CONTENTS

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REPORT OF THE SECOND CONFERENCE AND GENERAL MEETING OF THE GLOBAL PARTNERSHIP FOR PLANT CONSERVATION[1]

Peter Wyse Jackson[2]

Abstract

The second conference of the Global Partnership for Plant Conservation (GPPC) was organized by the GPPC, in association with the Secretariat of the Convention on Biological Diversity (SCBD) and Botanic Gardens Conservation International (BGCI). This general meeting was hosted by the Missouri Botanical Garden and was held 5–7 July 2011, in St. Louis, Missouri.

Key words: Convention on Biological Diversity (CBD), Global Partnership for Plant Conservation (GPPC), Global Strategy for Plant Conservation (GSPC).

At its sixth meeting, the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD, 2002) adopted Decision VI/9 on the Global Strategy for Plant Conservation (GSPC), which included outcome-oriented global targets for 2010. The ultimate and long-term objective of the Strategy is to halt the current and continuing loss of plant diversity. The aim of the Strategy is to achieve plant conservation, and it is also concerned with aspects of sustainable use, capacity building, and benefit sharing.

The GSPC Expert Group meeting in Dingle, Co. Kerry, Ireland, in October 2003 noted that the Strategy provides a useful framework to bring together organizations and initiatives to meet common objectives and recommended the establishment of a wide global partnership to support its implementation (CBD, 2003).

The Global Partnership for Plant Conservation (GPPC) was subsequently launched on 13 February 2004 at a meeting held during the seventh COP of the CBD, in Kuala Lumpur, Malaysia. In its Decision VII/10 on the GSPC (CBD, 2004), the COP welcomed the establishment of the GPPC and encouraged the participating organizations to continue to contribute to the implementation of the Strategy. It also invited other organizations to join the Partnership and encouraged Botanic Gardens Conservation International (BGCI) to continue its support for the Partnership.

The aim of the Partnership is to support the worldwide implementation of the GSPC, and its objective is to provide a framework to facilitate harmony between existing initiatives aimed at plant conservation, identify gaps where new initiatives are required, and promote mobilization of the necessary resources.

[1] This and the following 13 articles are the proceedings of the Global Partnership for Plant Conservation Conference, "Supporting the Worldwide Implementation of the Global Strategy for Plant Conservation." The conference was held 5–7 July 2011, at the Missouri Botanical Garden in St. Louis, Missouri, U.S.A.

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The Partnership also brings together a diversity of groups working in different areas for plant conservation, such as protected areas, species, botanic gardens, agricultural biodiversity, forestry, wetlands, etc.

The COP further welcomed the establishment, by the Executive Secretary, of a flexible coordination mechanism for the Strategy, comprising: liaison groups to be convened as necessary according to established procedures; national focal points, as determined by Parties; the GPPC; and the Secretariat, including the Programme Officer supported by BGCI. It encouraged Parties to nominate focal points, or designate from among existing focal points, for the Strategy in order to promote and facilitate implementation and monitoring of the Strategy at a national level; promote the participation of national stakeholders in the implementation and monitoring of the Strategy at a national level; and facilitate communication among national stakeholders and the Secretariat and GPPC.

In October 2010 in Nagoya, Japan, the 10th Conference of the Parties (COP 10) to the CBD adopted the Updated GSPC 2011–2020 by Decision X/17 (CBD, 2011a). This decision incorporated a consolidated update of the GSPC for the period 2011–2020. This updated GSPC includes 16 targets for plant conservation (CBD, 2011b) to be achieved by 2020 and invites Parties and other governments to develop or update national and regional targets as appropriate and, where appropriate, to incorporate them into relevant plans, programs, and initiatives, including national biodiversity strategies and action plans, and to align the further implementation of the Strategy with national and/or regional efforts to implement the Strategic Plan for Biodiversity 2011–2020 (CBD, 2011c).

The first Conference of the GPPC was held in Dublin, Ireland, in October 2005. Working practices for the GPPC were adopted by the GPPC (2005) at its first general meeting held in conjunction with this conference on 25 October 2005 in Dublin.

Introduction

The second conference of the GPPC was held from 5–7 July 2011 in St. Louis, Missouri. The second General Meeting of the GPPC was also held in conjunction with this conference on 7 July 2011. The conference was followed by a meeting of the GSPC Liaison Group, with their report through the CBD (2011d).

The 2011 conference was organized by the GPPC in association with the Secretariat of the Convention on Biological Diversity (SCBD) and BGCI; it was hosted by the Missouri Botanical Garden. The conference provided information through plenary sessions and strategic discussions to guide future plant conservation priorities in national development agendas with links to the implementation of the CBD's Strategic Plan, as well as providing guidance for countries that are updating national biodiversity strategies. The meeting was designed to showcase examples and share experience from around the world on GSPC implementation, particularly during the period of 2002–2010, to provide guidance and support for national and regional GSPC implementation entering into the new phase; to assist the ongoing efforts to consider and develop further the technical rationales, milestones, and indicators for the GSPC up to 2020; and to harmonize with the Strategic Plan for Biodiversity 2011–2020 (CBD, 2011e). A key objective of the conference was also to showcase and discuss a draft Toolkit for GSPC implementation.

The conference brought together plant conservation scientists, policymakers, and practitioners representing 27 countries from throughout the world to share methods and results to advance plant conservation measurably. The conference delegates shared their experiences and furthered the development of plant conservation science in the United Nations Decade of Biological Diversity (<www.cbd.int/2011–2020/>).

Opening, Discussions, and Progress

The conference opened with Dr. Peter Wyse Jackson, President of the Missouri Botanical Garden and Chairman of the GPPC, welcoming delegates to St. Louis. He noted with pleasure how many organizations and institutions active in plant conservation around the world were represented at the meeting. He also acknowledged the presence at the conference of Dr. Peter H. Raven, former President of the Missouri Botanical Garden, whose original call for the development of a global initiative for plant conservation to be developed through the United Nations had led to a resolution from the XVIth International Botanical Congress (IBC) in 1999 in St. Louis, Missouri, calling for such a program. Following this IBC, this had been taken forward by a group of botanists at a meeting in Gran Canaria, Spain, who developed an outline of what was later developed and adopted by the United Nation's CBD in April 2002. Dr. Wyse Jackson also recognized Dr. David Bramwell, Director of the Jardín Botánico Canario, Viera y Clavijo, Las Palmas de Gran Canaria, Spain, who had hosted the landmark Gran Canaria meeting in 2000.

Dr. Wyse Jackson thanked the members of the GPPC for their work in support of the GSPC since the Partnership had been established in 2004 (CBD, 2004). He noted that many members of the Partnership were represented at the conference and thanked participants for having traveled to St. Louis from so many countries to attend this meeting, an important landmark in the development and implementation of the GSPC, now entering its second phase following the adoption of the updated Strategy at the COP 10 to the CBD in Nagoya, Japan, in October 2010.

He noted that the outcomes of the conference would be communicated to and discussed by participants attending the fourth GSPC Liaison Group meeting that would be held also in St. Louis following the conference of 8–9 July (cf. CBD, 2011d). The conference, therefore, presented an important opportunity for many plant conservation practitioners, botanists, and policymakers to ensure that their concerns are communicated to the CBD's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), which would receive the Liaison Group's report and recommendations.

Ms. Sara Oldfield, Secretary General of BGCI, welcomed delegates on behalf of BGCI and thanked the Missouri Botanical Garden for hosting the conference. She pointed out the significant responsibilities of the conference to help determine priorities and new effective actions in order to achieve the GSPC targets.

Mr. Robert Höft, Environmental Affairs Officer at the SCBD, also welcomed delegates on behalf of Dr. Ahmed Djoghlaf and read a statement on his behalf (<http://www.cbd.int/doc/speech/2011/sp-2011-07-05-gppc-en.pdf>). In his remarks, Mr. Höft challenged the participants to consider the ways in which the GSPC could be made more relevant to and prominent in political processes worldwide, particularly at national levels, suggesting that only when plant conservation is effectively integrated into programs for sustainable economic development and poverty alleviation will its objectives be fully achieved. He pointed out the need for close operational links to be ensured between the GSPC and the Strategic Plan for Biodiversity, also adopted by the CBD in October 2010 in Nagoya.

St. Louis Public Radio, part of the National Public Radio network, had a special broadcast recorded live from the conference (<http://www.stlpublicradio.org/programs/slota/archivedetail.php?date='2011-07-06'>). Discussion was about The Future of Plant Conservation between the moderator and four panelists; the moderator took questions from the audience.

The 2011 GPPC Conference included six plenary sessions and eight workshops. Plenary sessions included: (1) the GSPC 2010–2020; (2) understanding and documenting plant diversity; (3) conserving plant diversity; (4) ecological restoration and the GSPC; (5) using plant diversity sustainably; and (6) building capacity for plant conservation. Workshop outcomes and recommendations are discussed below.

GPPC WORKSHOP NO. 1: THE WORLD FLORA: POSSIBILITIES AND PERSPECTIVES—A STAKEHOLDER CONSULTATION

(1) Major assets to complete a World Flora by 2020 include existing data and frameworks: (a) The Plant List to define the list of species to include in the World Flora; (b) more than 250 years of published floras, treatments, and monographs; and (c) the Angiosperm Phylogeny Group APG3 classification system (Stevens, 2001 onward) to define family-level framework.

(2) A major constraint for the GSPC Target 1, "an online flora of all known plants" (CBD, 2011b), is the 2020 deadline for delivery. Attendees acknowledged that achieving 100% completeness may be impossible, but believe that 80% completeness with 100% confidence in product could possibly be achieved. They also agreed that the project must leverage existing floras and datasets and do new fieldwork and taxonomic research only where data gaps occur.

(3) The World Flora should include a minimum set of required fields while maintaining high-quality, trustworthy data. The content should be defined by a working group who will take under consideration the audience for the project.

(4) Human capacity building is a key activity in delivering the World Flora, as the project has the potential to engage hundreds, if not thousands, of taxonomists, parataxonomists, students, and citizen scientists from all over the world. It is important to consider the human resources needed to execute the project as well as the resources needed post-2020.

(5) Building networks will be a key factor to achieve the GSPC Target 1, and participating institutions should work in areas of the world where they have regional or monographic focus.

(6) Tools for collaborative work should be developed, such as an interactive web site and application programming interfaces for data use.

GPPC WORKSHOP NO. 2: THE GSPC TOOLKIT—A DISCUSSION WORKSHOP

(1) The GSPC Toolkit (CBD, 2013) should include clear links to the CBD Strategic Plan Targets (CBD, 2011b) and to show the relevance of the GSPC in the context of national biodiversity strategies. Also included is basic information to explain why individual countries need to develop implementation strategies.

(2) The GSPC Toolkit should encourage individual organizations to take responsibility for specific GSPC targets and to help with peer review and quality control.

(3) The GSPC Toolkit should provide different entry points for different users to help them navigate more efficiently around the site.

(4) Off-line access is important; therefore, the GSPC Toolkit should consider generating a series of short publications that would be practical to produce and to update. Although a wiki-based approach and smart-phone accessibility are not taken initially, these should be considered in the longer term.

(5) Stakeholders could help to translate materials that are useful to make them available in different languages, although most resources should be made available in the language in which they are prepared.

GPPC Workshop No. 3: Red Listing and Achieving the GSPC Target 2

(1) Much greater progress toward achieving the GSPC Target 2, "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action" (CBD, 2011b), has been made than is currently realized, i.e., as perceived only through the lens of the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (IUCN, 2001, 2012), which includes just 17,604 plant species, or still only 5.7% of the estimated total. In fact, well over 100,000 plant species (Wyse Jackson, pers. obs.) have been assessed at either the global or national level for their conservation status in the past 25 years, many using the IUCN Red List Categories and Criteria, but also many others using different assessment systems. There is an urgent need to record and synthesize all of these assessments in an accessible online database to better inform conservation actions.

(2) Assessors should be strongly encouraged to use the IUCN Red List Categories and Criteria (IUCN, 2001, 2012) for future assessments. However, in order to expedite the incorporation of assessments on to the IUCN Red List of Threatened Species, it is suggested that IUCN should further review, revise, and clarify the minimum documentation standards required for inclusion on the Red List.

(3) Assessors should be strongly encouraged to use the IUCN Red List Categories and Criteria (IUCN, 2001, 2012) for future assessments. However, in order to expedite the incorporation of assessments within the IUCN Red List of Threatened Species, it is suggested that the IUCN should further review, revise, and clarify the minimum documentation standards required for inclusion on to the Red List.

(4) For the majority of plant species that are most likely of lesser conservation concern, more rapid assessment of their nonthreatened status can and should be achieved.

(5) The online World Flora (GSPC Target 1, CBD, 2011b) is the most appropriate place to attach and/or link conservation assessments of all plant species. Therefore, as the development of the World Flora moves forward, it is essential that considerations on how to link to existing online databases of conservation status, e.g., IUCN Red List or NatureServe (National Biological Information Infrastructure [NBII], 2013), as well as how to incorporate assessments that are not online, be addressed.

GPPC Workshop No. 4: Ecological Restoration and the GSPC

(1) Follow The Economics of Ecosystems and Biodiversity (TEEB, 2013; e.g., Wittmer et al., 2013) strategy of producing documents to explain the GSPC for five audiences: (a) scientists and professionals, (b) national and international policymakers, (c) corporate leaders and decision makers, (d) local and regional administrators, and (e) private consumers and citizens.

(2) Develop a framework to summarize, assess, promote, and multiply broad, integrated plant conservation and ecological restoration efforts that contribute to achieving the GSPC targets (CBD, 2011b). A summary of current efforts is needed to engage organizations, corporations, and institutions, and to help leverage resources for additional efforts and collaborations.

(3) Promote and link the long-standing efforts of the Society for Ecological Restoration, the GPPC, and others. Develop, document, and expand an international network of Long-term Ecological Restoration (LTER) areas (LTER Network, 2013). Encourage links with the work of the World Commission on Protected Areas (WCPA) in the area of ecological restoration (IUCN, 2013).

(4) The tools developed for implementing the GSPC targets and for achieving the GSPC Objectives (CBD, 2011b) should encourage and promote the use of the terms ecological restoration and Restoring Natural Capital (RNC), as used by TEEB and the RNC Network (Aronson et al., 2013).

GPPC Workshop No. 5: Technical Rationales, Milestones for the GSPC Targets—Linking with the CBD Strategic Plan

(1) The GSPC Technical Rationales (CBD, 2011e) are very useful to practitioners in explaining the GSPC targets to other stakeholders, including donors and policymakers in particular, as they explain the importance of the individual targets while also showing how the 16 targets link together into a plan.

(2) The GSPC Technical Rationales help users to define indicators and identify relevant stakeholders.

(3) These Technical Rationales should include explicit links to the CBD Strategic Plan (CBD, 2011c, 2011e). They should also provide the entry point for more detailed information as would be available, e.g., from the GSPC Toolkit.

(4) Technical Rationales should be kept brief and should be included in key materials about the GSPC (brochures and posters).

(5) Technical Rationales need to be made available as soon as possible in all the official languages of the CBD.

(6) If possible, GSPC Technical Rationales should include information on progress to date, suggested milestones, and indicators of success.

GPPC WORKSHOP NO. 6: LINKING THE GSPC AT AN INSTITUTIONAL LEVEL—A DISCUSSION WORKSHOP

(1) Insofar as possible, institutions should use the GSPC Objectives (CBD, 2011b) as a guide to help recognize their strengths and the work they are already doing in the conservation arena.

(2) Institutions should also use, as possible, the GSPC as a framework to build on these strengths and to set institutional priorities for the future, with the understanding that individual institutions need not necessarily address each GSPC target (CBD, 2011b).

(3) Institutions should make special efforts to work with their government representatives to raise awareness of and enlist support for advancing the GSPC.

(4) Institutions should use, as they can, the GSPC as a framework to integrate programs across the institution.

(5) Institutions should request that the SCBD invite the Parties to comply with the decision they have adopted to include the GSPC as part of their commitment to the CBD. They should also encourage the Parties to include the GSPC targets in their national biodiversity strategies and action plans.

(6) Institutions should develop networks, partnerships, or other types of institutional collaborations adapted to the particular situation of each country and capable of carrying out work in plant conservation to help realize the GSPC targets. To implement these collaborations, it will be important to find ways to identify and support individuals who will spur the formation of these collaborations.

GPPC WORKSHOP NO. 7: THE GSPC, ACCESS AND BENEFIT-SHARING, AND THE NAGOYA PROTOCOL

(1) The GPPC and individual organizations could provide educational opportunities around the operations and the documentation necessary for compliance and best practices in plant conservation. The GPPC could also play a role, through the member organizations, in the education of decision makers.

(2) The GPPC could play a greater role in representing the plant conservation community at meetings of Parties and negotiations. In addition, individual organizations should monitor and lobby to ensure that national laws remain open to scientific exchange of material.

(3) With regard to Article 10 ("Global Multilateral Benefit-Sharing Mechanism") and Article 11 ("Transboundary Cooperation") of the Nagoya Protocol (CBD, 2011f), the GPPC could play an important role in advocating for simplification to make securing prior informed consent easier.

(4) There is a need to focus efforts on the opportunities presented by the Access and Benefit-sharing (ABS) framework (CBD, 2011g), rather than on the challenges of obtaining genetic material.

(5) Benefits should be outlined from existing projects to provide a context for negotiation toward securing genetic material. It would be important to develop case studies, in particular cases that illustrate work conducted by those countries with large plant diversity that can provide guidance to others on maintaining open exchange of genetic material, as examples to help decision makers.

(6) Institutions should be more cognizant as a group not to make mistakes with negotiations and in the handling of plant material. In recognizing that a single institution can have a wider effect on the way in which institutions from an entire country could be viewed, the GPPC and individual institutions could help in raising awareness and providing support.

GPPC WORKSHOP NO. 8: PUBLIC AWARENESS AND THE GSPC

(1) The workshop focused primarily on the role of botanic gardens in public awareness on plant conservation and the GSPC. If botanic gardens are already collectively playing host to 250 million visitors a year, they should invest in ensuring that those 250 million visitors have an enriching, enlightening, and inspiring experience as possible.

(2) Botanic gardens should personalize learning opportunities and give people the opportunity to connect with the message in ways relevant to them. To make bigger impacts in the communities that they serve, botanical gardens should focus their message on targeted audiences and on specific groups whose decisions and actions can have long-term, significant conservation impacts.

(3) Botanic gardens should mobilize themselves in a way that leverages their collective reach. For example, if botanical gardens had e-mail addresses

for all 250 million visitors worldwide in one massive e-mail list, these institutions, through perhaps BGCI, could communicate and share discussions with patrons and visitors in entirely new ways.

(4) Botanic gardens should create a global campaign. With the diversity of media channels available today (social and traditional), botanic gardens should mount and disseminate a global campaign focused on the role of plants in human life.

Business Meeting

The meeting was opened by Dr. Wyse Jackson, Chair of the GPPC. Ms. Suzanne Sharrock (BGCI and GPPC Secretariat) acted as rapporteur for the meeting. The agenda for the meeting was as follows: (a) future priorities and role, (b) structure and membership, (c) election of officers, and (d) other business.

(a) future priorities and role

Discussion noted that various options exist for the future role of the GPPC by (a) maintaining the status quo, (b) developing a specific work program, (c) playing a direct role in supporting the development of the GSPC Toolkit, (d) focusing on communications, and (e) the sharing of resources between members. It was recommended that the presentations made during the GPPC Conference should be made publically available. It was also noted that Missouri Botanical Garden was considering publishing the proceedings of the conference in an issue of the *Annals of the Missouri Botanical Garden*.

Discussion pursued that the GPPC could play an important role in providing resources and advising and facilitating with the GSPC Toolkit. The issue of facilitating agencies for each GSPC target was discussed. It was believed that a wider number of institutions should now be engaged around each target and that among other tasks (e.g., monitoring and reporting on implementation progress), they should have a specific focus on supporting toolkit development. It was, therefore, recommended that the GPPC should establish a series of working groups, which would focus either on specific targets of the GSPC or on the broader objectives of the GSPC. The plans and objectives of these working groups would be developed by the GPPC Chair and circulated among the membership, together with a request for members to participate in the working groups. It was suggested that each working group should nominate a Chair who would act as the main liaison between the working group, the GPPC Chair, and the GSPC Toolkit administrator.

It was agreed that the document Working Practices of the GPPC should be revised and updated within the 2020 framework. The Chair of the GPPC will circulate this document to members, requesting comments and suggestions for updates. The updated draft of this document is included in Annex 1. This draft includes the modalities for the proposed GPPC working groups.

(b) structure and membership

Following discussion on the size of membership of the Partnership, it was agreed that structure and membership should be allowed to evolve naturally, with consideration given to increasing the scope and area of expertise of the members, e.g., by encouraging greater participation from the agriculture and forestry sectors.

(c) election of officers

The business meetings of the GPPC provide the opportunity for the GPPC Chair and Secretariat to be elected. Because there were no new nominations for either of these positions, it was agreed that Dr. Wyse Jackson would continue as Chair of the GPPC, and BGCI would continue to provide the secretariat until the next general meeting of the partnership.

(d) other business

The question of support for the GPPC Chair was raised, noting that up to now support has been informal, but the GSPC Liaison Group has played a role. With the formation of GPPC working groups, the Chairs of the working groups would be able to support the GPPC Chair. Dr. Wyse Jackson informed that he would look for additional institutional support from among the membership, including the Missouri Botanical Garden, where the office of the GPPC Chair would be maintained.

Following the completion of the General Meeting the conference was closed.

Conference Attendees and Program

A list of the GPPC Conference participants is provided at <https://mbgserv18.mobot.org/ocs/index.php/gppc/gppcstl/about/editorialPolicies#custom-0>.

The conference program and schedule, including the abstracts of presentations, are respectively provided at <https://mbgserv18.mobot.org/ocs/index.php/gppc/gppcstl/schedConf/program> and <https://mbgserv18.mobot.org/ocs/index.php/gppc/gppcstl/schedConf/schedule>.

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Annex 1. Updated Working Practices of the GPPC. The annex can be accessed at <http://www.plants2020.net/gppcworking-practices/>.

Introduction

1. The GPPC brings together international, regional, and national organizations in order to contribute to the implementation of the GSPC of the CBD. The Partnership aims to support the GSPC. The inaugural meeting of the Partnership was held as a side event of the seventh meeting of the

Conference of the Parties of the Convention in Kuala Lumpur in February 2004. The Conference of the Parties welcomed the establishment of the Partnership.

2. This note outlines the establishment of the Partnership and its Working Practices in relation to its aims, membership, functions, working modalities, chairmanship and secretariat, meetings and reporting.

3. Originally adopted by the GPPC at its first general meeting held in Dublin, Ireland, on 25 October 2005, this draft includes possible updates and revisions to be considered by the GPPC membership in response to the adoption by the CBD of an updated GSPC in November 2010 and the incorporation of GSPC targets for 2020.

4. It is noted that nothing in this Working Practices document should be read to contradict the principles of the CBD. Furthermore, it is recognized and accepted that this document is not legally binding and will have no effect as a legal or political precedent.

Establishment

5. At its sixth meeting, the Conference of the Parties to the CBD adopted Decision VI/9 on the GSPC, which includes outcome-oriented global targets for 2010. The ultimate and long-term objective of the Strategy is to halt the current and continuing loss of plant diversity. While the entry point for the Strategy is plant conservation, it is also concerned with aspects of sustainable use, capacity building, and benefit-sharing.

6. The GSPC Expert Group meeting in Dingle, Co. Kerry, Ireland, in October 2003 noted that "the Strategy is providing a useful framework to bring together organizations and initiatives to meet common objectives. Various organizations are already working towards the respective targets, and where possible, they are incorporating actions towards achieving targets into existing work programs. The need for wider partnerships has been noted, and to achieve this, mechanisms by which a wider group of organizations could be involved in the process are needed, with the emphasis being given to a partnership approach within the Strategy as a whole, rather than a specific target-related involvement" (CBD, 2003: 7; UNEP/CBD/SBSTTA/9/INF/24). The GSPC Expert Group, therefore, recommended that a global partnership for plant conservation be established, building upon the Gran Canaria Group, an informal consortium of international and national organizations that came together in 2000 to support the development of a global strategy for plant conservation. The Expert Group further proposed that a global partnership for plant conservation be open to all organizations that can contribute to the implementation of the Strategy.

7. In February 2004, in its Decision VII/10 on the GSPC, the Conference of the Parties welcomed the establishment of the Global Partnership for Plant Conservation and encouraged the participating organizations to continue to contribute to the implementation of the Strategy. It also invited other organizations to join the Partnership and encouraged BGCI to continue its support for the Partnership.

8. The Conference of the Parties further welcomed the establishment, by the Executive Secretary, of a flexible coordination mechanism for the Strategy, comprising: liaison groups to be convened as necessary according to established procedures; national focal points, as determined by Parties; the GPPC; and the Secretariat, including the Programme Officer supported by BGCI. It encouraged Parties to nominate focal points, or designate from among existing focal points, for the Strategy in order to promote and facilitate implementation and monitoring of the Strategy at a national level; promote the participation of national stakeholders in the implementation and monitoring of the Strategy at national level; and facilitate communication between national stakeholders and the Secretariat and GPPC.

9. The Partnership launched at an event held on 13 February 2004 during the 7th Meeting of the Conferences of Parties to the CBD in Kuala Lumpur, Malaysia. The establishment of the Partnership was welcomed by the CBD Executive Secretary and by representatives of a range of national and international organizations.

Aim of the Partnership

10. The aim of the Partnership is to support the worldwide implementation of the GSPC and its objective to provide a framework to facilitate harmony between existing initiatives aimed at plant conservation, identify gaps where new initiatives are required, and promote mobilization of the necessary resources. The Partnership also brings together a diversity of groups working in different areas for plant conservation, such as protected areas, species, botanic gardens, agricultural biodiversity, forestry, wetlands, etc.

Working Modalities

11. The Partnership represents a voluntary commitment by participating organizations to a common cause, the GSPC, who have agreed to come together in the framework of a GPPC to support the GSPC implementation. Furthermore, it is recognized that the Partnership does not seek to compromise the independence of any of its participating organizations but aims to create synergies and add value to existing initiatives, particularly in support of national GSPC implementation and in supporting efforts being made by Parties in responding to the GSPC.

12. The Partnership recognizes and accepts that guidance in relation to the GSPC are set by the Conference of the Parties to the CBD and its subsidiary bodies. Further, it acknowledges its role in the flexible coordination mechanism of the GSPC. The activities of the Partnership will be consistent with guidance provided by the Conference of the Parties and its subsidiary bodies and take account of advice provided through the flexible coordination mechanism.

13. The Partnership may play a role in identifying gaps so that individual organizations and institutions may then take a lead in developing projects to help address those gaps within the broad, flexible framework provided by the Partnership, involving organizations both within and outside the Partnership as appropriate. The Partnership will seek to focus on enhancing projects and other activities that respond to the GSPC and support its implementation, particularly at national levels rather than endorsing specific projects.

14. The activities of the Partnership are outlined in a program of activities prepared and agreed on from time to time by the members.

15. An important role of the Partnership will be to enhance communication and collaboration between participating organizations. The priority will be to minimize duplication of effort and maximize on available limited resources and ensure clarity in communication such as in relation to approaches to donors.

16. Every effort will be made to ensure that the Partnership remains as flexible and non-bureaucratic as possible and able to adapt easily and respond to changing circumstances and opportunities.

17. Participating organizations of the Partnership will encourage cooperation among themselves in the implementation of the GSPC and the implementation of the programs of

activities of the Partnership in areas of mutual interest and with other appropriate bodies, to avoid duplication and to benefit from existing resources and expertise.

