935 and was associated with the Garden until his death in 1988. Degener's magnum opus was the seven-volume *Flora Hawaiiensis*, initiated in 1932. His wife, Dr. Isa Degener, was also a taxonomic botanist, his lifelong collaborator. She was appointed Honorary Collaborator of Hawaiian Botany at NYBG in 1975. Collectively, they authored ten books and over 400 journal articles. In 1979, The Senate of the State of Hawaii issued a resolution of commendation citing the outstanding conservation efforts of the Degeners (Archives of Otto Degener, 1921–1988).

Along with the Brittons, the Degeners were among the first scientists associated with the Botanical Garden who effectively combined scientific careers with a passion for conservation, creating a role model for the Garden's scientific staff over the years. A statement made by renowned plant taxonomist and explorer Bassett Maguire in 1973 (Howard & Boom, 1990) is emblematic of this concern for not only discovering and documenting biodiversity but also its conservation:

> Effective, efficient and practical use of land and administration thereof in the neotropics can only derive from the application of information based upon thorough inventory of resources and technically sound interpretation of the whole bioecosystem of the neotropics. Such resulting practice will constitute the true conservation.

The Rise of the Environmental Movement and The New York Botanical Garden

As the public's interest in environmental causes grew beginning in the early 1960s, so too was there an increase in overt conservation activities at NYBG. One important development was the acquisition by the Garden of a

large tract of land in Dutchess County, New York, about 75 miles north of the Bronx. This property had been held by the Mary Flagler Cary Charitable Trust and the Garden competed for the property, which was also being bid on by several universities and national conservation organizations. In 1971, the Trust accepted the Garden's proposal to establish an arboretum on the property devoted to research and educational activities. Opening to the public in 1977, the disciplinary focus was on ecology. In 1983, the newly created Institute of Ecosystem Studies was founded at the Cary Arboretum and emphasis on the arboretum component of the property was reduced while the ecological research component was expanded under the leadership of Gene E. Likens. In 1990, the Institute of Ecosystem Studies (IES) became an independent, non-profit corporation. In 2008, the IES changed its name to Cary Institute of Ecosystem Studies.

Another institutional innovation contemporaneous with the creation of the Institute of Ecosystem Studies was the launch in 1981 of the Institute of Economic Botany, discussed in detail by Balick (2016, this issue). The Institute of Economic Botany, under founding Director Ghillean T. Prance, and subsequently under leadership of Michael J. Balick, has been instrumental in a wide range of diverse conservation-relevant initiatives around the world, as will be apparent in the discussion below. The Garden's Institute of Economic Botany advances conservation through the integration of research on traditional plant resources management studies with cutting-edge management ecological studies. E. O. Wilson (1992: 283) wrote a very eloquent passage about the rise of what he termed the "New Environmentalism" that quite well sums up the way that understanding the ways people use plants (or other components of the biosphere) offers an important way to contribute to biodiversity conservation:

> Only new ways of drawing income from land already cleared, or from intact wildlands themselves, will save biodiversity from the mill of human poverty. The race is on to develop methods, to draw more income from the wildlands without killing them, and so to give the invisible hand of free-market economics a green thumb.

Meanwhile, conservation gained a greater presence in the Garden's portfolio internationally. For example, Robert Goodland, who went on to become the first full-time ecologist with the World Bank, was contracted by the Garden in the 1970s to conduct a program of ecological research and environmental assessment, mostly in Latin America. Among his most notable accomplishments was publication of the book, co-authored by Garden scientist Howard Irwin, *Amazon Jungle: Green Hell to Red Desert* (Goodland & Irwin, 1975). This seminal book set the stage for a strong environmental focus on plants and the environment in Amazonian Brazil by subsequent Garden researchers, championed most prominently in the 1980s by Ghillean T. Prance, then Senior Vice President for Science. Prance (2014) recounted his 25 years of exploring for plants while at the Garden and discussed his deepening commitment to conservation concerns in the process.

The Global Strategy for Plant Conservation and The New York Botanical Garden

The Garden's conservation activities, past and present, can be discussed within the context of the Global Strategy for Plant Conservation (GSPC), a well-conceived and comprehensive document that serves as an internationally accepted guideline within the Convention on Biological Diversity for what needs to be achieved in plant conservation by 2020 (https://www.cbd.int/gspc/strategy.shtml). The GSPC has five broad objectives, and within these a total of 16 specific targets. This discussion of the Garden's conservation initiatives will be organized around the five objectives; in some cases, specific targets will be referenced when particular Garden projects tightly fit any given target.