18. The approach of the Partnership will be: (a) to operate in an open, transparent and flexible manner; (b) to share information on policies, programs, and activities among its participating organizations; (c) to encourage active participation in the implementation of the GSPC and the program of activities of the Partnership at all levels; and (d) to hold regular meetings and ensure other communication among its participating organizations to consider and agree on its activities and ongoing arrangements.

Membership

19. The Partnership consists of organizations, institutions, secretariats, and other bodies that have substantial programs in plant conservation, all of which shall be eligible for membership.

20. Any bona fide organizations and institutions, including governmental and nongovernmental organizations (NGOs), indigenous peoples organizations (IPOs), and the private sector, that are playing an important role in supporting the implementation of the GSPC, are invited to participate in the Partnership. Membership is open to all bodies that endorse the objectives of the GPPC and are committed to facilitating and promoting its implementation, unless the participation of that organization in the Partnership would be likely to jeopardize the aims of the Partnership.

21. Organizations may become members by an exchange of letters between a responsible official of the organization and the Chair of the Partnership. The letter from the applying organization should endorse the GSPC and accept the aims and Working Practices of the Partnership.

22. The Chair will acknowledge the membership of the body joining the Partnership. The name of the new member will then be added to the list of members of the Partnership maintained on the Partnership web site (<www.plants2020.org>). If the bona fide nature of the application of the applicant organization is in doubt, the Chair may consult with the Vice Chairs, and if necessary with the other members of the Partnership, before accepting a membership application.

23. Organizations may withdraw from the Partnership by informing the Chair in writing of their withdrawal. Organizations may also be withdrawn from membership by the Partnership itself by an affirmative vote of a two-thirds majority of the members present and voting at a General Meeting.

Functions of the Partnership

24. The functions of the GPPC include: (a) to support the Executive Secretary of the CBD, the Parties, and the flexible coordination mechanism for the GSPC to implement the Strategy and help monitor progress in the achievement of the 16 outcome targets by 2020; (b) to promote the implementation of the GSPC through the activities and initiatives of its participating organizations, other partners, and associated networks; (c) to support the development of collaborative initiatives among its members in support of the achievement of the GSPC targets; (d) to support the development and implementation of national and regional strategies for plant conservation and strengthen integration of the elements and targets of the GSPC into sectoral and institutional programs and initiatives; (e) to stimulate, encourage, and support the development of national partnerships for plant conservation; (f) to assist in the development and dissemination of relevant models with protocols for plant conservation, best practices and case studies and provide relevant scientific and technical tools where available, for the implementation of the GSPC; (g) to participate in the flexible coordination mechanism of the GSPC as established by the CBD Executive Secretary; (h) to participate in the development and maintenance of a Toolkit on GSPC implementation; (i) to maintain a web site on the plant conservation activities of its members worldwide, as a resource for interaction and communication between initiatives and organizations active in plant conservation, working in close collaboration with the Clearing House Mechanism of the CBD; (j) to identify gaps where new initiatives are required; (k) to support capacity building initiatives for plant conservation especially in developing countries; (l) to facilitate education and public awareness on plant conservation and the GSPC; and (m) to maximize and mobilize existing and new resources to support the implementation of the Strategy at all levels.

Chair and Secretariat

25. A Chair for the Partnership is elected at the General Meetings of the Partnership.

26. Any changes to the arrangements for the Partnership will be agreed by the Partners and adopted at its General Meetings. A Secretariat for the Partnership shall be selected or designated also at General Meetings. The term of office of the Chair and any other officers chosen will be from one General Meeting to the next.

Meetings

27. The primary governing and decision-making body of the Partnership will be at its General Meetings. The General Meetings will be the means by which the participating organizations will make collective decisions on all matters relating to the GPPC, which will then be put into effect by the GPPC Secretariat. The Partnership's activities will be guided by the General Meetings. General Meetings will be held from time to time, if possible no less than once every three years, convened by the Chair. All members will be invited to be represented at a General Meeting. The General Meeting should strive to work by consensus whenever possible. If consensus cannot be reached after reasonable attempts have been made, then in exceptional circumstances a decision may be approved by a majority vote of those members present at a General Meeting. All members present at a General Meeting will be entitled to one vote.

28. The General Meetings may: (a) agree on the activities that will be undertaken by the Partnership for the period between General Meetings or for other agreed periods of time. The Partnership may, by consensus, make adjustments to these activities at any time; (b) agree on practices as may be required for the sound management of the Partnership's activities, while assuring adherence to this document and to the principles of the CBD and GSPC; (c) appoint a Chair and other officers and select or designate a Secretariat; (d) consider any matters pertaining to the GPPC or its operations and the GSPC as submitted to it by the Executive Secretary of the CBD, the GPPC Secretariat, or by any member; (e) establish Working Groups to support, advise on, and help monitor the achievement of individual or groups of targets of the GSPC and to contribute to and support, as appropriate, the development and maintenance of the GSPC Toolkit. General Meetings may be supplemented by occasional meetings held by teleconference and/or electronic communications.

Working Groups

29. The establishment of Working Groups to support, advise on, and help monitor the achievement of the GSPC 2020 targets was agreed at the second General Meeting of the Partnership.

30. A series of Working Groups are constituted for each of the first four GSPC Objectives, viz: (a) Objective I, plant diversity is well understood, documented and recognized; (b) Objective II, plant diversity is urgently and effectively conserved; (c) Objective III, plant diversity is used in a sustainable and equitable manner; and, (d) Objective IV, education and awareness about plant diversity, its role in sustainable livelihoods, and importance to all life on Earth is promoted.

TERMS OF REFERENCE FOR WORKING GROUPS

31. The terms of reference of Working Groups are as follows.

(a) Provide advice to the Executive Secretary to the CBD on, inter alia, the technical terms and rationale for each target. Such advice may be provided either directly to the Executive Secretary or as part of consultations undertaken at Liaison Group meeting, through the flexible coordination mechanism.

(b) Assist in the development and maintenance of the GSPC Toolkit, including: (i) help in identifying existing tools for inclusion; (ii) document case studies and information on best practices supporting the development of new plant conservation tools that may not currently exist to support GSPC implementation and to address identified gaps; (iii) develop and implement opportunities to disseminate the use of the Toolkit for the development of national and regional responses to the GSPC; and (iv) provide advice for the incorporation of the GSPC and its targets into national biodiversity strategies and action plans.

(c) Assist in monitoring progress toward the achievement of the GSPC 2020 targets, including any indicators and milestones identified and existing baselines.

(d) Identify capacity-building and networking needs for the achievement of the GSPC targets and support, encourage, advise on, and assist in the implementation of capacity-building measures at all levels.

(e) Promote a wider understanding and awareness of the GSPC and its targets for 2020 among the botanical, conservation, and broader environmental communities.

(f) Contribute toward updates of the Plant Conservation Report and periodic other reviews of the GSPC and its progress.

32. Additional cross-cutting Working Groups may be established as needed on a permanent or temporary basis by the GPPC membership to address particular topics, such as emerging issues, items of more general importance to the GSPC, or to consider matters for which the Executive Secretary has requested specific advice.

MEMBERSHIP AND PARTICIPATION IN WORKING GROUPS

33. Participation in these Working Groups is open to all members of the GPPC. Nevertheless, it is expected that organizations and institutions will participate primarily in the Working Groups where they have a direct interest and specific expertise and involvement.

34. Each Working Group will appoint a Chair and Secretary who will liaise directly with the membership of the Working Group to manage and organize the work of the Group. The Chair and Secretary will also liaise with and report to the GPPC Chair and Secretariat, with the aim of reporting on progress, activities, and outcomes of the work of the Group. The Chair and Secretary will be appointed by the membership of the Working Group and with the agreement of the GPPC Chair. Such appointments shall generally be by consensus. If an appointment cannot be made by consensus, then a Working Group Chair may be appointed by the GPPC Chair after consultation with the full GPPC membership.

35. Working Group Chairs may invite the participation of a limited number of technical advisors or experts as observers when they may be able to contribute information or perspectives on the work of the Group that might not otherwise be available to it from within the membership of the GPPC.

36. It is expected that where a GPPC member wishes to be involved in a specific Working Group, the member will nominate one named individual to the GPPC Chair (or GPPC Secretariat). In the event that the nominated named individual is unable to participate in a specific meeting or activity of the Working Group, the GPPC member may nominate an alternative named individual.

37. The term of office of any member of a Working Group shall be from one GPPC General Meeting to the next.

38. The names of participating organizations and their representatives in each Working Group will be included in the GPPC web site.

MEANS OF WORKING

39. These Working Groups may operate by means of meetings, workshops, and other events, as well as using electronic and other communication tools.

40. Working Groups may also decide, if they wish, to constitute permanent or temporary task forces or committees to consider and advise on specific issues or individual or groups of targets. These subgroups will report to the Chair of the Group.

COMMUNICATIONS AND REPORTING

41. Communications between the Working Groups and the SCBD will normally be via the GPPC Chair and Secretariat.

42. Working Groups will be expected to provide an update on their work to the GPPC Chair on at least an annual basis.

Reporting

43. No formal reporting requirements will be required of members of the Partnership, except within the context of the activities of the Working Groups. However, participating organizations are encouraged to provide relevant information regularly, particularly relating to existing or planned activities concerning the implementation of the GPPC program of activities, or other policies, activities, and initiatives relevant to GSPC implementation. Such contributions can be included in or linked to the GPPC web site and made available to the Executive Secretary of the CBD, the Parties, and the flexible coordination mechanism for the GSPC to implement the Strategy and help monitor progress in the achievement of the 16 outcome targets by 2020.

SUPPORTING TARGET 4 OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION BY INTEGRATING ECOLOGICAL RESTORATION INTO THE MISSOURI BOTANICAL GARDEN'S CONSERVATION PROGRAM IN MADAGASCAR[1]

Chris Birkinshaw,[2] Porter P. Lowry II,[3,4] Jeannie Raharimampionona,[2] and James Aronson[3,5]

Abstract

The Missouri Botanical Garden (MBG) is supporting community-based conservation at 11 priority areas for plant conservation in Madagascar. Our strategy for conserving these sites integrates a range of activities that include research and monitoring, the creation and policing of local rules to enable the sustainable use of natural resources, environmental education, the provision of alternatives to the unsustainable over-exploitation of natural resources, poverty alleviation, and the restoration of degraded ecosystems. While this approach is successfully conserving biodiversity in the short term and at local scales, over a longer time period these reserves will become increasingly threatened by a rapidly growing human population whose livelihood is dependent on natural resources that will become increasingly rare outside of protected natural areas. Extensive ecological restoration of landscapes surrounding reserves is a prerequisite in Madagascar for the long-term conservation of these protected areas and will thus be an essential part of a national effort to achieve Target 4 of the Global Strategy for Plant Conservation (GSPC). Here, we describe our current restoration program, analyze its strengths and weaknesses, and consider the threats and opportunities relating to restoration in Madagascar. This information is used to identify key attributes for a proposed up-scaled restoration initiative that can serve to develop more sophisticated methods, strengthen expertise through training, and demonstrate the power of ecological restoration for achieving long-term, sustainable conservation outcomes, as called for by the GSPC.

Key words: Ecological restoration, Global Strategy for Plant Conservation (GSPC), Madagascar.

With an area of 587,040 km^2, roughly similar to the area of California and Arizona combined, the island nation of Madagascar has a remarkably diverse flora that comprises nearly 12,000 species of vascular plants already described, belonging to over 900 genera and 239 families (Madagascar Catalogue, 2013a), plus as many as 2000 additional species that remain to be scientifically named (Phillipson et al., 2006). In comparison, the flora of North America includes around 20,000 native species in an area more than 40 times as large. Even more striking is the level of endemism in the Malagasy flora, which was recently estimated as 84% of the published vascular plant species, and an even more remarkable 35% of the genera (Callmander et al., 2011), figures that will increase as new taxa are described. However, this exceptional botanical wealth, which also includes five endemic families, is acutely threatened because of the immense ecological footprint of the rapidly growing, largely very poor, human population

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(2.65% demographic growth per year; Central Intelligence Agency, 2013).

Madagascar's rural people rely on subsistence agriculture for their livelihoods, yet nearly all increases in agriculture come at the expense of natural ecosystems. Between 1950 and 2005, the country lost 40% of its cover of forest, woodland, and thicket (Harper et al., 2007), and during this same period many plant species undoubtedly went extinct. Today, almost all of the island's exceptional flora is threatened by habitat loss, making Madagascar one of the five hottest of the world's 34 recognized biodiversity hotspots (Mittermeier et al., 2004). This situation underscores the urgent need for coordinated action, as called for by the Global Strategy for Plant Conservation (GSPC) as established in Montreal (Convention on Biological Diversity [CBD], 2011a, 2011b, 2011c, 2011d), with its far-reaching set of objectives and targets.

In this paper, we explore how the ecological restoration activities now being developed and conducted by the Missouri Botanical Garden's (MBG) conservation program in Madagascar could be expanded to contribute significantly to the implementation of the GSPC in Madagascar, and in particular to the GSPC Target 4, which calls for securing "at least 15% of each ecological region or vegetation type by 2020 through effective management and/or restoration" (CBD, 2011d).

Missouri Botanical Garden's Conservation Activities in Madagascar: A Platform for Developing Ecological Restoration

MBG supports active programs in more than a dozen countries. The largest of these programs is in Madagascar, where over the last 25 years the organization has developed a program with over 100 local staff members conducting a wide range of activities. Initially, the program focused on botanical exploration, taxonomic research, and in-country capacity building, with a special emphasis on training. Led by our local field botanists, MBG has conducted one of the world's most productive modern field inventory programs, and our staff has made a large contribution to understanding the Malagasy flora. The results of these efforts have been made available to the world through the publication of scores of taxonomic revisions, species descriptions, and the online publication of the Catalogue of the Vascular Plants of Madagascar (Madagascar Catalogue, 2013a). Starting in the late 1990s, local members of MBG's staff in Madagascar came to the realization that plant conservation efforts were far from adequate, which instilled a growing desire to play a more direct and active role in achieving realistic conservation goals.

As an initial step toward addressing the critical need for expanded plant conservation efforts, we used the large body of information on Madagascar's flora gathered over the last quarter century to identify priority areas for plant conservation, the goal of which was to ensure that no plant species are lost to extinction. In 2001, a total of 78 priority areas were identified (Andriambolonera & Raharamampionona, 2005; Raharimampionona et al., 2006). The following year, we launched a pilot project to conserve one of these priority areas, the Agnalazaha Forest, a rare fragment of littoral forest, one of Madagascar's most highly threatened ecosystems (Consiglio et al., 2006). We adopted a community-based approach that emphasized a combination of conservation of native ecosystems, environmental education, and sustainable local economic development. Based on the success achieved at Agnalazaha, we embarked on an expansion of our program over the last decade, and today we are working with local communities at 11 priority sites with a total area of nearly 60,000 ha. These sites are situated throughout the country and encompass a broad diversity of vegetation types, including dry forest and thicket (Anadabolava and Oranjia), littoral forests (Agnalazaha and Pointe à Larrée), low-elevation humid forest (Analavelona, Analalava, Makirovana-Tsihomanaomby, Vohibe, and Ankarabolava-Agnakatrika), sclerophyllous woodland and shrubland (Ibity Massif), and mid-elevation humid forest (Ankafobe). All but one of these 11 sites, the tiny Ankafobe Forest managed as a community reserve, have now been formally accorded temporary protection by the Malagasy government, the first of two stages in the process leading to the forest's permanent designation as an official, nationally recognized protected area.

The approach used by MBG to achieve long-term conservation at each site involves basing a full-time, well-trained, and highly motivated Malagasy Conservation Facilitator within the community, located close to the conservation site. This person engages local stakeholders in a negotiation process that leads to a mutually acceptable delimitation and management zonation for the conservation site, and the Facilitator works with the stakeholders to develop and implement a set of community rules (*dina*) that are grounded in traditional customs and specifically designed to support sustainable management of the area's natural resources. To mitigate the negative impact of restricting access to the natural resources contained in the area being conserved, MBG also works with a local Management Committee, which we help to set up, to develop alternative resources for community members, and to identify and implement alternative income-generating methods for those persons whose livelihoods are most heavily affected. This basic approach is supported by ongoing research, monitoring, and information-sharing to enable informed decision-making by MBG, the community, and government agencies. In addition, sustainable economic development is actively promoted in these communities in order to reduce poverty and the resulting tendency to rely on the non-sustainable exploitation of natural resources. Examples of sustainable activities prompted at our sites include fish farming, organic gardening, nature tourism, and community-based plant nurseries.

The conservation program at each of the 11 sites where MBG is involved also includes a number of activities that contribute to ecological restoration, which may be defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed Society for Ecological Restoration [SER], 2004). Restoration activities include: (a) the control of particularly harmful, alien invasive plants such as the tea tree (*Melaleuca quinquenervia* (Cav.) S. T. Blake) and guava (*Psidium cattleyanum* Sabine); (b) the reduction of anthropogenic pressures, including burning and the unsustainable harvesting of trees, which constrain natural regeneration and reduce forest cover and integrity; and (c) the reforestation of degraded areas using native species with the aim to restore and expand the remaining forested area. The nature and scale of these actions at each of the 11 sites are summarized in Table 1.

Scaling-up Missouri Botanical Garden's Restoration Activities in Madagascar

While ecological restoration is making a positive contribution to conservation at each of MBG's 11 conservation sites, it is currently doing so within the limited context of a traditional fortress approach to conservation. In most cases, these sites constitute islands that are rich in biological diversity and natural capital but stand isolated in landscapes where these resources are much reduced and where most people are impoverished, relying on marginally productive agriculture for their livelihoods and desperately in need of access to resources. As long as this situation persists, external investment will be necessary to ensure that the natural fortress is not invaded. Although these reserves are successfully conserving biodiversity and providing ecological goods and services in the short term, it seems questionable whether this situation can be sustained over longer periods. A more stable future might, however, be envisaged if the Malagasy economy were to improve significantly and its population were to become less dependent on subsistence agriculture, although this does not currently seem likely. Alternatively, the long-term prospects of these reserves could also be improved significantly if the degraded landscapes surrounding them were to be restored, thus increasing their capacity to satisfy local requirements for natural resources. Thus, in a country such as Madagascar, the extensive use of ecological restoration may well be essential for achieving the sustainable, long-term conservation required to achieve Target 4 of the GSPC (CBD, 2011d).

While MBG's restoration activities in Madagascar are modest, our conservation program has several strengths on which more significant endeavors could be built. These include:

(1) The full-time presence of well-educated and highly motivated staff members at the conservation sites who have won the trust of the local community, have some experience of restoration interventions, and possess an understanding of the site-specific issues that impact whether restoration goals are reached;
(2) Well-developed, multi-faceted community-based conservation programs operating at each site that can facilitate restoration;
(3) A scientific ethos and intimate knowledge of the Malagasy flora that enable a rigorous and efficient science-based approach to restoration;
(4) An integrated network of conservation projects throughout the country that provides an opportunity for developing restoration protocols under diverse environmental and social conditions, and that facilitates the exchange of experience between restoration practitioners; and
(5) The presence at each site of largely intact natural vegetation that can provide both a reference ecosystem for setting restoration goals and key resources such as plant material and top-soil for implementing restoration activities.

The successful expansion of restoration activities at our sites will, however, require overcoming three major weaknesses. First, there is a paucity of public land near some of the 11 reserves that could be used for community-based restoration projects, which will require that we work closely with private landowners whose short-term land-use goals may be difficult to reconcile with the long-term goals of restoration. Second, there is a limited level of expertise and experience among our staff with regard to developing a robust restoration program and carrying out the full range of technical aspects needed for implementing

Table 1. Restoration activities at the 11 priority areas for plant conservation where the Missouri Botanical Garden is now facilitating conservation, restoration, and sustainable local economic development in Madagascar.

Site	Reforestation	Control of invasive alien species	Promotion of regeneration by reducing factors leading to ecosystem degradation
Agnalazaha	• Seedlings of native tree and shrub species propagated in village nurseries and planted in anthropogenic forest clearings (over six years, 30,000 seedlings produced and planted over 9 ha) • Research conducted to inform planting protocols (comparison of growth and mortality of seedlings with and without added compost in their planting holes)	• The local management committee supported for the establishment and implementation of local rules (*dina*) that encourage the use invasive species • *Melaleuca quinquenervia* felled in over 50 ha	• Risk of burning by wild fires reduced by creating firebreaks and by supporting fire-spotting teams during the dry season • New shifting cultivation stopped and exploitation of wood products (timber, fence posts, fuel) controlled by supporting the management committee in the development and application of local rules for forest use
Anadabolava			• New shifting cultivation stopped and exploitation of wood products controlled by supporting management committees in the development and application of local rules for forest use
Analalava	• Seedlings of native tree and shrub species propagated in village nurseries and planted in anthropogenic clearings within the forest (over six years, 31,000 seedlings produced and planted over 10 ha) • Research conducted to inform planting protocols (comparison of growth and mortality of seedlings with and without added compost in their planting holes) • Research conducted to define protocols for the vegetative propagation of native trees	• Research conducted to inform the development of a plan to control *Psidium cattleyanum* (comparison of costs and efficacy of various methods of controlling this invader)	• Risk of burning by wild fires reduced by encircling forest with a firebreak • Exploitation of wood products stopped by supporting a management committee in the development and application of local rules for forest use
Analavelona			• Risk of burning by wild fires reduced by creating firebreaks along the edge of parts of the forest that are most vulnerable to burning
Ankafobe	• Research conducted to inform the development of a restoration plan (classification and mapping of vegetation types and description of vegetation succession following forest felling and burning) • Anthropogenic grassland surrounding forest reforested using locally produced native tree seedlings (since 2005, 21,000 seedlings planted over 8 ha) • Research conducted to inform planting protocols (comparison of growth and mortality of seedlings in different size classes at time of planting) • Research conducted to inform planting protocols (comparison of growth rate of seedlings of four native pioneer species planted in anthropogenic grassland under two conditions: control versus added compost, mulch and shade)		• Risk of burning by wild fires reduced by encircling the forest with a double firebreak and supporting fire-spotting teams

Table 1. Continued.

Site	Reforestation	Control of invasive alien species	Promotion of regeneration by reducing factors leading to ecosystem degradation
Ankarabolava-Agnakatrika	• Research conducted to develop best protocols for the reforestation by the direct sowing of seeds of native trees in the sites where they will grow to maturity • Areas of former cultivation reforested within the forest using locally produced native tree seedlings (over one year, 3500 seedlings planted over 2 ha)		• Exploitation of wood products controlled by supporting several management committees in the development and application of local rules for forest use
Ibity Massif			• Research conducted to inform the development of a restoration plan for the site (relationship between fire frequency and vegetation types)
Makirovana-Tsihomanaomby	• Seedlings of useful native tree species propagated in village nurseries and planted in anthropogenic clearings within the forest (activity began in 2011)		• Exploitation of wood products and use of fire as an agricultural tool controlled by supporting several management committees in the development and application of local rules for forest use
Oranjia	• Seedlings of useful native tree species are propagated in village nurseries and planted in anthropogenic clearings within the forest (over two years, 3000 seedlings produced and planted over 4 ha)	• Research conducted to develop saleable, wooden handicrafts that could be made by local people using invasive alien species as an economic alternative to the exploitation of timber	• Exploitation of wood products controlled by supporting several management committees in the development and application of local rules for forest use
Pointe à Larrée	• Seedlings of native tree and shrub species propagated in village nurseries and planted in anthropogenic clearings within the forest (over three years, 23,000 seedlings produced and planted over 5 ha)	• *Psidium cattleyanum* controlled by uprooting and replanting the area it occupied with seedlings of native species	• Exploitation of wood products and use of fire as an agricultural tool controlled by supporting several management committees in the development and application of local rules for forest use
Vohibe	• Seedlings of native tree and shrub species propagated in village nurseries and young individuals planted in anthropogenic clearings within the forest (over six years, 50,000 seedlings produced and planted over 14 ha)		• New shifting cultivation stopped and exploitation of wood products controlled by supporting a management committee in the development and application of local rules for forest use

such plans. Third, to date, our restoration activities have been limited by funding constraints.

In addition to these strengths and weaknesses, several major external opportunities and threats will have to be taken into consideration as we develop restoration work at our sites. One important opportunity is the desperate need for new sources of income by rural populations in Madagascar, which strongly implies that if restoration projects are designed to maximize employment opportunities then they will likely receive strong support from local stakeholders and could contribute significantly to reducing poverty and the unsustainable use of natural resources. Another key opportunity is the presence in some parts of the country of large areas of degraded land that are currently perceived to have little value and thus could be made available for restoration projects without generating conflict with other land users. A significant threat, however, is presented by Madagascar's widespread poverty and the associated tendency to make land-use decisions that address short-term needs at the expense of compromising long-term options. Another threat is the current paucity of donors whose funding strategy is compatible with supporting the kind of long-term commitment needed for restoration projects to be successful. However, it is possible that the current REDD+ negotiations within the United Nations Framework Convention on Climate Change (UN-REDD Programme, 2009; Alexander et al., 2011), as well as discussions and ongoing projects under the CBD convention and the United Nations Convention to Combat Desertification (UNCCD, 2012), may lead to new funding opportunities for restoration in the coming decade.

The best approach to restoring the degraded ecosystems and fragmented landscapes in which the MBG's 11 conservation sites are situated will be to expand restoration activities to exploit these strengths and opportunities while addressing weaknesses and mitigating threats. These activities should seek to: (1) retain and strengthen local expertise; (2) encompass complimentary elements such as education and economic development; (3) employ a scientific approach that promotes regular evaluation and improvement throughout the life of the project; (4) promote the exchange of ideas and experience among restoration practitioners working at all 11 sites; (5) develop protocols that maximize the sustainable use of the natural resources available at each site; (6) seek incentives for private landowners to support restoration even if this sometimes requires adopting an approach that does not aim to restore entirely natural ecosystems; (7) increase MBG's capacity to design and implement ecological restoration; (8) exploit low-technology restoration methods that maximize rural employment opportunities; (9) focus restoration on highly degraded landscapes that have little current economic value; (10) collaborate with development organizations to reduce poverty in the vicinity of restoration projects; and (11) mobilize the full force of the botanical garden and conservation communities to secure support for expanding restoration projects and programs to ensure that restoration can make a significant contribution to biodiversity conservation and to achieving the targets set by the GSPC (CBD, 2011a, 2011b, 2011c, 2011d; cf. Hardwick et al., 2011).

The Importance of Model Restoration Projects to Inspire and Inform Expanded and More Effective Restoration Endeavors in Madagascar

MBG's current restoration activities in Madagascar are relatively simple and small scale, typical of those being implemented by other conservation organizations operating there and in many other developing countries. Two notable larger-scale restoration projects involving several hundred hectares are being undertaken in Madagascar at Fandriana-Marolambo (Roelens et al., 2010, unpub.) and within the Ankeniheny-Zahamena Corridor (Conservation International, 2011), but even they lack the sophistication of flagship restoration efforts elsewhere in the tropics, such as in Costa Rica (Janzen, 2002) and southeastern Brazil (Rodrigues et al., 2010). For the most part, restoration in Madagascar primarily aims to curtail human activities that lead to forest degradation and, thereby, promote natural regeneration while also planting native trees in areas where natural forest regeneration is thought to be blocked (Holloway, 2007). No projects effectively tap the full potential of large-scale, science-based ecological restoration for contributing to the conservation of Madagascar's biodiversity, increasing the country's natural capital, and promoting resiliency against climate change. Moreover, none of the current restoration projects can be regarded as a model of best practice for achieving effective ecological restoration. While Target 4 of the GSPC (CBD, 2011d) specifically calls for restoration, conservation decision-makers and technicians in Madagascar lack awareness of and exposure to successful restoration efforts, and they remain unconvinced of the importance of restoration. Model projects are, thus, urgently needed to increase the pace of progress toward achieving the GSPC Target 4. This will require additional investment and visibility, which MBG's conservation projects are in an excellent position to facilitate. Thus, while the long-term conservation of MBG's 11 priority areas for plant conservation will require greater investment in restoration than at present, if this scale-up can be done in such a way as to create a series of model restoration projects, then our contribution to achieving the GSPC Target 4 in particular, and to promoting biodiversity conservation and improving human livelihoods in Madagascar in general, would be significant.

In conclusion, the experience we have gained from conserving 11 priority areas for plant conservation in Madagascar suggests that ecological restoration will be a prerequisite in most situations for successful long-term conservation and, therefore, must be an essential element in a national effort to achieve Target 4 of the GSPC (CBD, 2011d). However, despite the importance of ecological restoration, its current application in Madagascar is both small in scale and technically primitive. To help overcome these issues, MBG is now endeavoring to scale-up the restoration component of the conservation strategies at its 11 conservation sites, some or all of which could be used to test and implement more sophisticated methods, develop expertise through training, and provide operating models to demonstrate the value of ecological restoration for delivering the kinds of lasting conservation and development outcomes called for by the GSPC.

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BUILDING CAPACITY FOR THE ACHIEVEMENT OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION IN THE CARIBBEAN REGION[1]

Colin Clubbe[2]

Abstract

Politically and botanically diverse, the Caribbean region is a biodiversity hotspot. Current estimates for seed plant species richness are nearly 11,000 indigenous taxa, of which approximately 72% are endemic to the region. Politically, the region comprises independent countries as well as overseas territories and countries of the European Union member states and the United States. Success in implementing the 2010 targets of the Global Strategy for Plant Conservation (GSPC) across the region was mixed, and a lack of capacity was consistently cited as a major impediment to full implementation. Several regional initiatives promote coordinated conservation activities and disseminate key information needed for GSPC implementation, including the Caribbean Botanic Gardens for Conservation, whose last meeting in Cuba identified capacity gaps needed for achieving GSPC success. This echoed an earlier regional GSPC workshop held in Montserrat and coordinated by Royal Botanic Gardens Kew and the Secretariat of the Convention on Biological Diversity (SCBD). RBG Kew has an active regional training program and is working with international partners to respond to needs identified locally. This coordinated approach, together with the development of the GSPC Toolkit, can provide a roadmap to meet the challenges of building capacity to achieve the revised 2020 targets in this biodiverse region.

Key words: Botanic gardens, Global Strategy for Plant Conservation (GSPC), networks, training, United Kingdom Overseas Territories (UKOT), West Indies.

The Caribbean region is politically and botanically diverse and comprises an archipelago of more than 1000 islands spread over approximately 3000 km separating the Atlantic Ocean from the Caribbean Sea. Politically, the region comprises 13 independent nations as well as overseas territories and countries of the European Union member states and the United States. A recognized biodiversity hotspot (Myers et al., 2000), current estimates for seed plant species richness are nearly 11,000 indigenous taxa, of which approximately 72% are endemic to the region (Acevedo-Rodriguez & Strong, 2008a, 2008b; Maunder et al., 2008, 2011); however, much of the region is experiencing increasing pressure from the familiar drivers of biodiversity loss, e.g., habitat loss and fragmentation, often driven by development, invasive species, pollution, and, increasingly, the negative impacts of global climate change (Millennium Ecosystem Assessment, 2005; Critical Ecosystem Partnership Fund, 2010).

The Global Strategy for Plant Conservation

A global analysis of the extinction risk for plants has revealed that more than 20% of the world's plant species are threatened with extinction and that human actions pose the greatest threats to the future of plant diversity (Plants Under Pressure, 2010). The Global Strategy for Plant Conservation (GSPC) aims to halt the current and continuing loss of plant diversity (Convention on Biological Diversity [CBD], 2002) and provides a challenge and opportunity for the international community (Wyse Jackson & Kennedy, 2009). Implementing the GSPC is based on achieving 16 outcome-oriented targets, initially by 2010, and now revised and updated for implementation by 2020 (CBD, 2011a). Achievement of the targets of the GSPC requires considerable capacity, and, consequently, Targets 15 and 16 of the GSPC focus on building capacity. Target 15 focuses on building individual skills and facilities, in particular "The number of trained people working with appropriate facilities sufficient according to national

[1] I would like to acknowledge the many colleagues worldwide who actively support our capacity-building programme and contribute their time and expertise helping us to implement Targets 15 and 16 of the GSPC. I would also like to acknowledge our many alumni who are working so selflessly and making a real difference to the conservation of plants. We have many generous sponsors and funders who make it possible to maintain our capacity-building programme, and with particular reference to activities related to the Caribbean I would like to thank: The Department of Environment, Food and Rural Affairs (Defra), Lennox Boyd Memorial Trust, the Overseas Territories Environment Programme (OTEP), and the Darwin Initiative.

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needs, to achieve the targets of this Strategy" (CBD, 2011d). Although Target 15 focuses on individuals, GSPC Target 16 stresses the collective importance of maintaining networks and partnerships: "Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels..." (CBD, 2011d). The GSPC estimates that the number of trained people working in plant conservation worldwide would have to double by 2010, and although a few national needs assessments have been undertaken, we have fallen well short of this figure (SCBD, 2009). Progress has been made in increasing the number of trained people working in conservation, and several institutions have ambitious international training programs, including the Royal Botanic Gardens Kew (RBG Kew), Chicago Botanic Garden, South African National Biodiversity Institute, and Botanic Gardens Conservation International (BGCI). However, the training impediment remains, and, consequently, Targets 15 and 16 in the revised GSPC 2011–2020 remain almost unaltered (CBD, 2011d). An exciting initiative to help implement the GSPC and to support the attainment of the targets is the development of a web-based GSPC Toolkit, launched in 2011, mediated by the Global Partnership for Plant Conservation (GPPC) and maintained by BGCI (Plants 2020, 2013).

Capacity Building for GSPC Implementation in the Caribbean

The RBG Kew has an active capacity-building program based on courses and individually tailored training on the Kew and Wakehurst Place sites, as well as an active regional program working with in-country partners (Clubbe et al., 2008; RBG Kew, 2011). The International Diploma Programme is the main capacity-building program at Kew and comprises four specialist professional training courses of five to eight weeks in duration. The topics comprise Botanic Garden Management, Plant Conservation Strategies, Herbarium Techniques, and Botanic Garden Education. These courses have recently been reviewed and restructured specifically to support implementation of the GSPC and to provide participants with specific skills and tools in the spirit of meeting GSPC Target 15. The course alumni comprise a powerful network sensu GSPC Target 16 that works on two levels. Such strong bonds are formed within a course that these relationships thrive and form a mutual support network, regardless of where in the world participants return to. Individual course members are then introduced to the wider alumnus via the "On Course" alumnus newsletter; many new relationships have been established via the recognition of common interests or local proximity. To date, 417 participants representing 109 countries and territories have taken a course in this programme, including 30 from 14 Caribbean nations and territories. This forms a powerful international network for implementing the GSPC. Core to this home-based program is the recognition that there is much to be gained from the international flavor and lifelong friendships created by bringing together a group of specialists for a course at Kew. Here, we can draw on wider expertise from, e.g., BGCI, other botanic gardens, and university-based colleagues to provide a stimulating forum for gaining knowledge, sharing experiences, and seeking solutions.

Kew's regional training programme is often based on an existing relationship with a former course alumnus who has returned home after taking one of the Kew courses. While implementing knowledge and skills gained during the Kew course, they identify the need and an opportunity to develop a regional course. In recent years, two such courses have been developed and run in the Caribbean region. In 2007, with funding from the United Kingdom's Department for Environment, Food and Rural Affairs (Defra), Kew teamed up with the Secretariat of the CBD (SCBD) and the BGCI to develop and run a Caribbean regional GSPC workshop. We were collaborating in a Darwin Initiative–funded project in Montserrat at the time (Hamilton et al., 2008) and so worked with our local partners to provide the context and some field experiences to illustrate what implementing the GSPC could look like. The organizing team involved three alumni, including the SCBD's GSPC Programme Officer, and two Montserratian forest officers. The funding enabled us to bring 15 participants from across the Caribbean to Montserrat to discuss GSPC implementation and the barriers to successfully meeting the targets, to review regional activity, and to explore regional cooperation. Experiences varied from Trinidad, where a national GSPC committee was already constituted, to St. Kitts and Nevis, where there was little knowledge at that stage of the GSPC. Significantly, relatively few Caribbean nations had appointed a GSPC national focal point and provided feedback to the SCBD; this has encouraged the implementation of this directive, although there are still only five Caribbean GSPC national focal points (CBD, 2011c). The Plant Conservation Report noted with disappointment that less than one third of parties to the CBD have appointed a national GSPC focal point (SCBD, 2009). The workshop has catalyzed action, e.g., the Trinidad delegate stated that he now had the framework to provide a re-invigorated agenda for the Trinidad and Tobago national GSPC committee and that this was being implemented. The St. Kitts and Nevis delegate stated that he now had the knowledge to start discussing national implementation.

An active network in the region is the Caribbean Botanic Gardens for Conservation. The network was originally established through a project funded by Cable and Wireless and coordinated by BGCI to strengthen the capacity of botanic gardens in the region for plant conservation and environmental education (Wyse Jackson, 1998). One of the outputs of the project was a conservation action plan, which, although published before the GSPC was adopted, identified many key issues and capacity gaps that still remain unfilled today (Burbidge & Wyse Jackson, 1998). At their most recent conference in Cuba, the network considered progress in implementation of the GSPC as one of its key themes, and presenters reviewed implementation at a global scale (Wyse Jackson, 2010) and a subregional level (Clubbe & Hamilton, 2010), both identifying gaps in capacity and the need to accelerate progress in meeting GSPC Targets 15 and 16 as key issues. Nine alumni from the Kew programme were delegates at this conference, presenting four oral papers and three posters; all are still very active in the field.

A recent review of progress toward implementing the GSPC in the Caribbean revealed that, although success had been variable, substantial progress had been made in many targets in Cuba, Cayman Islands, Guadeloupe, and Martinique in particular (Torres-Santana et al., 2010). The review also identified some of the priority needs and knowledge gaps, including limited financial resources, understaffing, lack of local training and appropriate equipment, lack of adequate protection of important plant areas, ineffective enforcement of environmental laws, limited flow of information, including difficult Internet access, and lack of environmental awareness among the public. Many of these are key needs for capacity building. Torres-Santana et al. (2010) identified the GSPC Target 1, "a widely accessible working list of known plant species, as a step towards a complete world flora" (CBD, 2002), as one of the targets achieved most consistently across the region where it was mostly achieved or good progress noted, with only Anguilla reporting no progress. This is critical because of the underpinning nature of the GSPC Target 1 (Paton & Nic Lughadah, 2011). At a global scale, the launch of the Plant List in December 2010 was a milestone, providing free, easy access to a web-based world checklist of plants (cf. The Plant List, 2013). With any undertaking of this nature and scale, it is a work in progress, and data quality is being regularly improved as a result of feedback and increased knowledge. With the launch of the Plant List, the GSPC Target 1 was achieved and the basis set for achieving the revised Target 1, "an online flora of all known plants," (CBD, 2011d) by 2020. The further implementation of GSPC Target 1 is to provide the same access and information at various scales. At the Caribbean regional scale, the Flora of the West Indies project has brought together a specimen-based distributional checklist for the West Indies that provides access via one web portal to all the indigenous taxa known from this region (Acevedo-Rodriguez & Strong, 2008b). At a subregional scale, the United Kingdom Overseas Territories (UKOT) Online Herbarium project provides a single web-based checklist and botanical information portal (UKOT, 2013). Again, the backbone of this are the plant species lists and specimen information for the five Caribbean UKOTs within the larger database dealing with all 16 territories. This also brings together other botanical resources in support of conservation action on the ground and implementation of the GSPC (Clubbe et al., 2010a). It is vitally important to support in-country partners with training in the core skills needed to use these resources and contribute to their continued use and success. At Kew, specific training is provided in these skills, including plant identification through the Tropical Families identification course as well as providing facilities to use the herbarium and work alongside experienced Kew botanists or taking the Herbarium Techniques course (RBG Kew, 2011). In-country, we work with local partners to put together workshops, courses, or other one-to-one training activities that respond to the identified local needs. For example, in 2007 we ran a Caribbean regional herbarium management course in Trinidad in collaboration with the National Herbarium, which focused on the role of the herbarium in conservation. Twenty-five participants from across the region attended and engaged in lively debate, including opening up herbaria and making their activities more relevant; a GSPC framework helped to facilitate this debate. Access to reliable, up-to-date plant taxonomic information was identified as one of the key barriers, and the development of online databases and online resources such as the digital library of JSTOR (2013) and the Biodiversity Heritage Library (BHL, 2013) are seen as real solutions. The challenge now is to accelerate global access to plant diversity information (Nic Lughadah & Miller, 2009). The production of locally specific field guides is also an important excellent contribution to improving access to plant diversity information, e.g., the guide to wild plants of Antigua and Barbuda (Pratt et al., 2009).

Targets 1 and 2 of the GSPC go hand in hand. Regional collaboration is vital to achieve GSPC Target 2: "a preliminary assessment of the conservation status of all known plant species, at national, regional and international levels." At a local level, success can be achieved where all the key stakeholders can be brought together in a workshop to assess the species endemic to individual islands and publish a Red List, e.g., the Cayman Islands (Burton, 2008) and Antigua and Barbuda (Pratt et al., 2009). For more widespread species, broader collaboration and data exchange are required, and there now needs to be much greater regional collaboration to achieve the red listing of the whole Caribbean flora. Several initiatives are underway in conjunction with training activities in applying the International Union for Conservation of Nature and Natural Resources (IUCN) Red List Categories and Criteria (IUCN, 2001); Red List training forms a key component of all the Kew regional courses and workshops. The Plants Under Pressure (2010) report by Kew highlighted that less than 3% of known plant species are currently on the IUCN Red List of Threatened Species, and the GSPC Target 2 activities need to be scaled up significantly if we are to meet the revised Target 2 by 2020. Future progress in plant red listing requires greater participation by the world's herbaria and increased support for expert networks (Schatz, 2009). New tools and techniques, as well as training in their use, are being developed to try and plug this gap (Bachman et al., 2011).

In addition to the sufficiency of trained people noted for GSPC Target 15, Target 16 further emphasizes the need for appropriate facilities, which provides different challenges and resource needs in meeting particular targets; capacity building needs to be directed at targets individually. For example, Kew's Millennium Seed Bank Partnership (MSBP) has an active Caribbean program and supports several local seed collector posts in the smaller islands where resources are very scarce. Training is provided and a collection strategy developed (MSBP, 2013). GSPC Target 8 refers to ex situ collections, at least 75% being preferably in the country of origin (CBD, 2011d). Some of the larger Caribbean countries such as the Dominican Republic are keen to develop their own local seed banking facilities and the MSBP is supporting these developments with technical assistance. However, many of the smaller islands, including the UKOT, prefer to keep their seed in long-term storage off-island and away from electricity surges, power outages, and threats from hurricanes. In these cases, the MSBP is able to offer free storage on mutually agreed terms in the MSBP at Wakehurst Place (MSBP, 2013).

At Kew, seed that is to be banked at the MSBP undergoes germination testing, and key species are grown in the Kew nurseries until flowering; a horticulture protocol is produced, which is shared with country partners. Parallel testing is undertaken in countries where horticultural facilities are available, and training is provided where needed. The protocols enable in-country horticulturists to more successfully grow plants for conservation, restoration, display, and education (Corcoran et al., 2010). It is these types of practical activities that we see as helping build capacity to meet GSPC Target 3: "information, research and associated outputs, and methods necessary to implement the Strategy developed and shared" (CBD, 2011d). These threatened species then go on display at Kew; the stories of these unique plants and their ongoing threats are told to the visiting public. This directly contributes to meeting the GSPC Target 14 on raising public awareness in the United Kingdom. A wide range of awareness-raising activities is also undertaken in the Caribbean as an integral part of all projects. These include talks in schools and to the general public, opportunities for people to join/observe fieldwork, plant naming competitions for endemic species without a local name, and the production of informative posters.

In-country support for developments in botanical infrastructure includes the establishment of native species nurseries with local botanic gardens and national trusts, as well as horticulture skills training where needed (Clubbe et al., 2010b). Native species nurseries provide varied functions. For example, at the Queen Elizabeth II Botanic Park in the Cayman Islands, the use of native species in landscaping is encouraged in response to current usage of non-native, and in some cases, invasive species (Clubbe et al., 2010c). In the Turks and Caicos Islands, the focus is on establishing an ex situ collection of the endemic *Pinus caribaea* Morelet *bahamensis* (Griseb.) W. H. Barrett & Golfari, which is being devastated in the wild by an invasive scale insect. This genetically diverse collection can then form the basis of a reintroduction program once the scale infestation has been controlled.

There needs to be a well-documented way to agree on priorities and actions and to measure success in implementing the GSPC. Consequently, the importance of developing realistic, accurate, and agreed upon management plans is vital. Ideally, species and habitat data should be integrated into an overall habitat-based plan, which links directly to or is actually part of the National Biodiversity, Strategy and Action Plan (NBSAP) as covered under the CBD (2011b). Achieving the GSPC targets is best integrated directly into this process, and this can be done by facilitating participatory workshops that bring all stakeholders together to agree on requirements and actions and to identify resource needs.

Toward Meeting the GSPC 2020 Targets

Do we have the capacity to achieve the 2020 targets in the Caribbean region? There is good progress in several areas, but many challenges remain. There needs to be greater mainstreaming of the GSPC. We need to increase the number of GSPC focal points to better champion the GSPC locally. Botanical capacity is still a challenge and provides opportunities for the larger, international institutions to work in partnership to help provide focused capacity building. There needs to be a better career structure for botanists and plant conservationists to retain trained personnel. There is still a lack of adequate botanical infrastructure in many places that needs to be urgently addressed. We need to strengthen international partnerships, and we need better support for existing networks to improve what they are already doing. All of these require financial investment at a time when resources are difficult to secure, and plant conservation is not necessarily seen as a priority at a political level. We can work more efficiently by maximizing the use of new technologies and communication tools and can catalyze positive action by exploring the role and use of social networking that is proving to be so successful in many walks of life.

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FROM CHECKLISTS TO AN E-FLORA FOR SOUTHERN AFRICA: PAST EXPERIENCES AND FUTURE PROSPECTS FOR MEETING TARGET 1 OF THE 2020 GLOBAL STRATEGY FOR PLANT CONSERVATION[1]

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Abstract

The exceptional botanical wealth of southern Africa has been known internationally since the early 17th century. However, it is only during the past 25 years that a succession of regional floristic checklists has been published, culminating in one for southern Africa (Namibia, Botswana, Swaziland, Lesotho, and South Africa) (Germishuizen & Meyer, 2003) and another enhanced with primary biological information such as growth form, plant height, and altitudinal range occurrence for South Africa (Germishuizen et al., 2006). These printed products (Germishuizen & Meyer, 2003; Germishuizen et al., 2006) delivered floristic checklists for southern and South Africa, respectively, on time for achieving Target 1 of the 2010 Global Strategy for Plant Conservation (GSPC). These works reflected the cumulative work of several generations of taxonomists, collectors, recorders, and databasers and were based on extensive regional herbarium collections. Two additional goals are now required for the first 2020 GSPC Target, namely adding descriptive and other Flora-style information, and disseminating such information electronically.

Key words: E-taxonomy, Flora of southern Africa (FSA), Global Strategy for Plant Conservation (GSPC), online flora, South Africa, southern Africa.

Consideration of the history of Flora writing for, and in, southern Africa is here undertaken to determine the likely rate of progress with producing an e-flora for the region. One questions whether delivery should or could proceed through conducting an established science in an established way. If a new way of Flora production is to be embraced, for example, through e-taxonomy, then this will inevitably require the overcoming of institutional, social, and technological challenges. Southern Africa is here defined as the Flora of southern Africa (or FSA) region, that is, Namibia, Botswana, Swaziland, Lesotho, and South Africa. We argue that South Africa has been well placed to play a leading role in transforming floristic texts produced prior even to the onset of the world wide web into web-based content that includes nomenclatural and descriptive content as well as plant identification tools.

Brief History of Floras in Southern Africa

Following publication of his *Flora Capensis* in 1823, Carl Peter Thunberg (1743–1828) became widely known as the "Father of Cape Botany." This major work on the Cape flora was preceded by the publication of two volumes of its forerunner, *Prodromus plantarum Capensium*, which Thunberg produced in 1794 and 1800, respectively. Describing just less than 2800 species, Thunberg's *Flora Capensis* was a major reference on the flora of the Cape for the better part of the ensuing 100 years (Gunn & Codd, 1981; Fraser & Fraser, 2011).

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However, this "primary" Flora was antecedent to the *Flora Capensis* initiated by Irish academic William Harvey (University of Dublin) and German apothecary Otto Sonder (Hamburg) (Hall, 1977), which represented the first true Flora for South Africa. It was started privately in the years 1859–1865, within which period the first three volumes were published (Harvey & Sonder, 1859–1860; 1861–1862; 1864–1865). The first significant book on South African botany published on South African soil, *The Genera of South African Plants*, was produced by Harvey about 20 years earlier in 1838 (Bullock, 1978; Gunn & Codd, 1981: 180). This marked the year that the comprehensive exploration of the South African interior gained momentum through a northerly and easterly Great Trek undertaken by the Boers who were, mostly, dissatisfied with British colonial rule following the second and final British invasion in 1806. Sir William Hooker was attributed with "urging its [*Flora Capensis*] prosecution on its originator, Dr. Harvey," although Kew was not at first formally involved in this colonial Flora (Anonymous, 1861: 259). The Flora series lapsed with the death of Harvey in 1866 and Sonder's disengagement from the project, when in 1875, he sold the greater part of his Cape Herbarium (Gunn & Codd, 1981). Sonder died in 1881, by which time the Philosophical Society of South Africa was already prompting a local dignitary to motivate for the completion of the Flora (Hall, 1977). After a lapse of 15 years, the Flora resumed in 1896 under the leadership of the Royal Botanic Gardens Kew, with the major portion of the work completed by N. E. Brown and C. H. Wright of that institute. A number of South African botanists also contributed treatments, however, including H. Bolus, F. Guthrie, E. Stephens, H. Pearson, and E. Phillips (Thiselton-Dyer, 1925; Phillips, 1930). The final fascicle of *Flora Capensis* (Hill, 1933), on gymnosperms, was printed as a supplement to Volume V. In total, 11,731 species were covered in seven volumes for the area chiefly south of the Tropic of Capricorn. At the time, the series was considered by some, such as J. Burtt Davy who was quoted from his correspondence, as "a permanent and sound foundation for a series of Local Floras of South Africa," and upon which he based his manual of plants of the Transvaal and Swaziland (Thiselton-Dyer, 1925: 291).

In February of 1955, just over 20 years after the final treatise in the *Flora Capensis* series appeared in print, the Botanical Survey Advisory Committee in South Africa unanimously supported the concept of producing an FSA to replace *Flora Capensis*, which was by then perceived as outdated. It was anticipated at the outset that the project would take about 40 years to complete, eventually covering 20,530 species in 180 angiosperm families. The Minister of Agriculture approved the project in principle, on the condition that the work be published in both Afrikaans and English and that no additional staff be asked for by the Botanical Research Institute (BRI; Verdoorn, 1958). The project was to cover the territories known today as South Africa, Lesotho, Swaziland, and Namibia (Marais, 1958) with the sequence of completion of volumes or fascicles in line with taxonomic revisionary work already in progress. The region then known as the Bechuanaland Protectorate (today Botswana) was to be covered by the Flora Zambesiaca, a project started in earnest during August 1956 and anticipated to take 20 years to complete (Wild, 1958), but which is still in progress. Wild (1958: 54) observed that the proposed Flora Zambesiaca represented "perhaps a more direct collaboration between an independent African herbarium [SRGH] and the European herbaria than in other [Tropical African] Floras which are more definitely the products of European centres." He also pointed out that the boldness of plans for a Flora that would cover what is today Zimbabwe, Botswana, Zambia, Malawi, and Mozambique prompted the South Africans to broaden their floristic vision. Wild (1958) reported that R. A. Dyer, then Director of Botanical Services for the Department of Agriculture in Pretoria, had planned for some years to complete the *Manual of the Flowering Plants and Ferns of the Transvaal with Swaziland, South Africa*, two fascicles of which had been produced by Burtt Davy (1926, 1932). However, learning of the scope of the Flora Zambesiaca project, Dyer decided rather to co-motivate for a much more ambitious FSA. This Flora was to complement the Flora Zambesiaca and the *Conspectus Florae Angolensis* and with them provide a complete floristic review of the whole area south of the Congo and Tanzania (Dyer, 1977).

The first FSA volume was generally well received on its publication in 1963, with a reviewer (Bullock, 1965: 224) observing that "throughout the text there is most encouraging evidence of the effectiveness of the Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale (AETFAT), the main objects of which are to encourage international discussion of taxonomic problems and to attain a high degree of uniformity in both taxonomic treatment and nomenclature in all the regional Floras currently in preparation." Dyer (1977) similarly acknowledged the role of AETFAT, which first convened in Brussels in 1951, in providing impetus to the preparation of regional Floras. Not surprisingly, AETFAT meetings have provided a regular opportunity for taxonomists to present on progress with the African Floras (e.g., Codd, 1965, 1968; Killick, 1971, 1976 for the FSA). Although AETFAT has continued to meet every three or four years over the past six decades, Flora reports have appeared less regularly in the proceedings resulting from recent conferences (sometimes presented only as posters), most notably for those Flora series that have progressed rather slowly.

Other than the FSA series undertaken by the then BRI of South Africa, often with overseas international collaborators, workers within several of the countries included in the geographical scope of the FSA contributed significantly toward Flora studies for their respective nations. Compton (1976) delivered *The Flora of Swaziland*, which treated 2118 species of flowering plants, providing brief descriptions as well as taxonomic keys, collection vouchers, and notes on ecological and taxonomic matters. A subsequent updated checklist (Braun et al., 2004) enumerates 3441 plant taxa from Swaziland, reflecting substantial botanical exploration of that country during the past four decades; Compton's Flora nonetheless remains a useful basis for delivery on Swaziland's Target 1 for GSPC by 2020. The Flora of South West Africa (FSWA), of the country known today as Namibia, was previously treated as a prodromus, a preliminary treatise respecting a subsequent more elaborate work as was intended by Merxmüller (1968). His part 1 (of five, by 1972) first appeared in 1966, some 15 years after the work initiated, it was anticipated that it would be possible to complete the entire work within three years thereafter (Merxmüller, 1968). Ultimately, publication would proceed over six years (Merxmüller, 1966–1972) and represent the treatment of ca. 4300 taxa from an area of 824,268 km^2. The early completion of Merxmüller's prodromus has well placed the taxonomic community in Namibia to further research and manage its flora, a good reminder that even the completion of a flora's prodromus, as would be the case with a Flora, is a means to further ends and not just an end in itself. Among the 10 participants in the Southern African Botanical Diversity Network (SABONET) program, Namibia has been outstanding in its delivery of useful products. It was the first to produce a country plant checklist (Craven, 1999) and a country-level plant Red Data Book (Loots, 2005). Presently, a modern, English-language Flora of Namibia is under development.