GSPC Objective I: Plant diversity is well understood, documented and recognized

The intellectual core and preponderance of NYBG's science and conservation efforts and accomplishments over the past 125 years align squarely with GSPC Objective I. The first step in NYBG's work to understand, document, and recognize plant and fungal diversity is through research expeditions and specimen collecting. More than 1000 expeditions were undertaken by NYBG staff, graduate students, and collaborators

between 1897 and 1994 (Boom, 1996a). From 1995 to the present, more than 1300 additional expeditions have been made by NYBG. Tangible testimony to the plant collecting efforts undertaken by NYBG staff, students, and collaborators is found in the more than 600 volumes of collectors' field notebooks in the Mertz Library's archives (Fraser, 1996). NYBG's history of specimen collecting expeditions was summarized by Thomas (2016, this issue).

NYBG's herbarium from its inception to 1995 was reviewed by Holmgren et al. (1996). Pace et al. (2016, this issue) summarized the development of the William and Lynda Steere Herbarium from 1995–2015. The digitization of specimens in the Steere Herbarium began in 1995, and Thiers et al. (2016, this issue) described the dramatic growth of this internationally important digital resource, the C. V. Starr Virtual Herbarium and its many electronic catalogs. Herbarium specimens are fundamental to the accomplishment of GSPC Objective I, as specimens are the tangible links between species in nature and all that science knows about them through scholarly and popular publications. Digital versions of specimens further the democratization of knowledge of plant and fungal diversity and, in turn, of the conservation of this diversity. The role of herbarium specimens in science and society was summarized in Boom (1996b).

Thomas (2016, this issue) discussed the floristic productivity of NYBG, and Daly (2016, this issue) the monographic and other outputs of systematic botany research at NYBG, which were all based on herbarium specimens, so those specifics will not be repeated here. Boom (2016, this issue) summarized the extensive and diverse scholarly publications produced by NYBG Press since 1896. Printed and electronic publications on the systematics and economic aspects plant and fungal diversity all underpin the understanding and recognition of plant and fungi diversity and make possible scientific bases for species conservation.

Under GSPC Objective I, Target 1 calls for "an on-line flora of all known plants," and a recently initiated international project, World Flora Online (WFO) is explicitly designed to accomplish that goal. NYBG is one of four botanical organizations leading the effort to forge the WFO, along with the Missouri Botanical Garden, the Royal Botanic Gardens-Kew, and the Royal Botanic Gardens-Edinburgh. The particular emphasis of NYBG on digitizing and providing information on species in this massive effort will be the plants of the Western Hemisphere, historically and currently an institutional geographical focus (Thomas & Tulig, 2015). The WFO is a critical first step in achieving both Targets 2 and 3, discussed below, and is one of the reasons WFO has received such high scientific and institutional attention at NYBG.

Also under GSPC Objective I, Target 2 is for "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation efforts." NYBG scientists have been engaged in producing conservation assessments of species since the early 20th century (e.g., E. Britton, 1917) in a qualitative manner, and more robustly ever since the International Union for the Conservation of Nature (IUCN) Red List was created a half century ago through participation in the Species Survival Commission (SSC) for a number of critical plant groups (e.g., cycads, palms, orchids, and lichens). Recent, specific examples are the review paper on the status of fungal conservation in the United States (Allen & Lendemer, 2015), and the successful petitioning of IUCN for Red Listing of the lichen species, *Cetradonia linearis* (A. Evans) J. C. Wei & Ahti as Globally Threatened (http://www.iucnredlist.org/details/70386009/0). The high-elevation southern Appalachian Mountains habitat for this species is shown in Fig. 2, and described within the context of a paper examining the climate change implications for lichen species endemic to this restricted habitat (Allen & Lendemer, 2016); the authors of the paper found that climate

FIG. 2. Doctoral candidate Jessica Allen searches for *Cetradonia linearis*, one of two fungi currently on the United States Federal Endangered Species List, in Forney Creek, Great Smoky Mountains National Park, in August 2015. She found it! Photo by Sean McKenzie.

change poses a significant threat to high-elevation lichens, and they provided a case study in the application of current modeling techniques for rare, montane species.

An examination of The IUCN Red List of Threatened Species (Version 2014.3) as to how many of the world's estimated 450,000 of the plant species have had their global threat status assessed reveals that number to be just under 20,000 species, due to the extensive time and effort needed for the required documentation. That fewer than five percent of the world's plant species have had their global conservation status assessed by the IUCN since The Red List was launched 50 years ago strongly suggests the urgent need for more streamlined methods to achieve such assessments in a timeframe sensitive to the world's conservation needs.