By the late 1970s it was realized that in order for the volumes to appear in the form planned initially, the progress with the FSA would need to proceed much more rapidly (see Dyer et al., 1963: vi–vii). Accordingly, the format of the Flora was modified (descriptions were shortened and specimen citations simplified) to speed up production without the loss of essential information, and fascicles with a minimum of 50 species were considered for publication (Leistner, 1983). This necessary change reflected a flaw in the original Flora planning process, which led to components of volumes being completed but not printed, as the balance of the anticipated contents was not ready for publication. As part of efforts to enhance the publication rate of small, but publishable units submitted to the FSA editorial office, the series "FSA contributions" within *Bothalia* was started in the mid-1990s (see, e.g., Smith, 1995a, 1995b). As conceived, the Flora was to appear in 33 volumes with some volumes split into a maximum of four parts for very large families, for example, Asteraceae, such that between 300 and 800 taxa would be treated per volume. Although information for inclusion in the planned FSA was considered by Verdoorn (1958: 74) to be "on the generous side," standard Flora-style information was ultimately presented. Each taxon and its relationships in both southern Africa and adjoining territories were considered critically, and taxonomic descriptions, keys, selected citations of specimens and literature given, along with distributional information, synonyms, nomenclatural types, notes, and at times illustrations.

At the present time, ca. 18% of the 24,393 plant taxa known from southern Africa (Germishuizen et al., 2006) have been treated in the FSA, and this after 55 years of work. The vast majority of treatments deal with South African species, which were recently enumerated at 22,604 taxa (Germishuizen et al., 2006). By 1970 alarm bells were already ringing, and Killick (1971: 77) reported to AETFAT that at the rate of progress then evident, although parallel monographic work was not included in the FSA, "the Flora will take another two centuries to complete." Five years later Killick (1976: 633) balefully projected that the Flora would be completed in 2345, although if one included the species already completed in the volumes then being tackled "the situation looks a trifle brighter: 8% completed and final date 2151." De Winter (1970) had estimated that five fully trained taxonomists dealing with 150 species per year would take only 18 years to complete the FSA. However, Killick (1971: 77) pointed out that although seven professional botanists were working on the Flora team, none worked full time on the project, resulting in "a most unsatisfactory state of affairs." Leistner (1983) appealed to members of AETFAT to cooperate on the FSA, noting that 48 taxonomists from outside the BRI of South Africa were already collaborating. However, it is likely that the apartheid policies of the then government of South Africa deterred participation, and within a few years an academic, cultural, and sports boycott of the country was in full motion. At the time, the other major African floras (Flora Zambesiaca, Flora of Tropical East Africa) were also struggling to improve their slow production pace, and most European taxonomists were already committed to those projects.

Collaboration North-South and South-South

Most large Flora projects, both historical as well as current, are clearly undertaken by major international herbaria such as those of the Royal Botanic Gardens, Kew (K) and the Missouri Botanical Garden (MO). Indeed, significant taxonomic achievements that yield regional Floras or checklists in sub-Saharan Africa have most often resulted from collaborations between north and south. The FSA is exceptional in that it has been attempted by a developing nation (South Africa), albeit to date with only partial success.

The hugely successful SABONET program, funded by the Global Environment Facility (GEF) and the United States Agency for International Development (USAID), developed through the United Nations Development Program (UNDP), but implemented through the then National Botanical Institute (NBI) of South Africa, represented an almost exclusively south-south collaboration where the main aim was capacity building, but the results included national plant checklists. In the first decade of the 21st century, the nature of such formal collaborations has taken the form of online e-taxonomy, where maximal use of the internet has provided access to regional inventories. In southern Africa, the most recent of these has been the production of inventories of plant diversity and common names for Angola (Figueiredo & Smith, 2008, 2012). The plant diversity inventory was supplemented by a wealth of biodiversity data available electronically and through the international collaboration of 30 scientists (Smith & Figueiredo, 2010). Online resources accessed in the course of this floristic work are detailed by these authors.

One of the most significant north-south projects for Africa to have been completed in recent years is the first-ever angiosperm checklist and database for sub-Saharan Africa (Klopper et al., 2006). The African Plant Checklist and Database project (APCD) is a collaboration between the South African National Biodiversity Institute (SANBI) and the Conservatoire et Jardin Botaniques de la Ville de Genève (Switzerland) and is available as a regularly updated online searchable database (African Plant Database, 2013). In line with the objectives of AETFAT, the APCD checklist was conceived in 1994 during the 14th congress of that Association; the full history of the project has been documented by Gautier et al. (2006).

Global Strategy for Plant Conservation Target 1 for 2020

The original Target 1 of the Global Strategy for Plant Conservation (GSPC; United Nations Environment Programme [UNEP], 2002) was conceived as "a widely accessible working list of all known plant species, as a step towards a complete world Flora." This target was considered well addressed when a global world plant list became available (Plant List, 2010) in late December 2010. In southern Africa, such a target had been achieved years earlier with the national checklists produced within the scope of the SABONET program (Craven, 1999; Braun et al., 2004; Kobisi, 2005; Setshogo, 2005; Germishuizen et al., 2006) and by the global sub-Saharan checklist for flowering plants (Klopper et al., 2006). Further progress toward delivery on this target for several components of the South African flora prior to 2010 has been provided by Smith and Smith (2006).

Looking ahead to the next stated interval, 2011–2020, the Global Partnership for Plant Conservation (GPPC, 2010) focuses on the enhancement of Target 1 with the following goals in mind: a) to add a more complete description and other Flora-style information to the checklist; and b) to make the working list "more useful, accessible, and functional for end-users" by disseminating such information electronically. Therefore, the first target of the GSPC aims now to produce an electronic Flora for all the world's plants by 2020. Significantly, the Secretariat of the Convention on Biological Diversity (SCBD, 1992 on) has unambiguously taken a dim view of the generally slow progress with Flora production globally, by challenging the taxonomic fraternity to produce an electronically accessible Flora for the world within the next seven years.

A recent assessment of the state of botanical research in South Africa (Bredenkamp & Smith, 2008) has highlighted local concerns related to the advancing group age of practicing botanists coupled with an inadequate rate of training and mentoring of young scientists. This gap in age and training is reportedly particularly acute in the formal South African systematics and taxonomic community (Herbert et al., 2001). Nonetheless, as Joppa et al. (2011) have pointed out in their global analysis of rates of species descriptions, systematics research continues apace, despite such contrary reports on the dissolution of taxonomic capacity. Joppe et al. (2011: 551) determined that "the numbers of [flowering plant] taxonomists are increasing. . .as are the numbers of taxonomists who are the senior authors on species descriptions." This led to their conclusion that "taxonomic description no longer belongs to those who do nothing else; species description is much more widely practiced." However, it must be noted that there is a great difference between describing one new species and producing a taxonomic revision for a group of species, the former being a task eagerly done by amateurs while the latter requires greater perspective and formal training. Regardless of who undertakes the taxonomic work, a strategy and supporting implementation plan for South Africa and southern Africa is required, if Target 1 of the revised GSPC is to be achieved by 2020.

The Way Forward in Southern Africa

The sound nomenclatural and taxonomic platform provided by the APCD supports not only ongoing floristic work in sub-Saharan Africa, but also the e-taxonomic and e-Flora efforts that will be needed by the constituent/participating African countries to support delivery on Target 1 of the 2020 GSPC. This target toward the completion of an accessible or online Flora of all known plants in the world has to build on the achievement of the 2010 target, namely, the working list of known plant species (<https://my-plant.org/news/plant-list-working-list-all-plant-species>). The structure and form of this online Flora are as yet uncertain, even in relation to the scope of content. The current authors consider that it should largely align with traditional concepts of a Flora (see e.g., Harvey & Sonder, 1859–1860) by including descriptive information and identification tools. The traditional format, at least in Africa, has been fairly uniformly modeled and typically concurs with Kirkup et al. (2005: 457), who consider a Flora to "provide an inventory of plants occurring in a particular geographic region and provide a means to identify these plants." Descriptive content and identification tools, such as dichotomous keys, are central to this definition.

Historical, colonial Floras drew on a concise format and taxonomic structure, were mindful of production costs, and provided the minimum needed to allow for the identification of a specimen drawn from, importantly, the defined geographic range for that Flora. With floristic texts and visual resources logarithmically expanding online (cf. Encyclopedia of Life [EOL], now including over a million species pages [Encyclopedia of Life, 2013]), one questions whether the traditional Flora format needs to be maintained, for the historic objectives can now be realized in a completely different way, through a product that might well look and feel vastly different. Importantly though, if a new way of writing and constructing a Flora is to be embraced and Target 1 of the 2020 GSPC achieved, taxonomists and their institutions will need to shift their mindsets, technology base, and approaches to collaboration within an e-taxonomy frame. Significant projects are already underway to harness the interest, expertise, and goodwill of large groups of taxonomists around the globe. The eMonocot initiative (eMonocot, 2013) is one such project that, through the web, will provide information such as up-to-date checklists, nomenclature, taxonomic descriptions, plant images, and identification guides, as well as geographical, ecological, DNA sequence, and conservation data. This is all structured around a taxonomy derived from the online World List of Monocotyledons (2012), which comprise an estimated 20% of flowering plants. If successful in capturing the anticipated data for 70,000 monocot species by 2020, an online world Flora is arguably expanded toward about one fifth of the global GSPC Target 1.

A project to digitize published African Floras was initiated at Kew 10 years ago, with the aim being to improve the accessibility and utilitarian value of the included plant species information (Kirkup et al., 2005). Similar projects have been developed elsewhere, such as the eFloras project hosted by the Missouri Botanical Garden and the Harvard University Herbaria (Brach & Song, 2006; eFloras, 2013). This website includes checklists and Floras for flowering plants and mosses from China, Nepal, Chile, Ecuador, Missouri, and North America, simply the diverse floristics products of active institutional programs. Most of the early e-Floras such as these facilitate access to information published in particular Flora volumes where access is by a quick search by scientific name, sometimes also by synonym, geographical area, or habitat. As indicated by Kirkup et al. (2005), reflecting changes or additions to the published text for the online version of Flora Zambesiaca were out of the scope of these projects. Interrogating these e-Floras will be the same as consulting printed versions of the Floras in a library, but quicker and more globally accessible. Links to other databases for updated nomenclature are sometimes provided, but such searches may yield irrelevant or inadequate information for the taxon being searched. More recently, other e-Floras have been established, such as the Flora of New Zealand (Flora of New Zealand Committee, 2013), where information from the original published Flora is dynamically supplemented with data from other sources and with links to other websites. In the near future, it is expected that e-Floras will evolve further, with direct links to information associated with each accepted plant name, and synonymy becoming standard practice. The integration of images of living plants and herbarium specimens (including types) and protologues in an e-Flora is now dramatically achievable. Furthermore, published information from related fields, such as ecology and ethnobotany, where names that are no longer accepted may be used, can also be linked and displayed. This would eventually transcend the function of e-Floras from plant identification tools to plant information systems (enter the ambitious EOL project). This can only be achieved through a collaborative consensus, integrating data from a vast array of different e-sources and with the allocation of resources especially to the most biodiverse areas (Paton, 2009).

The question is then one of how countries such as South Africa should approach Target 1 in order to be able to report at a national level on acceptable country- or regional-level progress toward this target of the GSPC. Whether a taxon-level approach, a geographic approach, or both, is adopted will depend on unfettered access to international initiatives such as eMonocot and its associated e-tools (e.g., the scratchpads so effectively utilized in eMonocots), and on continued, even accelerated progress with traditional Floras or in some instances (e.g., Namibia), development of Floras from their associated prodromi.

During the next eight years South Africa will adopt a dual-pronged approach in evolving e-taxonomy opportunities and existing commitments to provincial and biome-focused Floras, a number of which have already been completed. As early as the 1970s it was realized that the slow progress of the tradition-based FSA would take centuries to complete, and through the efforts of Bond and Goldblatt (1984), the first Flora-style treatment of the Cape Floristic region was published. This work has since seen a second comprehensive update (Goldblatt & Manning, 2000), with a third version now in print production. Similar but with a slightly different style and content, Retief and Herman (1997) produced a taxonomic treatment of the plants of the northern provinces of South Africa. Although the two regions, separated by South Africa's arid, karroid interior, have some species in common, the intelligent digitization of both tomes would provide a significant e-backbone for about 10,000 South African plant taxa. In addition, Retief and Meyer (in prep.) have made significant progress with Plants of the Free State, Snijman (in prep.) with the greater Cape Flora, including the succulent karoo biome, Bredenkamp (in prep.) with the Eastern Cape Flora, and the Northern Cape Flora (Magee & Boatwright, in prep.) having been initiated. This leaves only South Africa's eastern seaboard, essentially from the Drakensberg eastward to the KwaZulu-Natal coast, as lacking treatment. This should offer few challenges, though, as treatments of many species of that subtropical province can be derived from the treatments of the bordering Eastern Cape, Free State, and northern Provinces. These treatments will require significant work to harmonize them across the various in-country regions and to include traditional Flora content that has been occasionally omitted, ranging from protologue and type information, nomenclatural synonymy, as well as adequate identification keys and plant descriptions. It is arguably easier to equalize the treatments than to generate them afresh. The task has been made easier by the availability of much of the necessary information online. It is envisaged that a national e-Flora for South Africa will build from these in-country Floras and various internet resources. These range from taxonomic databases, such as the APCD, JSTOR Global Plants (2013), Kew's World Checklist of Plant Families, the International Plant Names Index (IPNI), and TROPICOS, and also extend to general plant websites such as Plants of Southern Africa (POSA; 2009). An electronic platform can then link all existing information, with additions of original content such as identification tools and distribution maps.

The other southern African countries have much lower plant diversity than that of South Africa (viz. Botswana: 2151 species, Namibia: 3961, Lesotho: 1591, and Swaziland: 3400; Golding, 2002). Electronic Floras for Botswana and Namibia are likely to be produced as outputs of current Flora projects (Flora Zambesiaca and Flora of Namibia) if these reach their end before the 2020 deadline. For Lesotho and Swaziland, e-Floras can be relatively easily accomplished in collaboration and through linking to the resources of the South African e-Flora. Successful delivery of e-Floras in southern Africa will not only require in-country, regional, and international coordination and collaboration with relevant planning, but should also anticipate that developments in information and communication technology (ITC) over the next eight years will provide as-yet unforeseen advantages and tools to develop online Floras.

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ACHIEVING TARGET 8 OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION: LESSONS LEARNED FROM THE NORTH AMERICAN COLLECTIONS ASSESSMENT[1]

Abby Hird[2] *and Andrea T. Kramer*[3]

Abstract

How much progress has North America made toward the Global Strategy for Plant Conservation (GSPC) Target 8 of at least 75% of threatened plant species in accessible ex situ collections by 2020? To answer this, the North American Collections Assessment was carried out in 2010. More than 200 botanical and conservation institutions in the United States, Canada, and Mexico contributed taxa lists to the Botanic Gardens Conservation International's (BGCI) online PlantSearch database for this assessment. By cross-referencing collection information with globally threatened species lists from the International Union for Conservation of Nature and Natural Resources (IUCN), NatureServe, and Mexico's Red List, we found that approximately 35% of North America's nearly 5000 most threatened taxa are currently in ex situ collections. This marks considerable progress toward the GSPC Target 8, but there is clearly much more to do. Future priorities include collaboratively and strategically increasing threatened species representation in collections and assessing genetic diversity among collections by comparing accession-level data.

Key words: Botanic garden, ex situ plant conservation, Global Strategy for Plant Conservation (GSPC), living plant collection, seed bank.

Well-documented, genetically diverse living plant and seed bank collections at botanic gardens and similar institutions support integrated plant conservation (Fig. 1) and provide critical insurance for many of the plant species now threatened with extinction, recently estimated at 100,000 total worldwide (Pitman & Jorgensen, 2002; Guerrant et al., 2004). But how many threatened species are safeguarded in collections, and which are not? While the botanical community as a whole does not know the actual representation in collections of threatened species, the Botanic Gardens Conservation International (BGCI) has a growing number of tools in place to help botanic gardens leverage their collective resources to address this and other challenges ahead.

Our Contributions to the Global Strategy for Plant Conservation

Botanic gardens have a global mandate to provide a safety net against extinction for threatened plants. The Global Strategy for Plant Conservation (GSPC), ratified by nearly every country in the world, was adopted by the Parties to the Convention on Biological Diversity in 2002 (CBD, 2002). The development and adoption of the GSPC were largely due to the efforts of the global botanic garden community, and we now play a key role in achieving its 16 outcome-oriented targets to halt the loss of plant diversity worldwide. Directly relevant to botanic gardens and their collections, GSPC Target 8 sets a goal to have at least 75% of threatened plants in accessible ex situ collections by 2020. While resources to meet this important target might be limited, the individual and collaborative work of botanic gardens and conservation organizations has made great progress in building ex situ conservation collections as a global safety net for threatened species. As the 2020 deadline approaches, it is critical that we know where we stand relative to this

[1] The North American Collections Assessment was carried out by the Botanic Gardens Conservation International (BGCI) U.S. in partnership with the United States Botanic Garden and the Arnold Arboretum of Harvard University, with additional funding from the Wallace Genetic Foundation. Collaboration with many organizations and botanic gardens throughout North America made this project possible, including the American Public Gardens Association, Center for Plant Conservation (CPC), Canadian Botanical Conservation Network, and Mexican Association of Botanical Gardens. Thanks are extended to all contributors for their support and participation, Suzanne Sharrock and Meirion Jones at BGCI, and special thanks to assessment co-authors Ray Mims, Michael Dosmann, and Kirsty Shaw.

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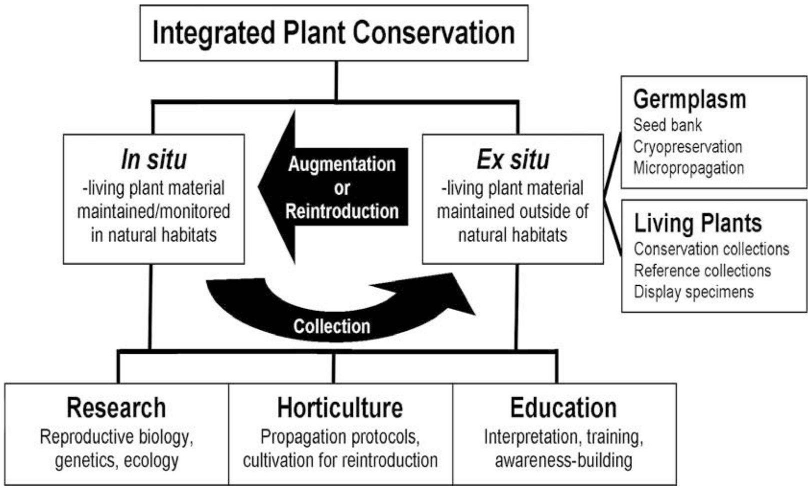

Figure 1. Integrated plant conservation combines in situ (on-site) and ex situ (off-site) conservation action to support species survival. In situ conservation protects species in their native habitat, while ex situ conservation ensures plant material is available for research, horticulture, and education activities that ultimately support reintroduction efforts, ensuring that ideally no species goes extinct.

ambitious target in order to inform future strategic and collaborative conservation efforts.

Measuring Global Progress

When the GSPC was adopted in 2002, the BGCI launched PlantSearch, an online database of botanic garden collections, as a means to measure basic, taxon-level progress toward the GSPC Target 8 (BGCI, 2012b). The PlantSearch database remains the only resource available to measure global progress toward the GSPC Target 8 and represents the only global database of plants in cultivation. All institutions that curate collections of living plants, banked seeds, or other plant germplasm are encouraged to upload a list of taxa in their collections to PlantSearch on an annual basis. This free database not only facilitates estimates of national and global progress toward Target 8, but also provides invaluable data for institutions to prioritize their collection efforts and to connect their collections to other collection holders and researchers nationally and worldwide. This connectivity makes such institutional collaboration and biological research on the conservation of threatened plant species more efficient and effective.

In 2010, the BGCI analyzed the data in PlantSearch and found that only 23% of all threatened plants, i.e., as included on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (IUCN, 2010), are known to be maintained in ex situ collections worldwide. These results are presented in a recent report on botanic gardens and the implementation of GSPC Target 8 (Sharrock et al., 2010). A similar report focused on threatened European plants found that 44% were held in ex situ collections (Sharrock & Jones, 2011). While this indicates positive progress, these results are also a call to action as they fall well short of the 2020 GSPC target of 75%. Highlighted below, the assessment of threatened North American plant species in collections (Kramer et al., 2011) exemplifies both the achievements made and limitations faced in North America as we work to conserve plant species and achieve the GSPC Target 8 by 2020.

Measuring North American Progress

In 2010, the BGCI U.S. partnered with the United States Botanic Garden and the Arnold Arboretum of Harvard University to conduct a North American Collections Assessment, the results of which were recently published and distributed as a report, available online and in print (Kramer et al., 2011). This assessment measured progress toward the GSPC Target 8, specifically within the North American botanical and conservation communities. This project resulted in the first compilation of North American threatened species lists from the varying systems used in the United States, Canada, and Mexico, i.e., NatureServe global threat ranks (NatureServe, 2012), IUCN Red List ranks (IUCN, 2010), and Mexico's NOM Red List (NORMA, 2001; Fig. 2). Taxonomic lists were utilized from over 200 institutions via the PlantSearch database to identify the number of

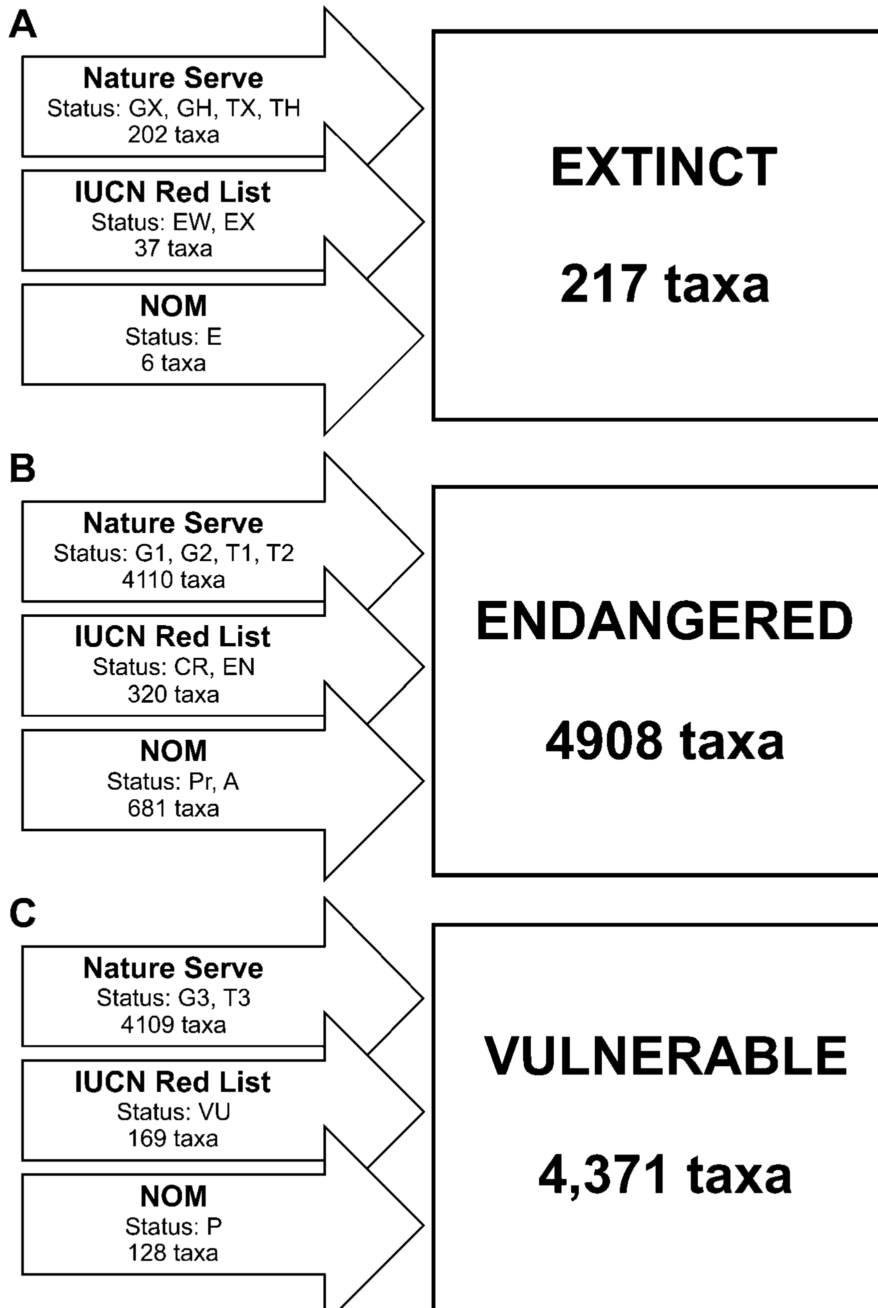

Figure 2. Three threatened species lists (NatureServe for Canada and the United States, NatureServe, 2012; IUCN Red List for plant taxa globally, IUCN, 2010; and the NOM Red List for Mexico, NORMA, 2001) were compiled into three categories (Kramer et al., 2011). —A. Extinct species are represented by NatureServe's assessments of GX or GH (presumed extinct or eliminated or possibly extinct or eliminated) and TX or TH (equivalent to GX or GH, but for a subspecies or variety); by IUCN's EX or EW (extinct or extinct in the wild); and by NOM's E (Probablemente extinta en el medio Silvestre, Probably extinct in the wild). —B. Endangered plant taxa are assessed by NatureServe as G1 or G2 (globally critically imperiled or imperiled) and T1 or T2 (equivalent to G1 or G2, but for a subspecies or variety); by IUCN as CR or EN (Critically Endangered or Endangered); and by NOM as Pr (Sujetas a protección especial, Subject to special protection). —C. Vulnerable taxa are categorized by NatureServe as G3 (globally vulnerable) and T3 (equivalent to G3, but for a subspecies or variety); by IUCN as VU (Vulnerable); and by NOM as P (En peligro de extinción, At risk of extinction). NatureServe rankings may be found at <http://www.natureserve.org/explorer/ranking.htm>; IUCN categories and criteria at <http://www.iucnredlist.org/documents/redlist_cats_crit_en.pdf>; and NOM criteria at <http://www.biodiversidad.gob.mx/pdf/NOM-059-ECOL-2001.pdf>.

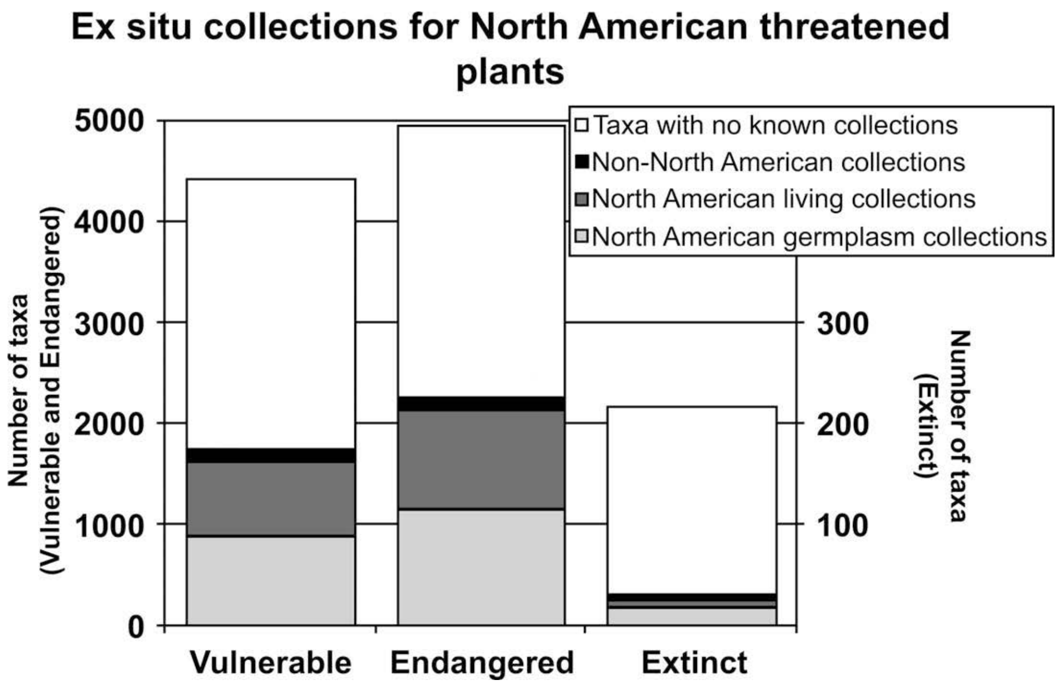

Figure 3. North American threatened taxa in ex situ collections. Threat category corresponds to the summed assessments seen in Figure 2 (endangered, vulnerable, and extinct). Light gray shading refers to germplasm (as seed banked, cryopreserved, or micropropagated material) and dark gray shading refers to living collections (plants). Note the 10-fold difference in y-axes for endangered and vulnerable plant taxa (at left) as compared to the known extinctions (at right).

threatened species maintained ex situ in North America.

Overall, data analyses revealed that 35% of the nearly 5000 most threatened North American species are maintained ex situ either as living plants or germplasm maintained in seed banks or as cryopreserved or micropropagated material (Fig. 3). Of particular concern, we found that nearly half of all endangered plant taxa identified in collections are maintained at only one institution (Fig. 4), which could lead to an ex situ bottleneck and reduction in genetic diversity. Taxa found in only one living plant collection likely exist as one or few specimens potentially of unknown or cultivated origins, which would capture little genetic diversity. This paucity in taxonomically representative specimens might rarely, if ever, be able to support successful reintroductions of extirpated populations.

Conversely, our assessment results are probably a slight underestimate of the number of threatened species in ex situ collections, as only 30% (230) of the known public gardens and similar institutions with living plant and germplasm collections in North America participated in the assessment (http://www.bgci.org/files/UnitedStates/NACA/naca_appendix_1.pdf; Kramer et al., 2011). Efforts were made, however, to ensure that institutions that support conservation of threatened species were able to upload a taxa list to PlantSearch. A large majority of gardens active in the Center for Plant Conservation (CPC) network (90.6%; CPC, 2012) and members of BGCI (85.6%) contributed taxa lists. Further, all but one (54) U.S. gardens reporting an ex situ conservation program in the GardenSearch database were able to contribute to the assessment (BGCI, 2012a). Many of the institutions unable to participate reported insufficient staff or technological resources to provide an electronic list of taxa in their collections. Regardless, these results indicate that we have much work ahead to ensure 75% of North America's threatened species are in accessible ex situ collections by 2020.

Summary and Future Work

It is clear that in order to achieve the GSPC Target 8 by 2020, North American botanical and conservation organizations must increase the number of species held in ex situ collections designed for conservation. Use of information compiled through this and similar assessments can facilitate the prioritization of species acquisitions at individual gardens and aid the broader botanical and conserva-

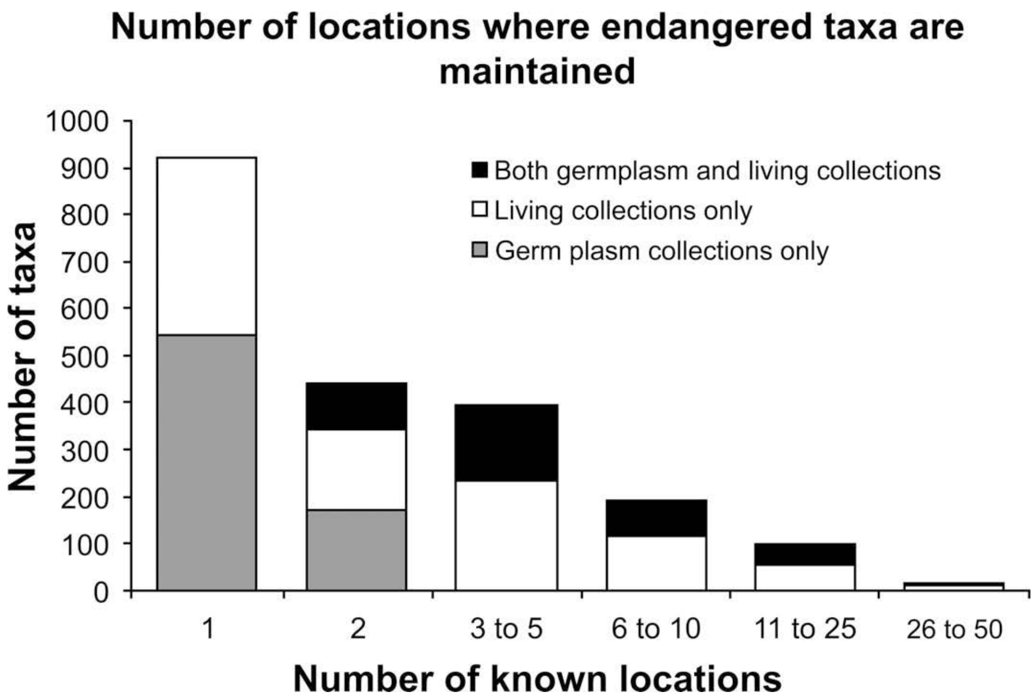

Figure 4. Representation of 2208 North American endangered taxa held in 230 ex situ collections (see Fig. 2 for details). Institutional locations are partitioned by collection type as germplasm (seed banked, cryopreserved, or micropropagated), living plants, or both. Note that many endangered taxa are held at only a single institution.

tion communities to work more effectively toward the successful achievement of Target 8. Additionally, assessments such as this allow progress over time to be documented and monitored, while providing quantitative data that demonstrate the collective impact and value of collections work.

Most institutions with ex situ collections of threatened plants can utilize the integrated plant conservation model to support important conservation, education, and research applications for those species (Fig. 1). Living plant collections in particular can promote threatened species conservation even if they were not designed to have direct, in situ conservation applications. Botanic gardens of every size and scope are uniquely positioned to wield their ex situ collections as tools to educate the public about conservation issues and the importance of plant diversity.

Living plant collection can also be used for research of understudied species (e.g., life history, ecology, propagation, pests/pathogens, or potential invasiveness) to improve conservation methods. Not all collections provide equal conservation value, however. While most collections of threatened plants can make important contributions to broader plant conservation initiatives through conservation-focused interpretation and education, not all collections provide direct conservation value at the research or reintroduction levels. Well-curated collections (living plant or germplasm) created from wild-collected, source-identified plant material can best support research and reintroduction applications for conservation.

Unfortunately, we do not currently understand the true conservation value of many of the collections included in this assessment. This must be resolved in the future by compiling and comparing accession-level data across living plant and germplasm collections to assess representation of natural populations in ex situ collections. We do know, however, that seed banks generally provide the highest conservation value in the most efficient manner, as they typically capture broad genetic diversity at relatively low costs over a long period of time. Seed banks can also provide plant material that is accessible and has direct, in situ conservation applications, to augment declining populations or reintroduce extirpated populations as needs arise. Therefore, there is an imperative to focus ex situ conservation efforts on building and strengthening seed bank collections for threatened species that produce orthodox seeds (able to be dried and stored). Currently in the United States, the collaborative network of the CPC is building secure, genetically diverse seed bank collections for hundreds of the nation's most imperiled flora (CPC, 2012), and work like this is growing around the world.

For species with recalcitrant seeds or species that are no longer able to produce seeds at all, other types of collections can be well suited to provide adequate conservation value. This includes micropropagated and cryopreserved collections of plant tissue, which can efficiently capture relatively high genetic diversity and provide direct conservation applications. However, cryopreserved collections are more expensive than seed banks to maintain long term, and protocols for long-term cryopreservation have not yet been perfected for many threatened species (e.g., threatened oak species in the United States; Kramer & Pence, 2012). Well-documented, wild-collected living plant collections designed to capture high levels of genetic diversity (and curated to avoid hybridization or adaptation to cultivation) can also have high conservation value, particularly for species that do not produce orthodox seeds. Good examples of this are the palm and cycad collections maintained by the Montgomery Botanical Center based in Miami, Florida, U.S.A. (Namoff et al., 2010). For living plant collections, which typically contain lower genetic diversity than other types of ex situ collections, much-needed collaborations such as the broad-based North American Plant Collections Consortium (NAPCC) allow duplication and collection of key species and populations to occur in a strategic fashion (NAPCC, 2011).

Achieving the GSPC Target 8 by 2020 will require the continued integration of collections data, as well as targeted acquisition and germplasm distribution. As technology advances, including the ongoing development of collaborative online databases, we will be able to gain a better understanding of the source and diversity of and can work strategically to build conservation value in collections. The need for effective ex situ plant conservation and the role botanical collections can play are only going to grow in the future. It is imperative that the North American and global botanical communities work together to ensure an effective ex situ safety net is squarely in place for threatened plant species (BGCI U.S., 2012).

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INTERNATIONAL TRADE IN ENDANGERED PLANT SPECIES IN THE CONTEXT OF THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA AND THE GLOBAL STRATEGY FOR PLANT CONSERVATION[1]

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ABSTRACT

Several international treaties contain provisions to regulate and reduce negative impacts of international trade on endangered plant species. Focusing on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Global Strategy for Plant Conservation (GSPC) of the Convention on Biological Diversity (CBD), this paper aims to elaborate existing and potential linkages between provisions and activities of these conventions. Based on an evaluation of CITES documentation, fields of potential synergies and/or joint activities between CITES and the GSPC are indicated.

Key words: Convention on Biological Diversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Global Strategy for Plant Conservation (GSPC).

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments aiming to ensure that trade in specimens of wild animals and plants does not threaten their survival. It entered in force on 1 July 1975 and, today, has 178 member parties (CITES, 2013a). Species covered by CITES are listed in three appendices. Appendix I comprises species threatened with extinction. CITES prohibits international trade in specimens of these species except for well-defined cases of noncommercial purposes. Appendix II includes species not necessarily threatened with extinction now, but in need of close controls to avoid detrimental trade. Appendix II also includes so-called "lookalike species" of species listed in the Appendices. Trade in Appendix II species is possible with CITES permits. Appendix III contains species based on a request by a Party to CITES that already regulates trade in that species and needs the cooperation of other countries to prevent detrimental exploitation (CITES, 2013b). The CITES Conference of the Parties (CoP) is the decision-making body of the Convention and comprises all its member States. Technical Committees like the CITES Plants Committee (PC) are established to provide, among others, scientific background for evaluations, discussions, and decisions at the CoPs. Terms of reference of the CITES PC include periodic reviews of listed species (in order to ensure appropriate categorization in the CITES Appendices) or the drafting of resolutions on plant issues for consideration by the CoPs (CITES, 2006).

THE GLOBAL STRATEGY FOR PLANT CONSERVATION OF THE CONVENTION ON BIOLOGICAL DIVERSITY

In 2002, the sixth CoP to the Convention on Biological Diversity (CBD) adopted, through Decision VI/9, the Global Strategy for Plant Conservation (GSPC). This strategy comprises 16 outcome-oriented targets to be reached by 2010 (CBD, 2002; Kiehn, 2002). After an evaluation of the implementation status of the targets in 2010, a consolidated and updated GSPC 2011–2020 with amended targets was adopted as Decision X/17 at the 10th CoP to the CBD

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in 2010 (CBD, 2011a, 2012). It is, however, widely accepted that its adequate implementation at a global level requires a major and proactive approach considering elements such as communication, capacity building, technology transfer, and financial support, among others (CBD, 2011b, 2013).

Convention on International Trade in Endangered Species of Wild Fauna and Flora and The Global Strategy for Plant Conservation

Already at the 13th Meeting of the CITES PC in Geneva, 2003, the CITES started to look into potential interactions between CITES and the GSPC. In the report of the working group WG5 of CITES PC13 (CITES, 2003), the responsibilities of CITES for the implementation of GSPC Target 11, "No species of wild flora endangered by international trade" (CBD, 2002, 2011c), are clearly expressed. It is noteworthy to mention here that, vice versa, the CBD in its 2009 Plant Conservation Report stated that "in essence, Target 11 forms the core business of CITES activities related to plants" (SCBD, 2009: 34). In addition to the focus on the GSPC Target 11, the working group WG5 of CITES PC13 also identified other GSPC targets where CITES activities are likely to provide useful contributions (CITES, 2003: 20; table 1). Since 2003, both the CITES CoPs and the CITES PC continued their evaluations of potential synergies and joint activities with the GSPC. The latest actions in this regard are documented by Decision 15.19 of CITES CoP 15 in Doha, Qatar, 2010. Directed to the PC and the Secretariat, this decision reads as follows: "The Plants Committee shall collaborate with the Global Strategy for Plant Conservation of the Convention on Biological Diversity, and with any processes established to develop the Strategy beyond 2010, provided it is related to CITES, as well as on other issues related to flora species included in the CITES Appendices, and the Secretariat shall communicate the contributions of CITES in the context of its Memorandum of Understanding with the CBD Secretariat" (CITES, 2010a). As a reaction to this decision, the 19th Meeting of the CITES PC prepared PC19 Doc. 8.4, which summarizes potential and real CITES contributions to the different targets of the updated GSPC 2011–2020 (CITES, 2011a). This document provides, in its Annex 1, a table that also can serve as basis for the discussion of such contributions (table 1). As a follow-up action, an intersessional working group was established at the 19th Meeting of the CITES PC (CITES, 2011e: 7) to draft a resolution related to the GSPC for discussion at the 20th Meeting of the CITES PC and for potential proposal as a resolution at the CoP 16 of CITES in 2013 (CITES, 2012).

What contributions does CITES offer to the GSPC (CBD) beyond Target 11?

Valuable contributions of CITES to Target 1 ("An online flora of all known plants") (CBD, 2011c) are checklists produced by CITES as part of its implementation processes. These checklists cover different plant groups that include several genera of the Orchidaceae (Roberts et al., 1995, 1997, 2001; Smith et al., 2006; Sieder et al., 2009), *Aloe* L. and *Pachypodium* Lindl., in the Xanthorrhoeaceae and Apocynaceae, respectively (Newton & Rowley, 2001; Lüthy, 2007), succulent Euphorbiaceae (Carter & Eggli, 2003), Cactaceae (Hunt, 1999), carnivorous plants (Von Arx et al., 2001), and bulbiferous plants (Davis et al., 1999). Meanwhile, most of these checklists are available online.

As regards to the GSPC Targets 2 ("An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action") and 3 ("Information, research and associated outputs, and methods necessary to implement the Strategy developed and shared") (CBD, 2011c), the listing of a plant species in an Appendix of CITES is already an indication for a certain need of conservation action related to this taxon. In addition, all listing and amendment proposals to the Appendices must be accompanied by an in-depth evaluation of the conservation status. These data are available for uses outside of CITES as well. In this context, it is also important to notice that only the Appendix I listing reflects an actual threat with extinction, while the Appendix II listing is intended to counteract a potential threat, if exploitation through trade is not controlled to be sustainable, or if the listed species can be confused with another one (lookalike taxa) that requires CITES protection (CITES, 2013b). Table 1 of the Working Group report to CITES PC20 (CITES, 2012: 4–5) mentions a number of other processes routinely carried out in the context of the work of CITES, which are potentially useful for the implementation of GSPC Targets 2 and 3: nondetriment findings (NDFs), periodic reviews of the three Appendices, and reviews of significant trade. These processes not only reveal additional data about the conservation status of the taxa involved, but also have produced methodologies, which are likely to be applicable for the implementation of GSPC Targets 2 and 3. See, e.g., information documents prepared for the 18th CITES PC Meeting (CITES, 2009).

In the context of the GSPC Target 7 ("At least 75 per cent of known threatened plant species conserved in situ"), the evaluation of the conservation status of taxa subject to listing and amendment proposals to the three CITES Appendices (cf. CITES, 2013b) normally includes data assessments on population level, with reference to distribution areas and habitats. These data can be helpful for in situ conservation programs for these species. This is exemplified in the Annexes 1 and 2 of CITES PC19 Doc. 14.3., related to Madagascan species of *Dalbergia* L. f. (Leguminosae) and *Diospyros* L. (Ebenaceae) (CITES, 2011b). Here, distribution and habitat data as well as the conservation status was assessed as the basis for potential listing proposals. In addition to these processes of data gathering and evaluation, efforts by CITES Parties to ensure sustainable use of CITES-listed species should also contribute to their survival in situ.

The CITES also contributes to Target 8 of the GSPC: "At least 75 per cent of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20% available for recovery and restoration programmes" (CBD, 2011c). In the context of its operational work, CITES management authorities, in collaboration with the scientific authorities, have installed rescue and propagation centers for confiscated plants. These centers are often connected with botanical gardens and aim at the best possible curation for CITES-listed plants illegally transferred across borders, including options for ex situ propagation and potential repatriation of the material into the country of origin (and thus also of relevance in the context of GSPC Target 7). Cooperation between ex situ breeding operations and in situ activities are also addressed by CITES Resolution Conf. 13.9 ("Encouraging cooperation between Parties with ex situ breeding operations and those with in situ conservation programmes"). It urges:

"a) Parties to encourage ex situ operations . . . that artificially propagate Appendix-I plant species to seek cooperative measures that would support in situ conservation based on resources generated by those captive-breeding operations; and

b) Parties to encourage ex situ operations that breed or artificially propagate Appendix-I species within the range State, to support in situ conservation programmes; such support could consist of, inter alia, technical support, contribution of funds, exchange of specimens for reintroduction into the wild, capacity building and training, technology transfer, investment, infrastructure and other measures" (CITES, 2004).

Ex situ propagation is also explicitly encouraged by CITES Resolution Conf. 9.19 (Rev. CoP15) "Registration of nurseries that artificially propagate specimens of Appendix-I plant species for export purposes" (CITES, 2010b). Artificial propagation of plant species on demand on the markets is considered as a useful tool to reduce the pressure on populations of these species in the wild.

The sustainability of the intended use is one important criterion for NDFs of plant species listed in the CITES Appendix (cf. CITES, 2013b). This directly relates to the GSPC Target 12 ("All wild harvested plant-based products sourced sustainably") (CBD, 2011c). Such NDFs are preconditions for the issuing of CITES export permits and in some cases also for import permits. In addition, annotations to the three Appendices enable the regulation of certain target commodities, e.g., tropical timber or medicinal plant species.

Substantial contributions of CITES to the GSPC Target 13 ("Indigenous and local knowledge innovations and practices associated with plant resources, maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care") (CBD, 2011c) relate to plant species used in traditional medicine. In Resolution Conf. 10.19 (Rev. CoP14), CITES (2010c) gives clear guidelines for trade in such taxa, respecting and securing the rights and knowledge of indigenous peoples. Also, discussions about CITES and livelihood have taken place in the CITES Standing Committee, in order to promote traditional knowledge that ensures adequate CITES implementation, in particular related to the assessments needed for the preparation of NDFs (CITES, 2011d). The issue was also addressed at a symposium organized in May 2011 by Austria and the European Commission on "The relevance of Community-Based Natural Resource Management (CBNRM) to the conservation and sustainable use of CITES-listed species in exporting countries" (Abensperg-Traun et al., 2011). While the subjects dealt with there referred to the management of animals listed under CITES, the same principles could also be applied for CITES-listed plant species.

CITES has developed, encouraged, or commissioned the development of numerous training tools related to CITES-listed plants. This directly contributes to the GSPC Target 14 ("The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programs") and GSPC Target 15 ("The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy") (CITES, 2011a). CITES activities in this context include checklists, slide shows, and training courses on CD-ROM (see, e.g., materials provided by the Royal Botanic Gardens Kew, <http://www.kew.org/conservation/cites-ind.html>) as well as training, Master's, and Ph.D. courses. The outreach of these courses is remarkable; e.g., the nine Master's degree courses in "management, access and conservation of species in trade: the international framework" at the Universidad Internacional de Andalucía in Baeza and the four associated Doctorate courses were attended by 235 individuals from 68 countries (CITES, 2011c). The latest development in this regard is the Virtual Campus, which is hosted by the Universidad Internacional de Andalucía in Baeza, Spain (<http://campusvirtual.unia.es/cites/>). This is still in development but already provides training material for NDFs and numerous resources.

Summary

The examples mentioned above are clear indications for the high potential of synergies between CITES activities related to plants and the GSPC. Undoubtedly, the main field of the GSPC where CITES provides valuable contributions is Target 11. However, CITES and the GSPC can share tools, scientific results, and methodologies in other areas like taxonomy, methods of assessing conservation status, or capacity building. Already existing interactions in these fields are encouraging but can be improved. Lastly, an intensified communication between national CITES and GSPC authorities, academic audiences, and NGOs, as well as between the Secretariats of CITES and the CBD, are essential cornerstones for successfully implementing joint collaborations of mutual benefit.

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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,

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%

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).

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;

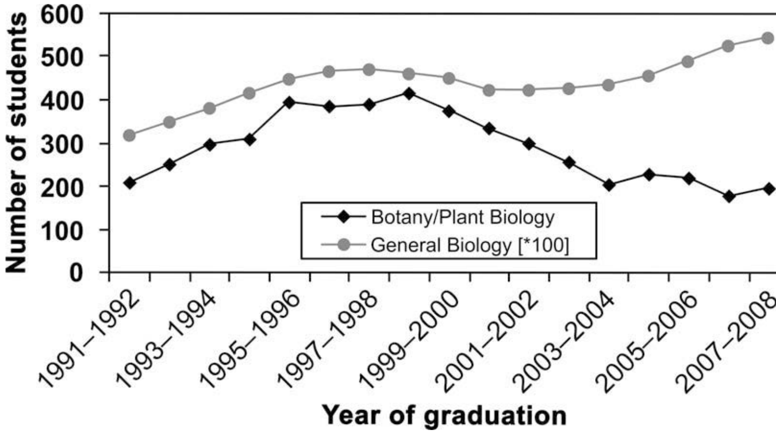

Figure 1. Comparison of undergraduate students graduating with a bachelor's degree in botany/plant biology versus a degree in general biology (data from the U.S. Department of Education, NCES, 2009). Note that numbers for general biology graduates are divided by 100 to facilitate viewing on a single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

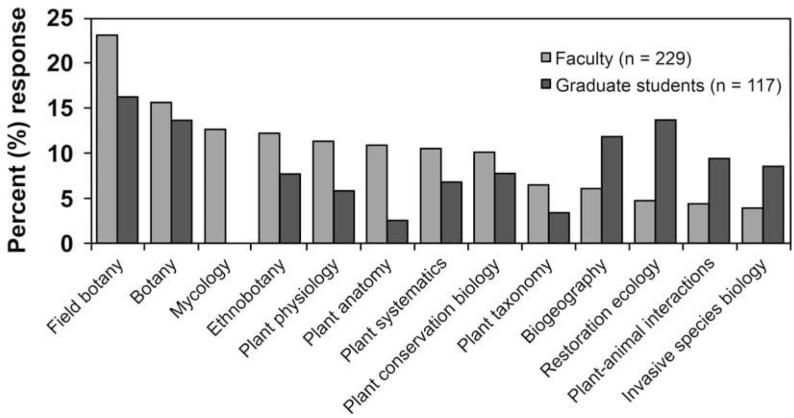

Figure 2. Plant science courses that faculty and graduate students responding to the survey felt should be added to their university's curriculum (Kramer et al., 2010).

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

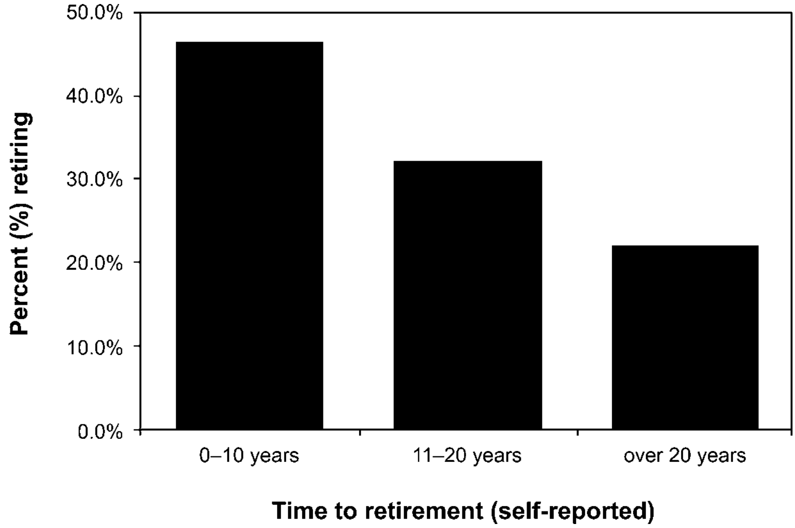

Figure 3. Retirement of survey respondents ($n = 147$) who are employed as federal botanists. There will be a significant need for a botanically trained workforce to fill the vacancies created by these retirements (Kramer et al., 2010).

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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THE STATUS AND FUTURE OF ORCHID CONSERVATION IN NORTH AMERICA[1]

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Abstract

The status and trends of issues related to the conservation of orchids native to the United States, Canada, and Greenland are considered. We focus on nine of the 16 Targets of the Global Strategy for Plant Conservation (GSPC). The first two targets, which all other targets rely upon, appear to have been adequately achieved, in addition to Target 11. Limited progress has been made on six other GSPC targets. Three case studies of efforts to conserve the native threatened orchids, *Platanthera leucophaea* (Nutt.) Lindl., *Isotria medeoloides* (Pursh) Raf., and *Tolumnia bahamensis* (Nash) Braem, are presented to demonstrate the difficulties as well as the issues associated with effective conservation. We describe our efforts to establish an international program to conserve all native orchids in the United States and Canada. The North American Orchid Conservation Center (NAOCC) is an internationally focused effort that is based on public-private partnerships. The goal of NAOCC is to conserve the genetic diversity of all native orchids through efforts to develop an international collection of seeds and orchid fungi. The NAOCC also focuses on the cultivation of all native orchids in an international network of botanic gardens, and they partner with private and public landowners to develop techniques to conserve and restore all native orchid species.

Key words: Endangered species, Global Strategy for Plant Conservation (GSPC), North American Orchid Conservation Center (NAOCC), Orchidaceae, restoration.

Beautiful, diverse, and often bearing large and showy flowers, orchids are an ancient plant family that has evolved an amazing array of bizarre flower types, unique pollination syndromes, and complex symbiotic interactions with animals and fungi. In the plant world, orchids reign supreme as about 10% of all flowering plant species are members of the Orchidaceae. No other plant family can match the peculiar array of evolutionary features that orchids collectively possess. Along with the Asteraceae, the Orchidaceae has more species, estimated to be between 20,000 and 35,000 taxa (Cribb et al., 2003), than any other family of flowering plants, and individual orchid species are often rare in nature, occurring in restricted and specific niches and habitats. Collectors prize orchids for their seemingly infinite variety of showy flowers; scientists have long been fascinated by the relationships between the plants and their pollinators and other symbionts.

Today, orchids have taken on even greater significance. Due to their interconnectedness with the species around them, orchids, highly sensitive to habitat change, are among the first casualties from environmental degradation. Most orchid genera contain threatened or endangered species (Swarts & Dixon, 2009). Orchids are found throughout North America, and many of the approximately 210 species found north of Mexico are threatened, endangered, or extirpated in at least part of their ranges because of habitat loss and alteration. Most North American orchids are terrestrial. Globally, terrestrial orchids make up only one third of orchid species with the other two thirds being epiphytes and lithophytes. However, terrestrial herbaceous perennials are disproportionately represented in the extinct plant species listed by The World Conservation Union (IUCN, 1999). Consequently, terrestrial orchids are likely subject to a greater extinction risk than epiphytes, particularly in response to current climate changes.