To address this conservation bottleneck, NYBG scientists and collaborators recently developed rapid protocols for making preliminary conservation assessments of plant species. As a test case based on species of seed plants of Puerto Rico, two different methods using information only derived from herbarium specimens, one developed at NYBG and the other at the Smithsonian, were jointly published (Miller et al., 2012). Then, these preliminary assessments were tested against a provisional IUCN Red List analysis by an expert panel of taxonomists in Puerto Rico. Both systems were effective at identifying plant species at risk, with the NYBG analysis identifying 98 percent and the Smithsonian analysis 85 percent of the plant species classified as Threatened in the IUCN Red List. Used in combination, the two streamlined methods identified 99 percent of the species IUCN would consider Globally Threatened (Miller et al., 2013). Using such methods reduces by orders of magnitude the amount of time needed to produce preliminary conservation assessments of species, and points the way to meet Target 2 by the year 2020, as stipulated by the GSPC.

Target 3 is "Information, research and associated outputs, and methods necessary to implement the Strategy developed and shared." NYBG scientists have been quite active in publishing books over the years related to this target of GSPC Objective I. In the realms of economic botany, ethnobotany, and sustainable development, examples include Prance and Balick (1990) on new directions in the study of plants and people, Peters (1994) on sustainable harvest of non-timber plant resources, and Alexiades (1996) on selected guidelines for ethnobotanical research. With respect to systematic botany, examples include the landmark writings of Arthur Cronquist (e.g., Cronquist, 1981), and the more recent research on the Tree of Life or Genealogy of Life project, funded principally by the National Science Foundation and private donors through the Lewis B. and Dorothy Cullman Program for Molecular Systematics (http://www.nybg.org/science/cullman.php).

GSPC Objective II: Plant diversity is urgently and effectively conserved

NYBG participates in a number of consortia, from local to international levels, active in this GSPC Objective. Locally, NYBG is currently a member of the Environmental Monitoring and Management Alliance (EMMA) and the Lower Hudson Partnership for Regional Invasive Species Management (PRISM). Nationally, NYBG is a member of the Center for Plant Conservation (CPC), and is the primary custodian for *ex situ* conservation of several threatened taxa (*Cerastium arvense* L. var. *villosissimum* Pennell, *Prunus maritima* Marsh. var. *gravesii* (Small) G.J. Anderson, *Helonias bullata* L., *Marshallia grandiflora* Beadle & F.E. Boynt., and *Carex barrattii* Schweinitz & Torrey). Internationally, NYBG is a member of the Botanical Garden Conservation International's Ecological Restoration Alliance (ERA). NYBG's participation in the ERA is primarily due to its stewardship of the 50-acre old growth forest on its 250-acre grounds in the Bronx, The Thain Family Forest, site of extensive and diverse long-term ecological research, monitoring, restoration, and environmental education (http://www.nybg.org/gardens/thain-family-forest/).

One of the most important conservation issues locally in the New York City area concerns not endangered species but invasive species. A recent case is that of the emerging invasive species *Corydalis incisa* (Fumariaceae), an escaped garden plant native to Asia, which arrived in the United States via nurseries in Europe. This invasive species was first documented in the Bronx in 2005 and subsequently to the north in Westchester County, New York (Atha et. al, 2014). More recently it has been found in the Philadelphia and Washington, D.C., areas. This species has the

potential to crowd out and dominate over native species. Early detection and rapid intervention comprise the best formula to at least contain and hopefully eliminate emerging invasive species.

Internationally, NYBG scientists have contributed expertise and data that led directly to the creation of protected natural areas. For example, in Brazil, Wm. Wayt Thomas and colleagues provided plant inventory data that led to the acquisition of land forming the largest state park in Bahia, the Parque Estadual Serra do Conduru. In Belize, Michael J. Balick and colleagues contributed data that led to the creation in 1993 of the world's first medicinal plant reserve; this 6000 acre reserve, dedicated to the preservation of potential lifesaving herbs, is called the Terra Nova Medicinal Plant Reserve. On the island of Eleuthera in the Bahamas, NYBG was a founding partner in the creation of the Leon Levy Native Plant Preserve, a conservation unit managed by the Bahamas National Trust. In southern Chile, data on bryophytes provided by William R. Buck and collaborators contributed the only botanical information available to make a successful case for creation of the Parque Etnobotánica Omora and the UNESCO Cape Horn Biosphere Reserve.

Another sort of international conservation service provided by NYBG is in the arena of broad assessments based on herbarium specimen data for plant species of a particular region. Such was the case for the Caribbean Islands Biodiversity Hotspot for a study commissioned by the Critical Ecosystem Partnership Fund (CEPF). To provide an informational basis for awarding conservation grants in the Caribbean region, the CEPF wanted an ecosystem assessment done. Brian M. Boom and Hannah I. Stevens, employed herbarium specimen data, which were analyzed in the NYBG's Geographic Information Systems Laboratory, to provide conservation assessments for plant species for this Biodiversity Hotspot (Anadón-Irizarry et al., 2012).

The CEPF recently announced the designation of the world's 36th Biodiversity Hotspot: the North American Coastal Plain (NACP) Biodiversity Hotspot (http://www.cepf.net/news/top_stories/Pages/Announcing-the-Worlds-36th-Biodiversity-Hotspot.aspx). In designating this Hotspot the CEPF emphasized specific ecosystems as important to plants, however Lendemer et al. (in press) have shown that other ecosystems in the region are of greater conservation importance to lichens. Lendemer and colleagues have studied the lichen biodiversity of the Mid-Atlantic Coastal Plain over the last four years, and their efforts have contributed in a multitude of ways to new species discovery, conservation, land-use management, and public awareness.

Within the United States, the many floristic and monographic projects of NYBG described by Thomas (2016, this issue) and Daly (2016, this issue) have contributed importantly to the nation's conservation of plant resources though protected areas or multi-purpose use areas such as national forests. The case of the *Intermountain Flora* provides an excellent illustration of the relationship between basic floristic research and the conservation of plant species and habitats because it is has been a project so well documented over its seven decades of specimen collecting and publishing, beginning in 1943 and concluding in 2016 with the publication of its final volume of (Holmgren & Holmgren, in press). In the Archives of the NYBG's LuEsther T. Mertz Library, there is a folder of more than three dozen letters from users of *Intermountain Flora* testifying how vital this reference is to their conservation work. Entities represented among the testimonial letters include the U.S. Forest Service, Utah State University, Canyonlands National Park, the Nevada Natural Heritage Program, the Department of Natural Resources of the State of Utah, the U. S. Geological Survey's Biological Resources Division, the Idaho Conservation Data Center, the Missouri Botanical Garden, the Smithsonian Institution, Harvard University, the U.S. Bureau of Land Management, the U. S. Fish and Wildlife Service, The Nature Conservancy, the University of Nevada's Environmental and Resource Sciences Department, and Grand Canyon-Parashant National Monument. This statement from Teresa Prendusi, Regional Botanist, the U.S. Forest Service Intermountain Region, sums up the importance of this publication as well as any of the letters in the archives:

> *Intermountain Flora* has been an indispensable tool for us as well as for other Federal (Bureau of Land Management, Fish and Wildlife Service, National Park Service, Natural Resources Conservation Service, Department of Energy) and State agencies for the Interior West. Every natural resource specialist in the fields of Botany, Ecology,

Range Management, Soil Science, and Forestry utilizes this reference on a regular, if not daily basis.

A specific, recent example of NYBG's contributions to plant conservation outcomes is the case of Williams' springparsley, *Cymopterus williamsii* R. L. Hartm. & Constance (Apiaceae), in north-central Wyoming. NYBG Press published this taxon as a new species in its journal of systematic botany, *Brittonia* (Hartman & Constance, 1985). This rare species was subsequently the subject of a Bureau of Land Management publication on its conservation status (Handley, 2016), and for it NYBG Press granted gratis permission for reproduction of the illustration of this species from the original *Brittonia* article. Such scenarios involving publication of new species and subsequent use of this information in conservation assessments have played out innumerable times over the past 125 years, and they represent a tangible and vital service to the conservation of plant and fungal species by NYBG.

GSPC Objective III: Plant diversity is used in a sustainable and equitable manner

The discipline of economic botany traces its origins at NYBG back to the late 19th and early 20th centuries through the pioneering efforts of Henry Hurd Rusby (Williams & Fraser, 1992). The creation of the Institute of Economic Botany in 1981 (Balick, 2016, this issue) set in motion a coordinated line of investigation at NYBG that explicitly addressed the spirit of GSPC Objective III. In fact, the entire productivity of the Institute of Economic Botany is supportive of GSPC Objective III, so the particulars do not need to be repeated herein.

Peters (2016, this issue) specifically detailed the sorts of projects undertaken by scientists and collaborators of the Institute of Economic Botany that supported the sustainable and equitable use of plant diversity. Concern for the human component of the discipline of economic botany was and continues to be a central feature of NYBG's efforts in this arena, and exemplified by many of the titles published in the series Advances in Economic Botany (e.g., Posey & Balée, 1989), currently offering seventeen titles. Beyond the NYBG Press' publications, other titles merit mention in this context. For example, the work of Denslow and Padoch (1988) was emblematic of the concern and focus on the equity issues surrounding the sustainable management of natural resources and set the tone of a generation of scholarship concerning the intersection of plant diversity and people that continues to this day.