Much of orchids' sensitivity to habitat change likely can be traced to their dependence on two, often

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very specific, types of symbiotic associations. Orchids' relationships with specific pollinators have been a subject of interest since before Darwin, but more recently orchid dependence on mycorrhizal fungi has also received substantial research attention (Waterman & Bidartondo, 2008). Identification of the fungi on which orchids depend requires DNA sequencing and analysis, but it is clear at this point that some orchids are dependent upon fungi that are free living in the soil, while others associate with fungi that are also connected to other plants, especially trees. As habitats change, the fungal community changes, and orchids may lose fungi upon which they depend for their survival.

As popular, desirable, and charismatic subjects for cultivation, orchids face another serious threat. Like precious gems, the most unique and rare orchids are sought by the most enthusiastic collectors. As word spreads about the location of a rare orchid, more and more demand is placed on already fragile populations. Unfortunately, without efforts to cultivate the symbiotic fungi, most of these plants are doomed in cultivation. Due to the combination of habitat loss and poaching, many orchid species, which were once widespread, are now found in small, ecologically fragile, fragmented populations. The majority of orchids are represented globally by tropical epiphytes, but temperate zone terrestrials make up a significant proportion (approximately 28%; Gravendeel et al., 2004) and conservation of terrestrial species has proven to be especially challenging (e.g., Stewart & Hicks, 2010). No orchid has ever been delisted, though one, *Isotria medeoloides* (Pursh) Raf., was upgraded from endangered to threatened in 1994 (U.S. Fish and Wildlife Service, 1994) after extensive directed searching uncovered new populations. A comprehensive holistic approach to species conservation has to be fully realized in conservation and restoration plans.

The orchid flora of North America represents an important scientific challenge for conservation biologists. Unlike many other plant species, where significant efforts are often employed to cultivate and reintroduce rare plants and to store germplasm, the majority of organizations that identify and protect orchids on public and private lands rely solely on habitat conservation for management. This conservation strategy has largely been dictated by the unique aspects of orchid biology that make them not amenable to standard plant conservation techniques. We propose a model of centralized but integrated orchid conservation that can provide one-stop shopping for agencies and organizations responsible for and actively participating in efforts to conserve native orchids.

We begin by identifying successes and major gaps in conservation strategies for North American native orchids by addressing nine of the 16 targets of the 2011–2020 Global Strategy for Plant Conservation (GSPC) in relation to the conservation of orchid species native to the United States, Canada, and Greenland. GSPC targets 4, 5, 6, 9, 10, 12, and 13 do not apply directly to native North American orchid species. We then propose a centralized North American Orchid Conservation Center (NAOCC) that addresses each deficiency.

Global Strategy of Plant Conservation Targets

target 1, an online flora of all known plants

A total of 210 orchid species are native to the United States, Canada, and Greenland (see Table 1), including one described as recently as 2007, as *Platanthera yosemitensis* Colwell, Sheviak & P. E. Moore (Colwell et al., 2007). The novel orchid list is a compilation of species from Kartesz (1994), the Flora of North America (Romero-González et al., 2002), Brown (2009), and NatureServe Explorer (NatureServe, 2011), and each name is accepted by The Plant List (<http://www.thePlantList.org>) and the World Checklist of Selected Plant Families (WCSP, 2011). Additionally, 135 orchid species are native to Puerto Rico and the Virgin Islands (Acevedo-Rodríguez & Strong, 2007), but of these species only those that extend into the mainland are treated here.

The 210 described species (Table 1) are distributed among 66 genera (Table 2), with 49 genera (74%) represented by only one or two species and a few genera being represented by more than three species (e.g., *Platanthera* Rich. with 35 species, *Spiranthes* Rich. with 23 species). While there are always questions of whether taxa should be split or lumped and questions about the treatment of hybrids, relationships between most genera in the Orchidaceae are well established (e.g., Górniak et al., 2010).

Native orchid species are found in all 50 states within the United States and all 10 provinces and three territories of Canada. On average, there are 40 native species per state, with Hawaii having the fewest native species (three) and Florida with the most (106). Other species-rich areas include the states along the East Coast associated with the Appalachian Mountains, especially North Carolina (67 species), Virginia (59 species), and New York (57 species). Of the Canadian provinces, Prince Edward Island and Ontario have an especially diverse orchid assemblage (59 and 58 species, respectively). All

Table 1. The 210 native orchid species of the United States, Canada, and Greenland, including conservation assessments, legal protections, and the number of botanic gardens holding ex situ collections. This list is a compilation of species from Kartesz (1994), the Flora of North America (Romero-González et al., 2002), Brown (2009), and NatureServe Explorer (NatureServe, 2011).

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Anoectochilus sandvicensis Lindl.	G3; S3	Vulnerable				1
Aplectrum hyemale (Muhl. ex Willd.) Nutt.	G5; SH, S1-S5, SNR			Endangered		11
Arethusa bulbosa L.	G4; SX, SH, S1-S4, SNR			Endangered		0
Basiphyllaea corallicola (Small) Ames	G2; S1			Endangered		0
Beloglottis costaricensis (Rchb. f.) Schltr.	G4; S1*			Endangered		0
Bletia patula Hook.	G4; SH					5
Bletia purpurea (Lam.) DC.	G5; S3			Threatened		17
Brassia caudata (L.) Lindl.	G3; SX			Endangered		37
Bulbophyllum pachyrachis (A. Rich.) Griseb.	G4; SX					0
Calopogon barbatus (Walter) Ames	G4; S1-S3, SNR					1
Calopogon multiflorus Lindl.	G2; SH, S1-S3			Endangered		0
Calopogon oklahomensis D. H. Goldman	G3; SH, S1, S2, SNR					0
Calopogon pallidus Chapm.	G4; S1-S5, SNR					2
Calopogon tuberosus (L.) Britton, Sterns & Poggenb.	G5; SX, S1-S4, SNR			Endangered		16
Calypso bulbosa (L.) Oakes	G5; SH, S1-S5, SNR			Endangered		8
Camaridium vestitum (Sw.) Lindl.	G4; S1*					5*
Campylocentrum pachyrrhizum (Rchb. f.) Rolfe	G4; S1			Endangered		1
Cephalanthera austiniae (A. Gray) A. Heller	G4; S2, S3, SNR				Threatened	1
Cleistesiopsis bifaria (Fernald) Pansarin & F. Barros	G4; S1-S4, SNR*					3*
Cleistesiopsis divaricata (L.) Pansarin & F. Barros	G4; SX, S1, S3, S4, SNR*			Endangered*		1
Cleistesiopsis oricamporum P. M. Br.	GNR; S2					0
Corallorhiza bentleyi Freudenst.	G1; S1					0
Corallorhiza maculata (Raf.) Raf.	G5; SH, S1-S4, SNR			Endangered		12
Corallorhiza mertensiana Bong.	G4; S2, S3, S5, SU, SNR					1
Corallorhiza odontorhiza (Willd.) Nutt.	G5; SH, S1-S5, SNR			Endangered		2
Corallorhiza striata Lindl.	G5; SH, S1-S4, SNR			Endangered		0
Corallorhiza trifida Châtel.	G5; S1-S5, SNR			Endangered		2
Corallorhiza wisteriana Conrad	G5; SX, SH, S1-S5, SNR			Endangered		2
Cranichis muscosa Sw.	G4; S1			Endangered		2
Cyclopogon cranichoides (Griseb.) Schltr.	G4; SNR*					0
Cyclopogon elatus (Sw.) Schltr.	G4; SH*			Endangered		4*
Cypripedium acaule Aiton	G5; S1, S3-S5, SNR			Endangered		22

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Cypripedium arietinum R. Br.	G3; SH, S1-S3			Endangered		1
Cypripedium californicum A. Gray	G3; S3					7
Cypripedium candidum Muhl. ex Willd.	G4; SX, SH, S1-S3, SNR			Endangered	Endangered	10
Cypripedium fasciculatum Kellogg ex S. Watson	G4; S1-S3					2
Cypripedium guttatum Sw.	G5; S2, SNR					7
Cypripedium kentuckiense C. F. Reed	G3; S1-S3			Endangered		14
Cypripedium montanum Douglas ex Lindl.	G4; S1-S4, SNR					3
Cypripedium parviflorum Salisb.	G5; SH, S1-S4, SNR			Endangered		12
Cypripedium passerinum Richardson	G4; S1-S4, SNR					2
Cypripedium reginae Walter	G4; SX, S1-S4, SU, SNR, SNA			Endangered		33
Cypripedium yatabeanum Makino	G4; SNR*					1
Cyrtopodium punctatum (L.) Lindl.	G5; S1			Endangered		22
Dactylorhiza aristata (Fisch. ex Lindl.) Soó	G4; S4					0
Dactylorhiza viridis (L.) R. M. Bateman, Pridgeon & M. W. Chase	G5; SX, SH, S1-S5, SNR*			Endangered		11*
Dendrophylax lindenii (Lindl.) Benth. ex Rolfe	G3; S2*			Endangered		7*
Dendrophylax porrectus (Rchb. f.) Carlsward & Whitten	GU; SNR*					0
Dichromanthus cinnabarinus (La Llave & Lex.) Garay	G5; SNR*					2
Dichromanthus michuacanus (La Llave & Lex.) Salazar & Soto Arenas	G4; S3, SNR*					0
Eltroplectris calcarata (Sw.) Garay & H. R. Sweet	G4; S1			Endangered		1
Encyclia tampensis (Lindl.) Small	G4; SNR					23
Epidendrum amphistomum A. Rich.	GNR; S3			Endangered		0
Epidendrum anceps Jacq.						10
Epidendrum blancheanum Urb.	G4; SX			Endangered*		1*
Epidendrum floridense Hágsater						5
Epidendrum magnoliae Muhl.	G4; S2, S3, SNR*					4*
Epidendrum nocturnum Jacq.	G4; S2			Endangered		25
Epidendrum rigidum Jacq.	G4; S3			Endangered		19
Epidendrum strobiliferum Rchb. f.	G4; S1			Endangered		1
Epipactis gigantea Douglas ex Hook.	G4; S1-S3, SU, SNR				Special Concern	37
Eulophia alta (L.) Fawc. & Rendle	G4; S4					6
Eulophia ecristata (Fernald) Ames	G2; S1, S2*			Endangered		0

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Galeandra beyrichii Rchb. f.	G4; SNR					0
Galeandra bicarinata G. A. Romero & P. M. Br.	G1; S1			Endangered		0
Galearis spectabilis (L.) Raf.	G5; S1-S5, SNR			Endangered		4
Goodyera oblongifolia Raf.	G5; S1-S5, SNR			Endangered		9
Goodyera pubescens (Willd.) R. Br.	G5; S1-S5, SNR			Endangered		27
Goodyera repens (L.) R. Br.	G5; SH, S1-S5, SNR			Endangered		14
Goodyera tesselata Lodd.	G5; SX, SH, S1-S5, SU, SNR			Endangered		3
Govenia floridana P. M. Br.				Endangered		0
Habenaria distans Griseb.	G5; S1			Endangered		1
Habenaria floribunda Lindl.	G4; SNR*					2*
Habenaria quinqueseta (Michx.) Sw.	G4; S1, SNR					1
Habenaria repens Nutt.	G5; S1-S3, SNR					4
Hammarbya paludosa (L.) Kuntze	G4; S1-S3, SNR*			Endangered*		2
Heterotaxis sessilis (Sw.) F. Barros	G4; S1*					18*
Hexalectris grandiflora (A. Rich. & Galeotti) L. O. Williams	G4; S2					2
Hexalectris nitida L. O. Williams	G3; S1, S3			Endangered		2
Hexalectris revoluta Correll	G1; S1, SNR					0
Hexalectris spicata (Walter) Barnhart	G5; SH, S1-S4, SNR			Endangered		3
Hexalectris warnockii Ames & Correll	G2; S1, S2					0
Ionopsis utricularioides (Sw.) Lindl.	G4; S1			Endangered		10
Isotria medeoloides (Pursh) Raf.	G2; SX, SH, S1, S2		Threatened	Endangered	Endangered	1
Isotria verticillata (Muehl. ex Willd.) Raf.	G5; SX, S1-S5, SNR			Endangered	Endangered	5
Lepanthopsis melanantha (Rchb. f.) Ames	G3; SH			Endangered		1
Liparis hawaiensis H. Mann	G3; S3					3
Liparis liliifolia (L.) Rich. ex Lindl.	G5; SX, S1-S5, SNR			Endangered	Endangered	4
Liparis loeselii (L.) Rich.	G5; SX, SH, S1-S5, SNR			Endangered		8
Liparis nervosa (Thunb.) Lindl.	G4; S2			Endangered*		10
Macradenia lutescens R. Br.	G4; SH			Endangered		0
Malaxis abieticola Salazar & Soto Arenas	G4; S1, S3*					0
Malaxis bayardii Fernald	G1; SH, S1, SU			Endangered		0
Malaxis brachystachys (Rchb. f.) Kuntze	G4; S3, S4*					0
Malaxis macrostachya (Lex.) Kuntze	G4; SNR, SNA					3*
Malaxis monophyllos (L.) Sw.	G4; SH, S1-S4, SNR*			Endangered*		1
Malaxis porphyrea (Ridl.) Kuntze	G4; S2, SNR					0

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Malaxis spicata Sw.	G4; S1-S3, SNR					0
Malaxis unifolia Michx.	G5; S1-S5, SX, SNR			Endangered		2
Malaxis wendtii Salazar	G2; S1					0
Mesadenus lucayanus (Britton) Schltr.	G4; S1, S2*			Endangered		1*
Microthelys rubrocallosa (B. L. Rob. & Greenm.) Garay	GNR; S1					0
Neottia auriculata (Wiegand) Szlach.	G3; S1-S3, SNR*			Endangered		0
Neottia banksiana (Lindl.) Rchb. f.	G4; S1-S4, SNR*					4*
Neottia bifolia (Raf.) Baumbach	G4; S1-S4, SNR*			Endangered*		5*
Neottia borealis (Morong) Szlach.	G4; SH, S1-S4, SNR*					0
Neottia convallarioides (Sw.) Rich.	G5; S1-S4, SNR*					0
Neottia cordata (L.) Rich.	G5; SH, S1-S5, SNR*			Endangered*		1
Neottia smallii (Wiegand) Szlach.	G4; S1-S4*			Endangered*		0
Oncidium ensatum Lindl.	GNR; S1			Endangered*		9*
Pelexia adnata (Sw.) Poit. ex Rich.	G5; S1			Endangered		1
Peristylus holochila (Hillebr.) N. Hallé	G1; S1*		Endangered*			3*
Piperia candida Rand. Morgan & Ackerman	G3; S2, S3, SNR					0
Piperia colemanii Rand.Morgan & Glic.	G3; S3					0
Piperia cooperi (S. Watson) Rydb.	G4; S3					0
Piperia dilatata (Pursh) Szlach. & Rutk.	G5; SH, S1-S5, SU, SNR*					5*
Piperia elegans (Lindl.) Rydb.	G4; S3, S4, SNR					1
Piperia elongata Rydb.	G4; S3, S4, SNR					0
Piperia leptopetala Rydb.	G3; S3					0
Piperia transversa Suksd.	G4; S3, S4, SNR					0
Piperia unalascensis (Spreng.) Rydb.	G5; S1-S5, SNR					0
Piperia yadonii Rand. Morgan & Ackerman	G2; S2		Endangered			0
Platanthera aquilonis Sheviak	G5; SX, S1-S5, SU, SNR					3
Platanthera blephariglottis (Willd.) Lindl.	G4; S1-S4, SNR			Endangered		4
Platanthera brevifolia (Greene) Senghas	G4; SNR					0
Platanthera chapmanii (Small) Luer	G2; S1, SH, SNR					1
Platanthera chorisiana (Cham.) Rchb. f.	G3; S2-S4			Threatened		2
Platanthera ciliaris (L.) Lindl.	G5; SX, SH, S1-S4, SNR			Endangered		5
Platanthera clavellata (Michx.) Luer	G5; SH, S1-S5, SU, SNR					2
Platanthera convallariifolia (Fisch. ex Lindl.) Lindl.						0

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Platanthera cristata (Michx.) Lindl.	G5; S1-S4, SX, SNR			Endangered		0
Platanthera flava (L.) Lindl.	G4; SX, S1-S4, SU, SNR			Endangered		1
Platanthera grandiflora (Bigelow) Lindl.	G5; SX, S1-S4, SNR			Endangered		3
Platanthera hookeri (Torr.) Lindl.	G4; SX, S1-S4, SH, SNR			Endangered		2
Platanthera huronensis Lindl.	G5; S1-S5, SU, SNR*					3
Platanthera hyperborea (L.) Lindl.	G5; S4			Endangered		5
Platanthera integra (Nutt.) A. Gray ex L. C. Beck	G3; S1-S3, SNR			Endangered		0
Platanthera integrilabia (Correll) Luer	G2; SH, S1-S3, SU		Candidate	Endangered		1
Platanthera lacera (Michx.) G. Don	G5; S1-S5, SNR					7
Platanthera leucophaea (Nutt.) Lindl.	G2; SX, SH, S1, S2		Threatened	Endangered	Endangered	2
Platanthera limosa Lindl.	G4; S4, SNR					0
Platanthera nivea (Nutt.) Luer	G5; SH, S1-S3, SNR			Endangered		1
Platanthera obtusata (Banks ex Pursh) Lindl.	G5; S1-S5, SNR			Vulnerable		1
Platanthera orbiculata (Pursh) Lindl.	G5; SX, SH, S1-S4, SNR			Endangered		1
Platanthera pallida P. M. Br.	GNA; SU, SNA, SNR*					0
Platanthera peramoena A. Gray	G5; SX, S1-S4, SNR			Endangered		1
Platanthera praeclara Sheviak & M. L. Bowles	G3; SH, S1-S3	Endangered	Threatened	Endangered	Endangered	1
Platanthera psycodes (L.) Lindl.	G5; SX, SH, S1-S5, SNR			Endangered		2
Platanthera purpurascens (Rydb.) Sheviak & W. F. Jenn.						0
Platanthera rotundifolia (Banks ex Pursh) Lindl.	G5; SX, SH, S1-S5, SNR*			Endangered*		1
Platanthera shriveri P. M. Br.	G1; S1, SNR					0
Platanthera sparsiflora (S. Watson) Schltr.	G4; S1, SNR			Sensitive		0
Platanthera stricta Lindl.	G5; S1-S5, SNR					4*
Platanthera tescamnis Sheviak & W. F. Jenn.						0
Platanthera tipuloides (L. f.) Lindl.	G4; S2					0
Platanthera yosemitensis Colwell, Sheviak & P. E. Moore	G2; S2					0
Platanthera zothecina (L. C. Higgins & S. L. Welsh) Kartesz & Gandhi	G2; S1, S2					0
Platythelys querceticola (Lindl.) Garay	G4; S1, SNR					0
Platythelys sagraeana (A. Rich.) Garay						0
Pogonia ophioglossoides (L.) Ker Gawl.	G5; SX, SU, S1-S5, SNR			Endangered		17
Polystachya concreta (Jacq.) Garay & H. R. Sweet	G4; S3			Endangered		13
Ponthieva brittoniae Ames	G3; S1			Endangered		1

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Ponthieva racemosa (Walter) C. Mohr	G4; S1-S3, SNR			Endangered		4
Prescottia oligantha (Sw.) Lindl.	G4; S1					1
Prosthechea boothiana (Lindl.) W. E. Higgins	G4; S1*					6*
Prosthechea cochleata (L.) W. E. Higgins	G4; S3*					65*
Prosthechea pygmaea (Hook.) W. E. Higgins	G4; S1*			Endangered		9*
Pseudorchis albida (L.) Á. Löve & D. Löve	G5; S3, SNR*					3
Sacoila lanceolata (Aubl.) Garay	G4; S3*			Threatened*		8*
Sacoila squamulosa (Kunth) Garay						0
Schiedeella arizonica P. M. Br.	GNR; S3, S4, SNR					0
Schiedeella confusa (Garay) Espejo & López-Ferr.	G3; SNR*					0
Spiranthes brevilabris Lindl.	G1; S1, SNR			Endangered		0
Spiranthes casei Catling & Cruise	G4; S1-S4, SNR			Endangered		0
Spiranthes cernua (L.) Rich.	G5; S1-S5, SU, SNR			Vulnerable		28
Spiranthes delitescens Sheviak	G1; S1		Endangered	Endangered		1
Spiranthes diluvialis Sheviak	G2; S1, S2		Threatened	Endangered		5
Spiranthes eatonii Ames ex P. M. Br.	G3; SH, S1-S3, SNR					0
Spiranthes infernalis Sheviak	G1; S1					0
Spiranthes lacera (Raf.) Raf.	G5; S1-S5, SNR			Threatened		5
Spiranthes laciniata (Small) Ames	G4; S1-S4, SU, SNR			Endangered		0
Spiranthes longilabris Lindl.	G3; SH, S1-S3, SNR			Threatened		0
Spiranthes lucida (H. H. Eaton) Ames	G5; SX, SH, S1-S5, SNR			Endangered		2
Spiranthes magnicamporum Sheviak	G4; SX, S1-S4, SNR			Endangered		2
Spiranthes ochroleuca (Rydb.) Rydb.	G4; SH, S1-S3, S5, SNR			Endangered		2
Spiranthes odorata (Nutt.) Lindl.	G5; SH, S1-S4, SU, SNR			Endangered		15
Spiranthes ovalis Lindl.	G5; SH, S1-S5, SNR			Endangered		3
Spiranthes parksii Correll	G3; S3		Endangered	Endangered		2
Spiranthes porrifolia Lindl.	G4; S1, S2, S4, SNR			Sensitive		3
Spiranthes praecox (Walter) S. Watson	G5; SH, S1-S4, SU					1
Spiranthes romanzoffiana Cham.	G5; SH, S1-S5, SU, SNR			Endangered		5
Spiranthes sylvatica P. M. Br.	GNR; S1					0
Spiranthes torta (Thunb.) Garay & H. R. Sweet	G4; S1*			Endangered		0
Spiranthes tuberosa Raf.	G5; SH, S1-S5, SNR			Endangered		4
Spiranthes vernalis Engelm. & A. Gray	G5; S1-S5, SNR			Endangered		5
Stelis gelida (Lindl.) Pridgeon & M. W. Chase	G5; S1*			Endangered*		3
Tipularia discolor (Pursh) Nutt.	G4; S1, S3-S5, SNR			Endangered		15

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Tolumnia bahamensis (Nash ex Britton & Millsp.) Braem	G3; S1			Endangered		5
Trichocentrum undulatum (Sw.) Ackerman & M. W. Chase	G4; S1*			Endangered*		1
Triphora amazonica Schltr.				Endangered		0
Triphora craigheadii Luer	G1; S1			Endangered		0
Triphora gentianoides (Sw.) Nutt. ex Ames & Schltr.	G4; SNR					0
Triphora trianthophora (Sw.) Rydb.	G3; SH, S1-S3, SNR			Endangered	Endangered	0
Triphora yucatanensis Ames	G1; S1					0
Tropidia polystachya (Sw.) Ames	G4; S1			Endangered		1
Vanilla barbellata Rchb. f.	G4; S2			Endangered		7
Vanilla dilloniana Correll	G3; SNR			Endangered		5
Vanilla inodora Schiede						1
Vanilla mexicana Mill.	G3; S1			Endangered		2
Vanilla phaeantha Rchb. f.	G4; S1			Endangered		8

* Listed in original publication under a synonymous name.

[a] Conservation assessments by NatureServe correspond to Global threats: G1 = Critically Imperiled, G2 = Imperiled, G3 = Vulnerable, G4 = Apparently Secure, G5 = Secure, GU = Unrankable, GNR = Not Yet Ranked, GNA = Not Applicable. Subnational threats follow similar values (S1 to S5, etc.), but apply at the state or provincial levels. NatureServe rankings are available through <http://www.natureserve.org/explorer>.

[b] International Union for Conservation of Nature and Natural Resources (IUCN), 2011.

[c] Endangered Species Act (ESA), 1973; U.S. Government Printing Office, 2012.

[d] U.S. State listing is at the highest level of protection among all states listed, as reported by the USDA PLANTS Database (USDA, NRCS, 2012).

[e] Species at Risk Act (SARA), 2002.

[f] The number of botanic gardens where the orchid species is conserved or present, according to Botanical Gardens Conservation International (2012).

Table 2. Species distribution among listed orchid genera in Table 1.

Genus	Species #	Percent of total species
Platanthera Rich.	35	16.7%
Spiranthes Rich.	23	11.0%
Cypripedium L.	12	5.7%
Piperia Rydb.	10	4.8%
Malaxis Sol. ex Sw.	9	4.3%
Epidendrum L.	8	3.8%
Corallorhiza Gagnebin	7	3.3%
Neottia Guett.	7	3.3%
Calopogon R. Br.	5	2.4%
Hexalectris Raf.	5	2.4%
Triphora Nutt.	5	2.4%
Vanilla Mill.	5	2.4%
Goodyera R. Br.	4	1.9%
Habenaria Willd.	4	1.9%
Liparis Rich.	4	1.9%
Cleistesiopsis Pansarin & F. Barros	3	1.4%
Prosthechea Knowles & Westc.	3	1.4%
Bletia Ruiz & Pav.	2	1%
Cyclopogon C. Presl	2	1%
Dactylorhiza Neck. ex Nevski	2	1%
Dendrophylax Rchb. f.	2	1%
Dichromanthus Garay	2	1%
Eulophia R. Br. ex Lindl.	2	1%
Galeandra Lindl.	2	1%
Isotria Raf.	2	1%
Platythelys Garay	2	1%
Ponthieva R. Br.	2	1%
Sacoila Raf.	2	1%
Schiedeella Schltr.	2	1%
Anoectochilus Blume	1	0.5%
Aplectrum Blume	1	0.5%
Arethusa L.	1	0.5%
Basiphyllaea Schltr.	1	0.5%
Beloglottis Schltr.	1	0.5%
Brassia R. Br.	1	0.5%
Bulbophyllum Thouars	1	0.5%
Calypso Salisb.	1	0.5%
Camaridium Lindl.	1	0.5%
Campylocentrum Benth.	1	0.5%
Cephalanthera Rich.	1	0.5%
Cranichis Sw.	1	0.5%
Cyrtopodium R. Br.	1	0.5%
Eltroplectris Raf.	1	0.5%
Encyclia Hook.	1	0.5%
Epipactis Zinn	1	0.5%
Galearis Raf.	1	0.5%
Govenia Lindl.	1	0.5%
Hammarbya Kuntze	1	0.5%
Heterotaxis Lindl.	1	0.5%
Ionopsis Kunth	1	0.5%
Lepanthopsis Ames	1	0.5%
Macradenia R. Br.	1	0.5%
Mesadenus Schltr.	1	0.5%
Microthelys Garay	1	0.5%
Oncidium Sw.	1	0.5%
Pelexia Poit. ex Lindl.	1	0.5%
Peristylus Blume	1	0.5%
Pogonia Juss.	1	0.5%
Polystachya Hook.	1	0.5%
Prescottia Lindl.	1	0.5%
Pseudorchis Ség.	1	0.5%
Stelis Sw.	1	0.5%
Tipularia Nutt.	1	0.5%
Tolumnia Raf.	1	0.5%
Trichocentrum Poepp. & Endl.	1	0.5%
Tropidia Lindl.	1	0.5%

state and provincial species numbers are according to the NatureServe Explorer (NatureServe, 2011). Three species are endemic to California, as *Piperia colemanii* Rand. Morgan & Glic., *P. yadonii* Rand. Morgan & Ackerman, and *Platanthera yosemitensis*, and three to Hawaii, as *Anoectochilus sandvicensis* Lindl., *Liparis hawaiensis* H. Mann, and *Peristylus holochila* (Hillebr.) N. Hallé. Two orchid species are endemic to Florida, *Govenia floridana* P. M. Br. and *Triphora craigheadii* Luer; one species is endemic, each to three states, with *Spiranthes delitescens* Sheviak in Arizona, *S. infernalis* Sheviak in Nevada, and *S. parksii* Correll in Texas.