Of the many studies that could be cited here, the long-term collaborative project in Belize between Ix Chel Farm and the NYBG is emblematic of the sorts of NYBG initiatives that address GSPC Objective III. Balick and Arvigo (2015) is the culmination of decades of research and outreach and concern for sustainable and equitable use of medicinal plant resources in Belize. Additional current projects that address this GSPC objective are taking place in localities such as Myanmar, Vanuatu, Brazil, and Jamaica.

A number of current projects in the NYBG's laboratory have relevance to the sustainable and equitable use of plant resources; for details and an historical retrospective, see D. W. Stevenson (2016, this issue). Warranting mention in this article are projects to conduct DNA barcoding of dietary supplements, a phylogenomic and systems biology approach to identify genes underlying plant survival in marginal, low-nitrogen soils, and a molecular-based plant inventory of a megadiverse Bahian forest (http://www.nybg.org/science-new/explore/laboratory-research.php).

GSPC Objective IV: Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on Earth is promoted

NYBG has a long tradition of outreach to the public and other professionals with respect to the importance of plant diversity to science and society. The institution's Adult Education program is the largest of any botanical garden in the world (http://www.nybg.org/adulted/). Abundant opportunities exist for the public to engage with conservation projects through the NYBG's Citizen Science offerings, particularly in The Thain Family Forest (http://www.nybg.org/

sustainability/citizen_science.php). NYBG also has a very robust and fully subscribed internship program for students, from high school through post-graduate, for science and conservation themed projects (J. Stevenson, 2016, this issue). This Objective of the GSPC is also supported importantly by the NYBG's publications program, which has issued scholarly publications on plants and fungi since 1896 (Boom, 2016, this issue); for the online catalog see http://www.nybgpress.org/. Public symposia on conservation-relevant topics are regularly offered by NYBG; several examples include *Climate Change: Prospects for Nature* in 2006, *Gardening in a Changing Climate* series in 2007, and the *Native Plants Summit* and *Invasive Species Summit* in 2015.

Another important way that NYBG contributes to this GSPC Objective is through the diaspora of hundreds of scientists who have graduated from its doctoral and masters programs conducted jointly with a number of academic institutions since 1896 (Lentz & Bellengi, 1996; Kelly, 2016, this issue). These former graduate students have taken professional positions in all continents, and not just at the expected academic and research institutions, but significantly also at governmental agencies and not-for-profit organizations that are relevant to conservation; examples include the Brazilian Agricultural Research Corporation (EMBRAPA), the Royal Forest Department of Thailand, Agricultural Research Service and the Animal and Plant Health Inspection Service of the United States Department of Agriculture, The Nature Conservancy, NatureServe, and the Fundación Ecuatoriana de Estudios Ecológicos (EcoCiencia).

NYBG addresses GSPC Objective IV on its Bronx campus, and it does so through its many projects around the world. Recent examples include support of an environmental non-governmental organization in Cuba, Planta!, which provides to the public information about the importance of plants and their conservation, and initiatives in Brazil, Myanmar, and Vanuatu that similarly provide public outreach regarding the biodiversity conservation results produced through NYBG research projects in those countries; for a selection of current conservation projects that address this GSPC Objective, see http://www.nybg.org/science-new/explore/conservation.php.

GSPC Objective V: The capacities and public engagement necessary to implement the Strategy have been developed

The main way NYBG has fulfilled this objective of the GSPC has been through its graduate studies program, documented in detail by Lentz and Bellengi (1996) and more recently by Kelly (2016, this issue); the author of this article (Ph.D., 1983, CUNY/NYBG) can attest personally to the program's efficacy! NYBG has also a solid track record of enabling the visits of researchers to use the collections of the William and Lynda Steere Herbarium and the LuEsther T. Mertz Library and to use the facilities of the Pfizer Plant Research Laboratory and the Geographic Information Systems Laboratory; for example, over the past quarter century, more than two dozen botanists from Cuba alone have made research visits to NYBG for these purposes. Resources available for researchers and the public who cannot visit NYBG include the Starr Virtual Herbarium and the Mertz Library online catalog and other digital resources.

Overseas, NYBG projects continue to engage the public and build capacity of professionals associated with the institution's collaborative projects, dating back to the Brittons' concerns for wildflower conservation and the forests of Puerto Rico, previously mentioned. An excellent present-day example from South America is the Act of Technical Cooperation between NYBG and the Brazilian Forest Service that gives NYBG a formal advisory role on aspects of forest inventory that involve training and identification of tree diversity (http://www.nybg.org/press_releases/AMAZONFORESTPROGRAMRELEASE.pdf). In Asia, a multidisciplinary project in Myanmar currently is engaging with the Forest Service and local universities to build capacity among staff and faculties and to develop plans to conserve the country's flora (http://www.nybg.org/press_releases/NYBGMYANMARPROGRAM.pdf). In the Pacific island nation of Vanuatu, NYBG has partnered with the Vanuatu Department of Forestry, the Vanuatu Cultural

Center, the Tafea Kaljarol Senta, and the Vanuatu Department of Environment and Conservation, as well as collaborators from the University of Hawaii and the University of the South Pacific to document the country's flora and to provide training to resident professionals (http://blogs.nybg.org/science-talk/2014/12/from-the-field-a-botany-lesson-in-vanuatu/).