TARGET 2, AN ASSESSMENT OF THE CONSERVATION STATUS OF ALL KNOWN PLANT SPECIES, AS FAR AS POSSIBLE, TO GUIDE CONSERVATION ACTION

Only two North American orchids have been assessed by the International Union for Conservation of Nature and Natural Resources (IUCN) and are listed as threatened on the 2011 IUCN Red List of Threatened Species (IUCN, 2011): *Anoectochilus sandvicensis* as Vulnerable (or VU), and *Platanthera praeclara* Sheviak & M. L. Bowles, as Endangered (or EN).

The U.S. Endangered Species Act (ESA; 1973; U.S. Government Printing Office, 2012) federally lists the four endangered species *Piperia yadonii*, *Peristylus holochila* [≡ *Platanthera holochila* (Hillebr.) Kraenzl.], *Spiranthes delitescens*, and *S. parksii*, as well as the four threatened species as *Isotria medeoloides*, *Platanthera leucophaea* (Nutt.) Lindl., *P. praeclara*, and *S. diluvialis* Sheviak, and the one candidate species, *Platanthera integrilabia* (Correll) Luer. At the state level, 57% (119 species) are protected as endangered, threatened, vulnerable, or sensitive in at least one state (cf. Table 1).

The Canadian Species at Risk Act (SARA; 2002) lists seven endangered orchid species, as *Cypripedi-*

um candidum Muhl. ex Willd., *Isotria medeoloides*, *I. verticillata* (Muhl. ex Willd.) Raf., *Liparis liliifolia* (L.) Rich. ex Lindl., *Platanthera leucophaea*, *P. praeclara*, and *Triphora trianthophora* (Sw.) Rydb. Further, one threatened species, *Cephalanthera austiniae* (A. Gray) A. Heller, is included, as well as one species that is noted of special concern for conservation, *Epipactis gigantea* Douglas ex Hook. (cf. Table 1).

All but 10 species of the 210 orchid names included in Table 1 have been assessed by NatureServe (2011), with 24% (50 species) listed as globally threatened. Of these 50 threatened species, 11 were assessed at the global scale as critically imperiled (G1), 13 are imperiled (G2), and 26 are vulnerable (G3; cf. Table 1). For subnational assessments by NatureServe, 14% (30 species) are presumed to be extirpated from at least one state or province, and an overlapping 23% (48 species) are possibly extirpated from at least one state or province. Also at the subnational level, 84% (176 species) are variably threatened (ranging from S1 or critically imperiled, S2 or imperiled, or S3 or vulnerable) in at least one state or province. In all cases, where an orchid had been extirpated in one or more states, it was also threatened or endangered in at least one other state.

Target 3, information, research and associated outputs, and methods necessary to implement the strategy developed and shared

As indicated by Stewart (2008), much of the information on conservation and reintroduction of orchids has been published in the "gray" literature and obtained from unreplicated efforts that are rarely designed as scientific studies to obtain statistically significant data. Academic research occasionally addresses aspects of orchid biology, but rarely includes the whole process from basic biology to application for conservation or reintroduction (e.g., Kindlmann et al., 2002; Dixon et al., 2003). Replicated assessment of conservation is sorely lacking. There are three major areas of orchid biology that urgently need additional research: (1) identification of fungi associated with nearly all orchids, (2) understanding of how those fungi contribute to seed germination in situ and in vitro, and (3) how to maximize survival of cultured seedlings or plants.

Seed banking alone cannot successfully preserve orchids, because using the seeds to eventually cultivate and restore plants in nature requires that appropriate mycorrhizal fungi are present, especially at the orchid's protocorm stage. Identifying, maintaining, and establishing the symbiotic fungi needed for orchid seed germination is technically difficult and requires specialized equipment (Liu et al., 2010; Seaton et al., 2010; Stewart & Hicks, 2010). However problematic, this is essential for propagation and establishment of self-sustaining populations. Few organizations have the capacity to handle these unique aspects of orchid biology, placing cultivation and reintroduction beyond the abilities of nearly all conservation agencies. Scientific research has made substantial progress in overcoming these difficult aspects of orchid ecology, but additional efforts are needed on all key elements of orchid life histories that must be understood if we are to successfully support conservation, reintroduction, and propagation efforts for native orchids. The techniques being developed by scientists are still, and likely will remain, beyond the capacity of most conservation agencies, and there exists no current network for scientific researchers either to support conservation program managers or to communicate with commercial or private growers and garden enthusiasts who would benefit from a more complete understanding of all aspects of orchid growth, cultivation, and conservation.

Target 7, at least 75% of known threatened plant species conserved in situ

When considering the proportion of threatened orchids that are conserved in situ, it is important to distinguish between species that are considered globally threatened and the majority of orchids that are threatened within a portion of their ranges. Conserved in situ means "that biologically viable populations of these species occur in at least one protected area or the species is effectively managed outside the protected area network, e.g., as part of a management plan" according to a recent GSPC Plant Conservation Report (Convention on Biological Diversity [CBD], 2009: 23–24). As previously outlined (cf. Table 1), of the 50 globally threatened (i.e., ranked G1, G2, or G3 by NatureServe) orchid species, only eight are protected under the ESA and one additional species, *Triphora trianthophora*, under Canada's SARA. An additional 22 species are protected at the state or province level. Taken together, a total of 62% (31 of 50 species, cf. Table 1) of native orchid species assessed as threatened are thus conserved in situ (i.e., have legal protection), which is far below the goal of Target 7. It is noteworthy that six of the 10 globally imperiled or critically imperiled species (G1 or G2) that currently have no protection at the federal or state level have only recently been described, suggesting that accurate identification and species delimitation have hampered attempts at species protection.

Beyond recognition of the need to protect orchid taxa is the degree to which protection is actually accomplished. The level of protection provided by state or federal protected status depends on both the number and distribution of plants on protected land and also on the knowledge of the species' biology needed to determine whether protection is adequate. A number of protected reserves in the United States and Canada focus to some degree on orchids or on habitats with disproportionately many orchids. One such example is the Bruce Peninsula National Park in Ontario, which supports 43 of the orchid species native to Canada that will be threatened as a result of climate change (Suffling & Scott, 2002). The heart of the Niagara Escarpment Biosphere Reserve includes the Bruce Peninsula National Park, a Nature Conservancy Preserve, and First Nations lands, all of which share knowledge about species at risk. The stated park goal is to maintain viable populations of all native species in situ, and there is a program underway to report on the condition of all SARA species, including trends in populations and the factors that contribute to their condition.

Attributing population trends to particular factors highlights the importance of in-depth understanding of species biology for accomplishing effective conservation. Most endangered orchids in North America have had at least some investigation of population genetic structure, and this has been used to understand connectivity between populations and to determine the contribution of outlying populations to species integrity. For example, Wallace (2003) found that *Platanthera leucophaea* was a predominantly outcrossing species and that inbreeding depression, especially in small populations, suppressed seed viability. These results suggested that larger, more diverse and outcrossing populations were needed to support population genetic variability in the current fragmented landscape. This white-fringed orchid historically was distributed from Missouri and Iowa to Ontario with disjunct populations in Maine, New Jersey, and Virginia (Bowles et al., 2005). The current distribution is, however, much reduced and few populations are self-sustaining.

Also important to consider are critical issues of land management. Many terrestrial orchids are pioneer species and cannot compete with overgrown habitat. One prime example is the Green Swamp Preserve of southeastern North Carolina in Brunswick and Columbus counties. Originally established to protect the habitat of the Venus fly trap (*Dionaea muscipula* J. Ellis, Droseraceae), a great variety of orchids, including species of *Calopogon* R. Br., *Platanthera*, and *Cleistes* Rich. ex Lindl., exist in the preserve. The reserve's 17,424 acres are owned and managed by The Nature Conservancy, and its longleaf pine savannas must be periodically subjected to prescribed burns to keep the habitat prime for the smaller, herbaceous species that would be otherwise crowded out by succession.

In contrast, other woodland species, such as *Cypripedium acaule* Aiton, *C. fasciculatum* Kellogg ex S. Watson, *C. montanum* Douglas ex Lindl., and *C. reginae* Walter, have ecological strategies and dependencies based both on edaphic constancy and occasional disturbance of their environments. For example, even though *C. fasciculatum* and *C. montanum* grow sympatrically in old growth forest, there is evidence that *C. montanum* needs occasional disturbances, such as fire or tree-felling and thinning, to create open, sunnier areas in which they will bloom and set seed more freely. Its sympatric relative, *C. fasciculatum*, conversely seems to be inhibited by burns and other such disturbances. Therefore, it becomes increasingly important to investigate the individual ecological complexities of each individual species if comprehensive management plans are to be created.

Understanding what factors influence population dynamics is critical for understanding how species will respond to warming global temperatures. With orchids, this uncertainty may be compounded by considering the other species on which they depend. Some orchids may be limited by the availability of pollinators. For example, the deceptive orchid *Cyrtopodium punctatum* (L.) Lindl. depends on oil-gathering *Centris* bees for pollination. These bees rely on other flowering plants, especially *Byrsonima lucida* (Sw.) DC. (Malpighiaceae), for the oils they collect. This led Pemberton and Liu (2008) to suggest that *B. lucida*, which is almost completely absent from the areas where the few remaining native orchid populations of *C. punctatum* persist, be planted in the vicinity of orchids to attract and support the bees that pollinate both taxa. Such activities may also be needed to support the interaction between orchids and their pollinators in the face of climate change. In particular, Liu et al. (2010) suggested that warming temperatures in southwestern China are differentially affecting pollinator and orchid phenologies such that availability of pollinators and orchid flowering may be increasingly out of synchronization. Effects of climate change on orchid mycorrhizal fungi are completely unknown, reflecting that very little is known about what factors drive the distribution and abundance of nearly all fungi. Because of this, conservation of fungi must be largely accomplished through habitat conservation.

Target 8, at least 75% of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs

The Botanical Gardens Conservation International's (BGCI; 2012) Plant Search database shows that 66% (139 species) of native North American orchids are found in ex situ collections in botanical institutions around the world (Table 1). Each of these species is reported from an average of six botanic gardens, but more than 25% (36 species) are reported from a single botanic garden only. The species most prevalent is *Prosthechea cochleata* (L.) W. E. Higgins [≡ *Encyclia cochleata* (L.) Dressler], a species easily propagated (Pugh-Jones, 2009), which is reported from 65 botanic gardens. Only two of 11 species ranked G1 by NatureServe are found in any botanic garden collection, being *Peristylus holochila* at three gardens and *Spiranthes delitescens* at one institution. Five of 13 species ranked G2 are represented in botanic gardens, but only two are reported from more than one garden (two and five gardens, *Platanthera leucophaea* and *S. diluvialis*, respectively). It is highly unlikely that any of these ex situ collections represents a genetically representative sample of the species.

The major method likely to preserve species genetic variation is seed banking, as storing many genetically distinct orchid seeds requires very little space. Accomplishing such genetically representative conservation is a major goal of the project Orchid Seed Stores for Sustainable Use (OSSSU; Seaton et al., 2010). This project is initially focusing on hotspots of orchid diversity but is also beginning to work with groups within North America to organize locations and organizations for genetically representative orchid seed storage. The Center for Plant Conservation (CPC; <http://www.centerforplantconservation.org>) maintains seed collections for eight orchid species, two of which are ranked G1 (*Peristylus holochila* and *Spiranthes delitescens*), three G2 (*Isotria medeoloides*, *Platanthera leucophaea*, and *S. diluvialis*), and three G3 (*Cypripedium kentuckiense* C. F. Reed, *Platanthera praeclara*, and *S. parksii*). These species are specifically directed to be available for conservation and restoration activities, so this would suggest that seeds of 16% (eight of 50) of threatened North American orchid species are available for conservation and restoration, though the extent to which their collections are genetically representative is unclear.

One shortcoming of seed storage for orchids is that all orchids are dependent on or benefit from mycorrhizal fungi for seed germination and all species are dependent on fungi for protocorm growth. While fungal requirements can sometimes be overcome under specialized conditions in the laboratory, there is little question that under natural conditions fungi are required for orchid recruitment and long-term survival of populations. Many orchids require specific fungi at all life history stages (e.g., McCormick et al., 2004), while other more generalist orchids use fungi from one or a few families (e.g., Shefferson et al., 2010). As a result, effective ex situ conservation of orchids will require not just seed banking, but also maintenance of required mycorrhizal fungi. This goal is still far from being accomplished. One of the central difficulties has been to simply identify the needed fungi. Most orchid mycorrhizal fungi rarely produce spores and so were known only from the anamorphic stage for many years. Now they can be identified largely by DNA sequencing. This rarity of spore production, coupled with inconspicuous and morphologically depauperate sporulating bodies, has resulted in a poorly defined taxonomy of these cryptic fungi (e.g., Swarts & Dixon, 2009); DNA sequences rarely match the taxonomically described species. Furthermore, with few spores produced, the fungi that an orchid needs can rarely be stored as spores and so must be maintained as active cultures. However, some researchers have been testing methods for storing fungal cultures in liquid nitrogen (Batty et al., 2001). If these methods prove successful, then conservation of genetically representative collections of mycorrhizal fungi may become more common.

As yet there are relatively few orchid mycorrhizal fungi in culture. The University of Alberta Mycological Herbarium's (UAMH; <http://www.uamh.devonian.ualberta.ca>) culture collection currently maintains 113 fungal cultures obtained from 37 orchid species. The Smithsonian Environmental Research Center (SERC) currently maintains more than 400 fungal isolates in culture from more than 40 native orchid species (D. F. Whigham, M. K. McCormick & J. P. O'Neill, pers. comm.). The American Type Culture Collection (ATCC) maintains 30 isolates from 13 orchid species (<http://www.atcc.org>). Other scattered fungal cultures exist in laboratories around the country where orchid research is conducted, but the maintenance of these collections is often uncertain. Most of the existing collections focus on saprotrophic *Tulasnella* J. Schröt. and *Ceratobasidium* D. P. Rogers fungi, while many orchids rely on fungi that form ectomycorrhizal associations with other plants. These fungi are often difficult to culture and many cannot be grown without a photosynthetic host, often a tree, making them very difficult to establish or maintain in culture. Even when fungi are available in culture, however, their role in facilitating seed germination is far from certain.

Germination requirements for seven of 11 G1-ranked and five of 13 G2-ranked orchids have yet to be studied (Stewart & Hicks, 2010). One threatened orchid (*Isotria medeoloides*) has so far proven completely recalcitrant in culture or in the field. Of the 11 G1- and G2-ranked orchids for which some level of germination success has been obtained, two have had only limited asymbiotic success and only five have been germinated symbiotically. Symbiotic germination has not been reported for the other six of these 11 species. Symbiotic germination is expected to be the method that leads to seedlings best able to survive reintroduction and also provides a method for co-introducing needed fungi and orchids (e.g., Stewart, 2008).

Few well-documented orchid reintroductions exist. Often reintroductions occur in one location at one time and either succeed or fail without providing information about what may have been suboptimal or may increase success in the future (Stewart, 2008). Two examples of reintroductions designed as studies are outlined by Stewart (2008). Elements of another reintroduction are described by Zettler and Piskin (2011). All three studies were designed to assess effectiveness of introduction into different habitats, but only one utilized symbiotic seedlings because fungi were not available for the other two species. In two of the three studies, survival was highest in sites that already had the target orchid species. In the third study, reintroduction was only attempted in sites with the target species so existing plants could act as sources for mycorrhizal colonization of the transplants. This suggests that mycorrhizal colonization may be critical for reintroduction success. No mention of pollinator availability was made in these three studies.

TARGET 11, NO SPECIES OF WILD FLORA ENDANGERED BY INTERNATIONAL TRADE

The United States and Canada are both parties to The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; <http://www.cites.org>), the lead coordinating agency for the implementation, monitoring, and review of Target 11. All orchid species are listed in CITES appendix II, thus preventing the endangerment of North American orchids by over-exploitation caused by international trade. Artificially propagated plants, hybrids, plant parts, products, or derivatives, with a few exceptions, require permits or certificates to import, export, or re-export orchid species across international lines. However, the smuggling of wild orchids remains a problem (Phelps et al., 2010).

TARGET 14, THE IMPORTANCE OF PLANT DIVERSITY AND THE NEED FOR ITS CONSERVATION INCORPORATED INTO COMMUNICATION, EDUCATION, AND PUBLIC AWARENESS PROGRAM

As environmental awareness matures and enters the digital age, several organizations previously limited to spreading their messages slowly though periodicals and mailings have found much broader and enthusiastic younger audiences. One example is the Native Orchid Conference (<http://tech.groups.yahoo.com/group/nativeorchidconference/>) that has become the "go to" place for information about native orchid species and access to experts, photographs, ecology, phenology, and field information to any interested party. It is particularly useful to the public, who may not otherwise have access to or might be intimidated by scientific publications.

Botanical institutions nationwide, such as the Smithsonian Institution and the U.S. Botanic Garden (USBG), provide a type of outreach through conservation messages that regularly appear in exhibits, particularly annual orchid exhibits, and are viewed by their many visitors. In addition, speakers from these institutions regularly travel around the country discussing conservation values to likely interested parties at orchid societies and special events across North America. These efforts, however, are not sufficient. Considerably more could, and should, be done to raise public awareness about the importance of North American native orchid species.

TARGET 15, THE NUMBER OF TRAINED PEOPLE WORKING WITH APPROPRIATE FACILITIES SUFFICIENT ACCORDING TO NATIONAL NEEDS, TO ACHIEVE THE TARGETS OF THIS STRATEGY

Without a centralized organization focusing on North American orchids, it is difficult to assess how many trained individuals work on the in situ and ex situ conservation of orchid species. Kramer et al. (2010) report on a U.S. survey that revealed a major decline in botanical courses and degree programs at universities and colleges nationwide, as well as a deficiency of botanists at U.S. government agencies. With fewer college graduates entering the botanical workforce and many government botanists retiring in the coming years, it will be difficult to increase the number of trained people working on orchid taxonomy and conservation.

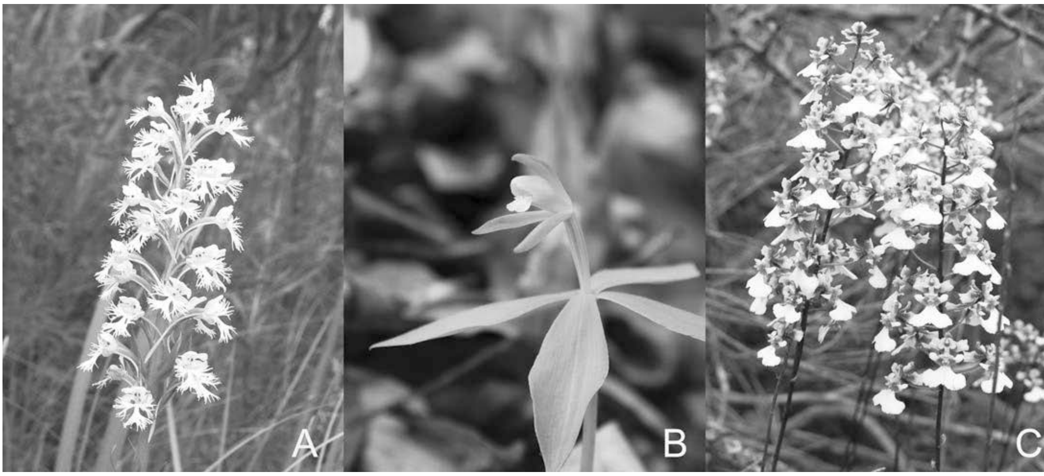

Figure 1. Three endangered orchid species. —A. *Platanthera leucophaea* (Nutt.) Lindl. (photo by Timothy Bell). —B. *Isotria medeoloides* (Pursh) Raf. (photo by Melissa McCormick). —C. *Tolumnia bahamensis* (Nash) Braem. (photo by Matt Richards).

TARGET 16, INSTITUTIONS, NETWORKS, AND PARTNERSHIPS FOR PLANT CONSERVATION ESTABLISHED OR STRENGTHENED AT NATIONAL, REGIONAL, AND INTERNATIONAL LEVELS TO ACHIEVE THE TARGETS OF THIS STRATEGY

The CPC is a successful network of botanic institutions dedicated to preventing the extinction of U.S. native plants by ensuring that ex situ material is available for restoration and recovery efforts. Orchids, however, are unique in that effective ex situ conservation of orchids requires not just seed banking, but also maintenance of cultures of required mycorrhizal fungi. A network of partnerships focusing exclusively on the needs of orchids is necessary.

Three Case Studies

As described throughout this manuscript, effective conservation of any orchid species is a complex undertaking that includes a wide range of variables from long-term storage and maintenance of collections of materials (e.g., seeds and mycorrhizal fungi) that would be required for cultivation and propagation to the establishment and maintenance of habitats that support the long-term success of orchid populations. For many of the reasons described above, we are unaware of any effort that has been fully successful in assuring the long-term survival of any native orchid species. There are, however, a few examples of the efforts that are necessary to build an information base, which can support further attempts to conserve all native orchid species.

Effective orchid conservation must integrate the understanding of existing and future environmental threats, taxonomic distinctiveness, numbers of individuals in populations, reproductive biology, ex situ propagation, and the maintenance of evolutionary processes influencing population distribution patterns. In order to do this, conservation must combine detailed experimentation directed at continued survival of the species both in situ and ex situ (Ramsay & Dixon, 2003). The integrated conservation strategy emphasizes the study of interactions among land conservation, biological management, research and propagation and reintroduction and habitat restoration (Hopper, 1997).

CASE 1

Platanthera leucophaea (Fig. 1A) is currently listed as federally threatened, under the ESA, and has declined in the United States by more than 70% from estimates provided by original county records. This decline has mainly been due to habitat loss. Most of the remaining 79 populations are small, these with fewer than 50 plants, and only 28% have adequate protection and management (U.S. Fish and Wildlife Service, 2007). Investigation of the orchid's genetics indicates that the species is primarily outcrossing and demonstrates significant inbreeding depression particularly prevalent in small populations (Wallace, 2003). Despite the low number of protected populations, the outlook for conservation of *P. leucophaea* is relatively good. Well-coordinated efforts to recover this species are currently in place and involve a network of scientists, private landowners, and volunteers (Zettler & Piskin, 2011). Fungi needed by *P. leucophaea* are known, and symbiotic germination is regularly accomplished in laboratory cultures, although successful transplantation of seedlings into natural populations has met with limited success (Zettler et al., 2005; Zettler & Piskin, 2011). Genetic surveys have found that even small populations of *P. leucophaea* may retain relatively high levels of genetic diversity (Holsinger & Wallace, 2004), potentially resulting in significant seed production and recruitment where habitat is available. This level of information about the species and the network of public and private agencies cooperating toward the orchid's conservation suggest that *P. leucophaea* has a strong potential for recovery.

CASE 2

In contrast to the favorable outlook for *Platanthera leucophaea*, *Isotria medeoloides* (Fig. 1B) is listed by NatureServe as imperiled (G2) in 14 (78%) of the 18 states and provinces in which it is still known to occur; the orchid is thought to be historical or extirpated in five states. Nowhere across its distributional range in eastern North America is *I. medeoloides* considered secure or common. The primary threat to its existence is destruction of its woodland habitat for development or forestry. The majority of its populations number fewer than 25 plants and are thus vulnerable to local extinction (U.S. Fish and Wildlife Service, 1994). Many of the extant populations, including some of the largest populations, occur on land protected by federal or state agencies or the U.S. military, and on this basis the plant might be considered well protected (U.S. Fish and Wildlife Service, 1994). Its preferred habitat conditions have also been identified (Sperduto & Congalton, 1996), and searching these habitat types allowed researchers to locate many new populations in the late 1990s. However, the plant's biology throughout much of its range is defined by many small, ephemeral populations that make it quite difficult to target areas to protect. Additionally, long periods of dormancy, common in many terrestrial orchids, are characteristic of the lifecycle of this species, making it difficult to assess population sizes or even plant presence (Mehrhoff, 1989).

Ongoing management experiments of *Isotria medeoloides* are beginning to reveal a management technique, tree thinning, which can benefit local populations (e.g., Brumback et al., 2011). The fungi needed by this orchid have recently been identified (M. K. McCormick, unpubl. data), but they have so far been resistant to culture in the laboratory. Seed germination, either symbiotic or asymbiotic, has never been accomplished either in the field or in the laboratory, yet based on population demographic studies (Mehrhoff, 1989) and preliminary genetic analyses (M. K. McCormick, unpubl. data), recruitment from seed is critically important to both population persistence and also the founding of new populations. This suggests that this species, many of whose extant populations are relatively well protected, is sufficiently poorly understood and that its maintenance in the face of a changing climate is a serious concern.

CASE 3

An additional case study involved returning a semiepiphytic species, *Tolumnia bahamensis* (Nash ex Britton & Millsp.) Braem (Fig. 1C), to reasonably pristine habitat, where ostensibly all the other pieces of the ecological puzzle remain. In this case, suitable unspoiled, historical habitat in Jonathan Dickinson State Park in southern Florida was assessed and the few extant plants of *T. bahamensis* were cross-pollinated and grown ex situ at Atlanta Botanical Garden. With most of the host plants and presumably mycorrhizal fungi intact in the orchid's preferred environment, reintroduction has initially been successful. These types of enrichment reintroductions should be attempted whenever suitable protected habitat is available. This underscores the need for a holistic approach to orchid conservation in which entire habitats and ecosystems are sought to be preserved whenever possible (Jonathan Dickinson State Park, 2011).

THE FUTURE OF ORCHID CONSERVATION

International efforts such as CITES have focused on the illegal trade of orchids and many organizations have been established to cultivate, market, and enjoy orchids, but there is no one national organization that focuses on their conservation and restoration. Neither is there one entity devoted to educating the public about the evolutionary and ecological importance of orchids. Organizations (e.g., federal agencies and the U.S. military) that are mandated to identify and protect orchids on public lands have been involved in research on relatively few species (see examples above), and they rely mostly on habitat conservation for management. While habitat management is important, ecological attributes of orchids (e.g., the obligatory relationships between orchids and fungi at critical life history stages) dictate that habitat management alone will not result in orchid conservation or restoration. Every U.S. state lists at least one orchid species that is rare or threatened and most states list multiple orchid species. There is, however, little coordination among states and no one organization that can provide answers to basic questions that would guide effective management plans. Private land-management conservation groups (e.g., The

Nature Conservancy) face a similar dilemma. Perhaps most important, the public has little recognition of the diversity and importance of orchids and there is no central organization that focuses on orchids as an important aspect of education and outreach to the public.

We propose a possible solution to the lack of coordination and the pooling of resources to focus on the more than 200 native orchids listed within the United States and Canada. The NAOCC (http://northamericanorchidcenter.org) is the first internationally focused public–private effort to support the conservation, cultivation, and restoration of native orchid species. NAOCC began as a collaborative effort between the SERC, Smithsonian Gardens, Department of Botany at the National Museum of Natural History (NMNH), Exhibits and Park Management Department of the National Zoological Park (NZP), and USBG. Other government agencies, botanic gardens, and public and private landowners are joining the collaboration. NAOCC launched in 2012 and the network that will support the effort will be developed over approximately 10 years.

The NAOCC's mission is to conserve the native orchid heritage of the United States and Canada through preservation, restoration, and cultivation of native orchids and to convey the importance of NAOCC to the public through innovative educational programs. The goals of NAOCC are to:

- Develop an international seed bank collection, in collaboration with the CPC, that will be representative of the genetic diversity of all North American orchid species.
- Develop an international collection of fungi representative of the genetic diversity of mycorrhizal fungi required by native orchids.
- Develop techniques to conserve the genetic diversity of all native orchids by cultivating them in an international network of botanic gardens and arboretums.
- Use seed and mycorrhizal fungal banks to develop techniques for restoring, conserving, cultivating, and restoring orchids in native habitats.
- Support efforts to conserve orchid populations through habitat conservation and restoration.
- Develop web-based materials that will provide up-to-date information on the ecology, conservation status, and techniques for the cultivation of North American orchids.