Locally, in the New York City area and the surrounding region, current projects likewise engage the public and develop capacity, such as the Flora of Central Park project (http://www.nybg.org/files/scientists/datha/CentralPark/Index.html), the revision of the classic Gleason and Cronquist *Manual of Vascular Plants of the Northeastern United States and Adjacent Canada* (http://www.nybg.org/science-new/explore/newmanual.php), and monitoring the spread of the invasive alga, Starry Stonewort (http://www.nybg.org/science-new/explore/nitellopsis.php).

Center for Conservation Strategy

In January 2015, The New York Botanical Garden established a new conservation program, the Center for Conservation Strategy, to increase its effectiveness as a global leader in conservation. As outlined above, NYBG has been concerned with conservation issues since the founding of the institution. What is new is that for the first time NYBG has a program dedicated to this important endeavor. A local initiative is the Flora of Central Park in New York City. That project will be leveraged into a citywide eco-flora of New York City. An eco-flora would be much richer than a typical flora because it would have numerous ecological parameters for each species. Remarkably, it does not exist already, and NYBG has all the resources to do it in partnership with other New York City-based organizations. On the other end of the scale, NYBG is undertaking a more global project addressing Target Two of the Global Strategy for Plant Conservation, namely to assess the conservation status of all plant species by 2020. NYBG has proposed to take a leadership role in getting these assessments done for the New World plants, which comprise probably about 125,000 species.

The Center for Conservation Strategy will integrate talents and energies from across the institution to maximize creative and effective conservation outcomes. Why should NYBG do this now? The world's environmental situation seems so dire that this institution needed to take its conservation responsibilities to a new level and give them new focus and energy and funding. NYBG needed to do it in a way that results in concrete actions, tangible conservation work, focusing on those places in the world for which the institution is uniquely positioned to make a difference.

Acknowledgments

The author is very grateful to the generosity of two members of the NYBG's Board of Managers for providing initial funding for the Center for Conservation Strategy, and he is also appreciative for the helpful suggestions that two reviewers provided for improving this manuscript. Lisa Vargues of the Steere Herbarium provided valuable assistance with research on the conservation initiatives of the Brittons, and she also contributed the photograph (Fig. 1) of the bronze plaque from the NYBG's Native Plant Garden to honor Elizabeth Britton's contributions to wildflower conservation. Sean McKenzie took the photograph featuring the Lichen Conservation Project in Great Smoky Mountains National Park (Fig. 2).

Literature Cited

Alexiades, M. N. 1996. Selected Guidelines for Ethnobotanical Research: A Field ManualAdvances in Economic Botany, Volume 10.

Allen, J. L. & J. C. Lendemer. 2015. Fungal conservation in the USA. Endangered Species Research 28: 33–42.

——— & ———. 2016. Climate change impacts on endemic, high-elevation lichens in a biodiversity hotspot. Biodiversity Conservation. Published online February 27, 2016. http://link.springer.com/article/10.1007%2Fs10531-016-1071-4.

Anadón-Irizarry, V., D. C. Wege, A. Upgren, R. Young, B. Boom, Y. M. León ,Y. Arias, K. Koenig , A. L. Morales, W. Burke , A. Pérez-Leroux, C. Levy, S. Koenig, L. Gape & P. Moore. 2012. Sites for priority biodiversity conservation in the Caribbean Islands Biodiversity Hotspot. Journal of Threatened Taxa 4(8): 2806–2844.

Archives of Nathaniel and Elizabeth Britton. 1891–1934. http://mertzdigital.nybg.org/. LuEsther T. Mertz Library, New York Botanical Garden.

Archives of Otto Degener. 1921–1988. http://sciweb.nybg.org/science2/libr/finding_guide/degener3.asp.html. LuEsther T. Mertz Library, New York Botanical Garden.

Atha, D, J.A. Schuler & S. Lumban Tobing. 2014. *Corydalis incisa* (Fumariaceae) in Bronx and Westchester counties, New York. Phytoneuron 2014-96: 1–6.

Balick, M. J. 2016, this issue. Transforming the study of plants and people: A reflection on 35 years of the NYBG Institute of Economic Botany. Brittonia 68(3).

——— **& R. Arvigo.** 2015. Messages from the Gods: A Guide to the Useful Plants of Belize. Oxford University Press: Oxford.

Boom, B. M. 1996a. Botanical expeditions of The New York Botanical Garden. Brittonia 48(3): 297–307.

———. 1996b. Societal and scientific information needs from plant collections. Pp. 16–27. *In*: T. F. Stuessy & S. H. Sohmer (eds.). Sampling the Green World. New York: Columbia University Press. **289 pp**.

———. 2012. Biodiversity without borders: Advancing U.S.-Cuba cooperation through environmental research. Science & Diplomacy 9(3): 49–68. http://www.sciencediplomacy.org/article/2012/biodiversity-without-borders

———**.** 2016, this issue. Get it into print! 120 years of scholarly publishing by The New York Botanical Garden. Brittonia 68(3).

Britton, E. K. 1912a. Thoughtless destruction of Jack in the Pulpit. Journal of The New York Botanical Garden 13(149): 68–69.

——— 1912b. Wild plants needing protection. Journal of The New York Botanical Garden, published series 1912–1929.

——— 1913. Disappearing wild flowers. Torreya 20:101.

——— 1916. Public parks as preserves of native plants. Torreya 16:182–183.

———. 1917. The conservation of wildflowers. American Museum Journal 17: 350–352.

Britton, N. L. 1902. Results of the use of the Stokes Fund for the Conservation of Native Plants. Journal of The New York Botanical Garden 3: 179–180.

Britton, N. L. 1918. Flora of Bermuda. Scribner: New York. **614 pp**.

——— **& A. Brown.** 1913. An illustrated flora of the northern United States, Canada and the British possessions, from Newfoundland to the parallel of the southern boundary of Virginia, and from the Atlantic Ocean westward to the 102d meridian. 2d ed. rev. and enl. C. Scribner, N.Y.

——— **& C. F Millspaugh.** 1920. The Bahama Flora. The authors: New York.

——— **& J. N. Rose.** 1919–1923. The Cactaceae: descriptions and illustrations of plants of the cactus family. Carnegie Institution of Washington: Washington, DC.

——— **& P. Wilson.** 1923–1930. Botany of Porto Rico and the Virgin Islands. Descriptive flora, Spermatophyta. Scientific survey of Porto Rico and the Virgin Islands. v.5-6. New York Academy of Sciences: New York.

Cronquist, A. C. 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press: New York.

Daly, D. C. 2016, this issue. Systematics and systematists at The New York Botanical Garden. Brittonia 68(3).

Degener, O. 1932. Flora Hawaiiensis; the new illustrated flora of the Hawaiian Islands. Honolulu.

Denslow, J. S. & C. Padoch (eds.). 1988. People of the Tropical Rain Forest. University of California Press: Oakland, California.

Fraser, S. 1996. Collectors' field notebooks at The New York Botanical Garden Library. Brittonia 48: 308–317.

Gager, C. S. 1940a. Mrs. Britton honored in dedication of plaque by New York Bird and Tree Club in Wild Flower Garden. Journal of The New York Botanical Garden 41(486): 129–137.

———**.** 1940b. Elizabeth G. Britton and the movement for the preservation of native American wild flowers. Journal of The New York Botanical Garden 41(486): 137–142.

Goodland, R. J. A. & H. S. Irwin. 1975. Amazon Jungle: Green Hell to Red Desert: an ecological discussion of the environmental impact of the highway construction program in the Amazon Basin. Elsevier Scientific Publishing: New York.

Handley, J. 2016. Status of *Cymopterus williamsii* (Williams' springparsley), north-central Wyoming. Report prepared for Bureau of Land Management – Worland Field Office and Wyoming State Office by Wyoming Natural Diversity Database – University of Wyoming Laramie, Wyoming.

Hartman, R. L. & L. Constance. 1985. Two new species of *Cymopterus* (Umbelliferae) from western North America. Brittonia 37: 88–95.

Holmgren, P. K., J. A. Kallunki & B. M. Thiers. 1996. A short description of the collections of The New York Botanical Garden Herbarium (NY). Brittonia 48(3): 285–296.

Holmgren, N. H. & P. K. Holmgren. In press. Potpourri: Keys, History, Authors, Artists, Collectors, Beardtongues, Glossary, Indices. Intermountain Flora, volume 7.

Howard, R. A. & B. M. Boom. 1990. Bassett Maguire – annotated biography. Memoirs of The New York Botanical Garden 64: 1–28.

Kelly, L. M. 2016, this issue. Training the next generation: Graduate studies at The New York Botanical Garden, with emphasis on 1996–2015. Brittonia 68(3).

Lendemer, J. C., R. C. Harris & A. M. Ruiz. In press. A review of the lichens of the Dare Regional Biodiversity Hotspot in the Mid-Atlantic Coastal Plain of North Carolina, eastern North America. Castanea.

Lentz, D. L. & M. Bellengi. 1996. A brief history of the Graduate Studies Program at The New York Botanical Garden. Brittonia 48: 404–412.

McNeely, J. A. 2002. The role of taxonomy in conserving biodiversity. Journal for Nature Conservation 10: 145–153.

Mickulas, P. 2007. Britton's Botanical Empire: The New York Botanical Garden and American Botany, 1888-1929. Memoirs of The New York Botanical Garden. 94: 1–317.

Miller, J. S., H. A. Porter-Morgan, H. Stevens, B. Boom, G. A. Krupnick, P. Acevedo-Rodríguez, J. Fleming & M. Gensler. 2012. Addressing target two of the Global Strategy for Plant Conservation by rapidly identifying plants at risk. Biodiversity and Conservation 21(7): 1877–1887.

———**, G. A. Krupnick, H. Stevens, H. Porter-Morgan, B. Boom, P. Acevedo-Rodríguez, J. Ackerman, D. Kolterman, E. Santiago, C. Torres & J. Velez.** 2013. Toward Target 2 of the Global Strategy for Plant Conservation: An expert analysis of the Puerto Rican flora to validate new streamlined methods for assessing conservation status. Annals of the Missouri Botanical Garden 99: 199–205.

Pace, M. C., N. Tarnowsky, E. D. Bloch, A. Weiss, C. Zimmerman & B. Thiers. 2016, this issue. An updated description of the collections and history of The New York Botanical Garden Herbarium (NY): 1995–2015. Brittonia 68(3).

Peters, C. M. 1994. Sustainable Harvest of Non-timber Plant Resources in Tropical Moist Forest: An Ecological Primer.

The Biodiversity Support Program, c/o World Wildlife Fund: Washington, DC.

———. 2016, this issue. Community forestry and sustainability research at The New York Botanical Garden. Brittonia 68(3).

Posey, D. A. & W. Balée (eds.). 1989. Resource Management in Amazonia: Indigenous and Folk Strategies. Advances in Economic Botany, Volume 7.

Prance, G. T. 2014. That Glorious Forest: Exploring the Plants and their Indigenous Uses in Amazonia. New York Botanical Garden Press: New York.

———, W. Balée, B. M. Boom & R. Carneiro. 1987. Quantitative ethnobotany and the case for conservation in Amazonia. Conservation Biology 1: 296–310.

——— & M. J. Balick (eds.). 1990. New Directions in the Study of Plants and People. Advances in Economic Botany, Volume 8

Rogerson, C. T. & G. J. Samuels. 1996. Mycology at The New York Botanical Garden, 1895-1995. Brittonia 48: 389–398.

Rydberg, P. A. 1900. Catalogue of the flora of Montana and the Yellowstone National Park. Memoirs of The New York Botanical Garden. 1: 1–492.

———. 1917. Flora of the Rocky Mountains and adjacent plains: Colorado, Utah, Wyoming, Idaho, Montana, Saskatchewan, Alberta, and neighboring parts of Nebraska, South Dakota, North Dakota, and British Columbia. Published by author: New York.

Small, J. K. 1933. Manual of the southeastern flora :being descriptions of the seed plants growing naturally in Florida, Alabama, Mississippi, eastern Louisiana, Tennessee, North Carolina, South Carolina and Georgia. Published by author: New York.

Stevenson, D. W. 2016, this issue. The history of laboratory research at The New York Botanical Garden. Brittonia 68(3).

Stevenson, J. W. 2016, this issue. Science internships at NYBG: Origins, history, and current status. Brittonia 68(3).

Thiers, B. M., M. C. Tulig & K. A. Watson. 2016, this issue. Digitization of The New York Botanical Garden Herbarium. Brittonia 68(3).

Thomas, W. W. 2016, this issue. 125 Years of Floristic Research and Collecting at The New York Botanical Garden. Brittonia 68(3).

——— & M. Tulig. 2015. Hard copy to digital: Flora Neotropica and the World Flora Online. Rodriguésia 66: 983–987.

Underwood, L. M. 1900. Our native ferns and their allies with synoptical descriptions of the American Pteridophyta north of Mexico. Henry Holt: New York. **184 pp**.

Williams, D. E. & S. M. Fraser. 1992. Henry Hurd Rusby: The Father of Economic Botany at The New York Botanical Garden. Brittonia 44: 273–279.

Wilson, E. O. 1992. The Diversity of Life. Harvard University Press: Cambridge.