An initial goal of the network of botanic gardens is to grow and display all native orchids in the United States and Canada using an ecoregional approach. The primary partners play different yet integrated roles. NAOCC administration and research are based at the SERC, which provides research services to private and public organizations, and collaborates with the CPC and other affiliated organizations (e.g., Kew Gardens and the U.S. Bureau of Land Management's Seeds of Success program) to develop a genetically diverse seed bank for all native orchids. The seed collection will not only be used to assure the long-term survival of the germplasm of each species, but will also serve as a resource for material to support efforts to grow and cultivate all native orchids. SERC is collaborating with the partners of NAOCC to expand its collection of orchid mycorrhizal fungi to include fungi from all native orchids. SERC is also playing a lead role in developing a network of laboratories that provides services for the molecular analysis of orchid fungi. The Smithsonian's Department of Botany at the NMNH will focus on the development of a well-curated and complete herbarium-based orchid collection and will develop DNA barcodes for all North American orchids. NMNH will also develop a digital library of all North American orchids, including visual images of all species, and will actively partner with SERC and NAOCC to develop web-based technologies to provide up-to-date public access to orchid information. Smithsonian Gardens, the Exhibits and Park Management Department of the NZP, and the USBG will coordinate efforts to cultivate all orchids within the Washington ecoregion into their living collections, and they will collaborate with partner-gardens to develop and put into effect a plan to cultivate all 210 native orchids in a range of gardens across the United States and Canada. The Smithsonian and the USBG will also include exhibits about native orchids in their biannual orchid show.

Conclusion

Native orchids occur in every state in the United States and every Canadian province, and one or more species is listed as endangered or threatened in every state and province. As described above, national and international efforts have provided a degree of protection for native orchids, and there have been efforts to conserve and restore a small number of species. It is our view that progress toward the effective conservation of the numerous species that are listed as threatened or endangered will require a large-scale integrated effort to develop the knowledge base required to develop effective management strategies to assure the survival of the more than 200 species of native orchids. In establishing the NAOCC, our goal is to develop the resource base and integration of public and private organizations responsible for or interested in native orchids to ultimately assure the survival of all native orchid species. The success of NAOCC will require long-term commitments to obtain the financial support for the research, training, and education necessary to reach the organization's goal of conserving the genetic diversity of all native orchid species.

In addition to botanic gardens, research organizations, and private and public groups devoted to orchid conservation, the success of NAOCC will also require the establishment of a dynamic web site and associated web-based materials that will enlist the public in the effort. The ultimate success of NAOCC and its partner organizations is important for other reasons. While the orchid family is the most diverse family of flowering plants on earth, the number of species in the United States and Canada is relatively small, and conserving our native orchids would be a success that has never been obtained. Orchids are more than just beautiful flowers. They are an important component of North America's ecology, biological richness, and heritage, and they need greater protections than they currently receive. With so many uncertainties in the future due to habitat degradation, urban sprawl, and climate change, it is incumbent on organizations with the infrastructure necessary to guide and coordinate the efforts of the many individuals and organizations that have a stake in native orchid preservation. NAOCC seeks to be this important resource for North American orchid species and ultimately to serve as a model for similar conservation organizations in other parts of the world.

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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[1]

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Abstract

Target 2 of the 2020 Global Strategy for Plant Conservation (GSPC) calls for a comprehensive list of the world's threatened plant species. The lack of such a list is one of the greatest impediments to protecting the full complement of the world's plant species, and work to achieve this has been slow. An efficient system for identifying those species that are at risk of extinction could help to achieve this goal in a timeframe sensitive to today's conservation needs. Two systems that efficiently use available data to assess conservation status were tested against a provisional International Union for Conservation of Nature and Natural Resources (IUCN) Red List analysis to evaluate the native seed plant species of Puerto Rico. It was demonstrated that both systems efficiently identify species at risk, which is a step toward both the GSPC Target 2 and a more comprehensive IUCN Red List for plants. Both systems were effective at identifying plant species at risk, with the New York analysis identifying 98% and the Smithsonian analysis 85% of the plant species considered Threatened in the IUCN Red List. Both analyses to some extent overestimated those plants at risk, but the species identified are all range restricted and, thus, of some conservation interest.

Key words: Global Strategy for Plant Conservation (GSPC), IUCN Red List, Puerto Rico.

Estimates of the number of flowering plant species vary widely, from about 250,000 to more than 400,000 (Stebbins, 1974; Prance et al., 2000; Govaerts, 2001; Bramwell, 2002; Miller, 2011), many with restricted ranges (Joppa et al., 2010), and perhaps more than a quarter of all flowering plants still have not been described and named (Prance et al., 2000; Miller, 2011). Furthermore, many of these species are at risk of extinction in the near future as a consequence of deforestation and habitat destruction and perhaps 94,000 species are so endangered (Pitman & Jorgensen, 2002). There is perhaps no

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greater impediment to ensuring that these threatened species persist into the future than the lack of a comprehensive list of those plant species that are at risk and most desperately need our conservation attention.

The Global Strategy for Plant Conservation (GSPC) was adopted at The Hague, The Netherlands, at the sixth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD) in 2002, establishing 16 targets under five broad aims designed to prevent the loss of plant diversity and encourage its sustainable use to improve human livelihoods (CBD, 2002). Target 1 of the GSPC was the production of "a widely accessible working list of known plant species, as a step towards a complete world flora," and Target 2 was "a preliminary assessment of the conservation status of all known plant species, at national, regional, and international levels." The GSPC was originally designed with the intention that targets would be met by 2010, and while some progress was made on some of the targets, they were not fully accomplished, and in 2010 in Nagoya, Japan, a revised GSPC with 2020 targets was adopted (CBD, 2010). In the 2011–2020 GSPC, Target 1 was revised as "an online flora of all known plants," and the second target remained similar to the original target, being "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action" (CBD, 2011).

While the GSPC Target 2 calls for a comprehensive survey of the conservation status of all plant species, it does not identify any specific method for performing the assessments. A variety of methods are in wide use for assessing threat, including Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO's) system used to assess threat for both plants and animals in Mexico (SEMARNAT, 2002) and the system of NatureServe (<www.natureserve.org>), but the most widely used procedure has been that of the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (IUCN, 2001, 2008, 2009, 2011), the only system that has been used to any significant degree globally. The Red List has been very successfully used to accomplish comprehensive assessments for amphibians (Stuart et al., 2008), birds (BirdLife International, 2008, 2013), and mammals (Schipper et al., 2008). However, collectively these vertebrate groups have fewer than 22,000 species, so completion of their conservation assessments is less daunting than it is for flowering plants, with more than 300,000 species, and to date less than 15,000 species of plants have been assessed (IUCN, 2011). Numerous Red Lists have been published, assessing the conservation status of species on a regional rather than global basis, but the only taxonomically comprehensive studies completed to date for plants are for cycads (Donaldson, 2003) and conifers (Farjon et al., 2006). The goal of the present study is to validate a streamlined system for rapid assessment of the conservation status of plant species that is complementary with the Red List procedures and to represent a first step toward accomplishing Red List analyses, but also with preliminary assessments that are useful for immediate conservation decisions.

Background

One benefit of the IUCN Red List system is its flexibility, allowing evaluation by any one of five different criteria, depending on the type of data available, thus making it applicable to a broad range of plant and animal groups (IUCN, 2001). The IUCN Red List methods identify Threatened species and assign them to categories of Vulnerable (VU), Endangered (EN), or Critically Endangered (CR), as threat increases. Demographic data gathered over time are seldom available for plants, but the geographic range of most plant species can be determined from locality data associated with herbarium specimens with a reasonable degree of accuracy, and used to calculate Extent of Occurrence (EOO) and Area of Occupancy (AOO; Willis et al., 2003; Brummitt et al., 2008). Under the IUCN Criterion B, species are considered Threatened if their EOO or AOO values fall below specified thresholds and if they also meet two of three additional subcriteria: (a) severe fragmentation or a small number of known localities, (b) continuing decline in range, habitat, number of subpopulations, or number of individuals, or (c) extreme fluctuation in range, habitat, number of subpopulations, or number of individuals (IUCN, 2001). While both EOO and AOO can be easily calculated from locality information from herbarium specimens, there are a number of confounding issues. All of the herbarium specimens of any given species are generally distributed throughout many of the world's herbaria, rather than being together in a single institution. Furthermore, locality data from only a tiny percentage of herbarium specimens have been entered into publically available databases and only a percentage of these records are associated with geographic coordinates required for geographic information system (GIS) analysis. Rigorous and comprehensive Red List analysis using the Red List's Criterion B thus requires assembly of a great amount of specimen locality data from multiple herbaria and secondary efforts to georeference the records.

The less than 15,000 Red List assessments completed to date for plants are only a small step toward the GSPC 2020 Target 2, and a more efficient method than the Red List procedures could help generate the list of endangered plant species in a timeframe more sensitive to conservation needs. It seems preferable to use a streamlined procedure that would complement, rather than substitute for, the Red List system. Two systems have been developed with the aim of completing conservation assessments rapidly and efficiently, using readily available data (Miller et al., 2012), and they were tested by evaluating the global conservation status of Puerto Rican plant species and identifying those species that are At Risk. The terms "Not At Risk" and "At Risk" were specifically chosen as they do not overlap with IUCN's Red List category names and cannot be confused, but the At Risk category used here can be considered an approximation of IUCN's Threatened category, including the subcategories CR, EN, and VU. Both analyses used herbarium specimen locality data readily available in the Global Biodiversity Information Facility (GBIF) and institutional databases and did not require compilation of a set of data that was labor intensive to assemble. A detailed review of Puerto Rican native plants (Miller et al., 2012) produced provisional Red List assignments (pending their submission, approval, and acceptance by the Species Survival Program at IUCN), and results of the earlier studies were compared to validate the streamlined methods.

The flora of Puerto Rico was chosen as a test case for the proposed conservation assessment methods because it is a reasonable size, with 2009 native seed plant species (Acevedo-Rodríguez & Strong, 2007, 2008), it is comparatively well known for a tropical flora, and it is well documented by herbarium collections. Only 53 native plant species from Puerto Rico have been identified to date as globally Threatened in the Red List (IUCN, 2011; <www.iucnredlist.org>), but this number is almost certainly an underestimate as only a small percentage (3.9%; 76 species) have been evaluated. Therefore, the flora of Puerto Rico is in serious need of assessment. It is also an appropriate size to test the validity of two streamlined methods for the conservation assessment of plant species.

Methods

Geographic distribution information was compiled in a database hosted by The New York Botanical Garden (NY; The Puerto Rican Endangered Plants Initiative, 2012) to provide detailed information about the range of each seed plant species native to Puerto Rico. Herbarium specimen locality records from NY and GBIF from earlier analyses were supplemented with data from the Smithsonian Institution (US) and three Puerto Rican herbaria, the University of Puerto Rico, Río Piedras (UPRRP), the Jardín Botánico of the University of Puerto Rico (UPR), and the University of Puerto Rico, Mayagüez (MAPR). Two streamlined analyses were conducted to evaluate the global conservation status of Puerto Rican seed plant species. The New York Botanical Garden's GIS lab method (NYBG-GIS) calculated the EOO from the complete herbarium specimen locality database (Miller et al., 2012). EOO was calculated for all species with at least three unique known localities by creating a minimum convex polygon using the ArcGIS extension, Hawth's tools (Beyer, 2007), the smallest polygon that encompasses all specimen localities and has no angles that exceed 180° (IUCN, 2008). Areas of unsuitable habitat, such as large bodies of water, were excluded from the EOO calculations, using ArcGIS 9.2 (ESRI, 2007; IUCN, 2008). All species with EOO values greater than 20,000 km^2 were considered to be Not At Risk. For those with calculated EOO values below 20,000 km^2, collection data without geographic coordinates were retrospectively georeferenced, and EOO was recalculated. Those species with EOO values remaining below the 20,000 km^2 threshold were considered At Risk. The Smithsonian method (Krupnick et al., 2009), from the Plant Conservation Unit (US-PCU), is a four-step evaluation that considers temporal, spatial, and abundance data inferred from herbarium records from US. The species is considered At Risk if all known specimens were collected before 1900, if available collections are from five or fewer localities, or if the species is known from less than the median number of specimens per species collected since 1960 from the area being evaluated.

Species identified as At Risk in both analyses were considered to be of conservation concern, and those species that were identified as At Risk by one, but not both, analyses were subjected to further review. In August 2011, an expert panel was convened at the University of Puerto Rico's Botanical Garden to test the validity of the results of the streamlined analyses. The panel was comprised of botanists from the UPRRP, MAPR, the University Botanical Garden, NY, US, the USDA's Institute for Tropical Forestry, the Department of Natural and Environmental Resources, and the Fideicomiso de Conservación de Puerto Rico. The global conservation status of each individual species was reviewed, including geographic range, as documented by herbarium specimens, supplemented with field observations from the experts. All species considered At Risk in either streamlined analysis were reviewed; any species considered Not At Risk in both analyses but considered to be of conservation concern by any of the experts were also included. All species provisionally assigned to one of the Red List Threatened categories under IUCN's Criterion B had an EOO less than 20,000 km^2 and also met two of three subcriteria (IUCN, 2001). Thus, the primary goal of the expert panel was to evaluate those species with restricted geographic ranges for the three possible subcriteria, fragmentation, decline, or fluctuation of known populations. For each species, experts' observations on numbers of known populations, numbers of available herbarium specimens, patterns of abundance, and numbers of individuals, when known by one or more panel members, was recorded.

Results

Results of the two streamlined analyses were previously reported (Miller et al., 2012), but in this review, the NY analysis was rerun with a much larger set of specimen data that recognized 2009 native seed plant species from Puerto Rico. Data from GBIF and NY were supplemented with herbarium specimen records from the three major Puerto Rican herbaria. The NY analysis identified 398 At Risk plant species, reduced from the 459 reported earlier (Miller et al., 2012), because of more adequate documentation of range and, therefore, greater EOO values resulting from the larger dataset and leading to fewer At Risk species. In the original NY analysis, it was not possible to calculate EOO for 142 species, which were known from fewer than three specimens, but with the larger dataset, it was possible to calculate EOO for all but 106 species, and the larger EOO values reduced the At Risk species by 62. The US analysis recognized 359 At Risk species, based on the original dataset (Miller et al., 2012). In total, 510 species were considered At Risk in one or the other analyses, and 247 of these were identified as such in both.

The results of the expert analysis to provisionally assign all species to the IUCN Red List categories are summarized in a table available on NY's website (<http://sweetgum.nybg.org/caribbean/J_Miller_et_al_Puerto_Rican_plant_conservation_status.pdf>). Species were considered Threatened when their calculated EOO was less than the 20,000 km^2 threshold for VU, and when experts' observations confirmed fragmented populations and likely decline in known populations or available habitat. The analysis identified 72 species as CR, 97 species as EN, and 86 species as VU, for a total of 255 Threatened species. In addition, 44 more species were identified as Near Threatened (NT), and 1710 species were considered Least Concern (LC). The two streamlined conservation analyses both proved very effective at predicting which species were considered Threatened by more detailed IUCN Red List analyses (Table 1). Both predicted all 72 species considered to be CR, the NY analysis predicted 96 (99%) and the US analysis 91 (94%) of 97 EN species, and the NY analysis predicted 82 (95%) and the US analysis 53 (62%) of 86 VU species. In total, the NY analysis predicted 250 (98%) and the US analysis 216 (85%) of 255 Threatened species, but the difference among the methods was not quite significant (chi square = 4.32, $df = 2$, $P = 0.12$). The NY analysis considered 148 more species At Risk, or 58% more than were not considered Threatened in the provisional IUCN listing. The US analysis identified 143 more species, or 56% more than were actually Red Listed. The three methods (the panel's assessment and the US and NY rapid assessment methods) did not differ significantly in the number of species assigned to the three categories (chi square = 5.71, $df = 4$, $P = 0.22$).

Table 1. Results of conservation analyses of Puerto Rican seed plants, contrasting provisional Red List category assignments with identification of species At Risk in the two streamlined conservation assessment methods. Provisional IUCN assignments were made by a local panel of experts. CR = Critically Endangered; EN = Endangered; VU = Vulnerable.

Provisional IUCN assignments	Streamlined assessment assignments		
NY method	US method		
CR	72	72 (100%)	72 (100%)
EN	97	96 (99%)	91 (94%)
VU	86	82 (95%)	53 (62%)
Total (Threatened)	255	250 (98%)	216 (85%)

While each of the analyses was effective at identifying plants that would be considered Threatened by IUCN, they were even more effective when combined. The two analyses together identified all 169 CR and EN species and 83 of 86 species that IUCN would consider VU. In total, the combined analyses identified 99% of the species IUCN would consider Threatened. There were 258 species identified as At Risk in one or the other analyses that were not considered Threatened in the Red List assignments, though 38 were among 44 species considered NT in the provisional Red List.

Discussion

It is clear that only a small percentage of the world's plant species have had their conservation status evaluated and that a streamlined, efficient process would help produce assessments in a timely manner that is responsive to the immediate threat that many species face. This study aimed to evaluate two methods that efficiently assess conservation status and used the flora of Puerto Rico as a test case.

Validation of the results of the two streamlined methods requires an assessment conducted by a method proven to produce credible results, against which the streamlined results can be compared. The panel of experts on the flora of Puerto Rico assembled at the University of Puerto Rico Botanical Garden in August 2011 used the IUCN guidelines (IUCN, 2001) to assess conservation status of all species potentially considered to be of conservation concern, under IUCN's criterion B. Geographic range has been considered a valid measure of conservation status in many previous studies (e.g., Gaston & Fuller, 2009) and is one of the five measures that IUCN accepts for Red List assignments (IUCN, 2001). The expert review assigned 12.7% of the flora to one of the three Threatened categories, which is less than the 20% or more estimated for most tropical floras (Pitman & Jorgensen, 2002; Brummitt et al., 2008), but quite similar to the 13.6% of the Puerto Rican flora considered to be endemic (Acevedo-Rodríguez & Strong, 2007). It is likely that the results of this analysis are conservative in the sense that they identify only those species for which restricted geographic ranges clearly document evident conservation concern, and in this analysis, 44 additional species were considered NT.

Comparison of the results from the two streamlined methods with the provisional Red List indicates that they were both excellent predictors of conservation concern, with the NY analysis identifying 250 (98%) of 255 Red List Threatened species and the US analysis identifying 216 (85%) of 255 Threatened species. The NY analysis identified an additional 148 species (58%) and the US analysis 143 species (56%) as At Risk, beyond those considered Threatened in the Red List analysis. No further analysis of the geographic ranges of these additional species were completed, but review of the information included in this analysis supports the assumption that the vast majority of species considered At Risk but not Threatened are species with restricted ranges and that are hence of some conservation concern. In fact, 44 of the additional species were considered NT in the Red List analysis.

The two methods did yield somewhat different results. The NY method predicted 98% of the Red List Threatened species as compared with only 85% by the US method. Given that the two methods evaluated here both use readily available data and can be completed efficiently, they can be a realistic approach to identifying the list of species needed to satisfy Target 2 of the GSPC, the same group of species that most desperately need conservation to ensure their near-term survival.

Conclusions

The most widely used system for assessing conservation status, the IUCN or IUCN's Red List system, has made only limited progress reviewing the conservation status of plants, providing assessments for fewer than 15,000 species, or only about 4% of the estimated seed plant species. Given this progress, it seems unlikely that the 2020 deadline for Target 2 of the GSPC, a list of the world's endangered plants, will be met. A streamlined system that can expedite review of the conservation status of individual species, using readily available data, is needed to rapidly compile the list of species that merits conservation attention. The two systems reviewed here, to assess the validity of the conservation assessments that they produce, are intended to provide the means to rapidly evaluate large numbers of plant species and achieve Target 2 of the GSPC. Used either individually or in tandem, these systems provide an efficient approximation of and a first step toward a Red List and could facilitate assessments rather than being an alternative system that would replace the Red List.

The congruence between the NY analysis and the provisional Red List assessments from the expert panel was very good, with the NY list of At Risk species including all but five, or 98%, of the species "Red Listed" as Threatened. The US analysis was not quite as effective, identifying only 85% of the Red Listed Species, 216 of 255. The provisional Red List was conservative in recognizing Threatened species, and both analyses identified significantly more At Risk species, 148 additional in the NY and 143 more in the US analyses. Given that the provisional Red List also included 44 NT species, and that most of the At Risk species are range restricted even if not sufficiently so to be considered Threatened in the Red List, the results of both analyses are very efficient at identifying Threatened species and the additional species they identify are almost certainly worthy of some conservation concern.

The two analyses combined were even more effective at identifying the Threatened species.

Given the efficiency at which the two tested methods evaluated the flora of Puerto Rico, using data that are readily available in internet-accessible databases, these methods could be very effective in evaluating the large numbers of species that will be necessary to reach Target 2 of the GSPC. Both methods require only a reliable checklist of the native plant species from the region to be evaluated (evaluations could also be organized taxonomically) and access to available herbarium specimen locality data. With the recent publication of checklists for Venezuela and Brazil (Hokche et al., 2008; <http://floradobrasil.jbrj.gov.br/2010/>) and pending checklists for Bolivia and Colombia (Jorgensen, in prep.; Bernal, in prep.), the only part of the New World not likely to have the necessary data available in the near future would be Mexico.

The two efficient analyses tested here both provide a means of realistically working to complete the assessments required to attain Target 2 of the GSPC. Furthermore, the list of species that they would generate would almost certainly contain nearly all of the species that would be identified as Threatened in a comprehensive Red List analysis, as well as a modest percentage of species that are range restricted, though not sufficiently to be considered Threatened. This list would be a decisive positive step toward completing a much greater number of Red List assessments, because it first essentially Green Lists a large percentage of species that IUCN would consider LC, and then allows labor for more complete analyses to be focused on the species that might possibly be of conservation concern. Furthermore, completing the analyses via the NY method focuses the most labor-intensive work, namely georeferencing those specimen records with locality data lacking geographic coordinates, on those species whose conservation status might actually be affected by redefinition of their geographic range. It is clear that some more efficient method will be required to achieve Target 2 of the GSPC, and the two methods presented here could both play a significant role in achieving that goal.

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FROM WORKING LIST TO ONLINE FLORA OF ALL KNOWN PLANTS—LOOKING FORWARD WITH HINDSIGHT[1]

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Abstract

The aim of this paper is to identify factors that might assist implementation of Target 1 for the Global Strategy for Plant Conservation (GSPC) for 2020: "an online flora of all known plants." This is done by considering progress in large regional floras to date and production of The Plant List online, in conjunction with lessons learned from the first 10 years of GSPC implementation. If the online flora is to support GSPC implementation, then it has to be able to support conservation and sustainable-use projects at national and local levels in addition to linking to information concerning global plant diversity. This will require strong partnerships and collaborations across the botanical community. Measurement of progress will help identify gaps and direct efforts, and indicators for measuring progress are suggested.

Key words: Flora, Global Strategy for Plant Conservation (GSPC), The Plant List, Targets.

The Global Strategy for Plant Conservation (GSPC) was adopted by the Conference of Parties (COP) of the Convention on Biological Diversity (CBD) in April 2002 (CBD, 2002). Target 1 ("a widely accessible working list of known plants species as a step towards a World Flora") was globally achieved on schedule on 29 December 2010 with the online launching of The Plant List (<www.theplantlist.org>). Ten years on from the original setting of Target 1, what lessons have we learned that can guide our responses and the implementation of the new Target 1 for 2020? As agreed at the 10th COP of the CBD in Nagoya, Japan, the revised Target 1 is "an online flora of all known plants" by 2020 (CBD, 2010a; <http://www.cbd.int/decision/cop/?id=12283>).

The Plant List

The Plant List was created to meet the 2010 Target 1 of the GSPC. This was a broad collaboration, coordinated by the Royal Botanic Gardens, Kew, and the Missouri Botanical Garden (MO), involving diverse partnerships. These extended from global data resources such as The International Compositae Alliance, which produced the Global Compositae Checklist (<http://compositae.landcareresearch.co.nz/>), the International Legume Database and Information Service (<http://www.ildis.org/>), to the International Plant Names Index (IPNI; <www.ipni.org>). Regional resources included various regional checklists held within the Tropicos database, including the African Plant Database (<www.ville-ge.ch/musinfo/bd/cjb/africa/index.php>), as well as contributions from many individuals. For example, over 155 collaborators from 22 countries have supported Kew's World Checklist of Selected Plant Families (WCSP; <www.kew.org/wcsp>).

The Plant List provides a working list of known plant species that aims to be comprehensive in coverage at species level for all names of mosses and liverworts and their allies (bryophytes), and for all names of vascular plants, which include the flowering plants (angiosperms), conifers, cycads and their allies (gymnosperms), as well as the ferns and their allies, including horsetails and club mosses (ferns and lycophytes). For each name at the species level, information in The Plant List includes the describing author(s) of the name, the original place of publication, and an assessment of whether the name is accepted in current taxonomic use or is a synonym for another name. For each name included, wherever possible, links are also provided to an online database record, to its corresponding entry in IPNI, and to any further sources of information about that plant taxon. For each name record, The Plant List indicates the level of confidence that the status of the name record is correct; the confidence assessments are based primarily on the nature and taxonomic

[1] I am grateful to the following individuals for information relating to the progress of major floras: Wayt Thomas (Flora Neotropica), Annette Wilson (Flora of Australia), Nick Turland (Flora of China), Jim Zarucchi (Flora of North America), Sandy Knapp and Gerrit Davidse (Flora Mesoamericana), Henk Beentje (Flora of East Tropical Africa), Jonathon Timberlake (Flora Zambesica), and Marco Roos (Flora Malesiana); and to Rafael Govaerts for analysis of WCSP data.

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integrity of the source data. Currently, The Plant List recognizes ca. 298,900 accepted names (28.7% of the total) and 477,601 synonyms (45.9%). There are 263,925 names unresolved for taxonomic status, which constitutes 25.4% of all names in Version 1 of The Plant List. This latter category represents work in progress because there was insufficient information held in the component data sets contributing to The Plant List to determine whether these names should be accepted or considered as synonyms of other names. The Plant List is a working list, and future versions are planned to improve the quality and to reduce the number of unresolved names. There are opportunities to broaden the network of collaborators supporting The Plant List, which should thus help to reduce the number of unresolved names and to improve the quality of data. In future versions of The Plant List, it will be important to further broaden the scope of institutional and individual collaborations to help improve the quality and long-term maintenance of the data.

Global Strategy for Plant Conservation (GSPC) Perspective—Strengths and Weaknesses

From a GSPC perspective, The Plant List could be viewed as a success in several ways. It was the result of a global partnership, illustrating how a clearly agreed upon target can focus the activities of interested parties, helping them to achieve a common objective. The process in constructing The Plant List demonstrated the importance of GSPC cross-cutting issues, such as the development of tools and methodologies (Target 3), and of strengthening networks and collaboration for plant conservation at national, regional, and international levels (Target 16; CBD, 2010a). However, it is a significant lesson for the implementation of the GSPC, generally, that the partners involved already had their business aims closely aligned to the Target (Paton & Nic Lughadha, 2011). The production of taxonomic checklists has long been one of the principal activities of taxonomic institutions, and the vast majority of contributors were engaged in activities complimentary to Target 1 before it was set. Target 1 provided a focal point for collaboration rather than driving larger-scale business change within the institutions involved.

An important aspect of enabling institutional and individual collaboration was the ability to monitor progress toward Target 1. Measures such as the number and families of taxa covered in component global checklists enabled a gap analysis to be conducted. In 2005, this analysis enabled the Global Biodiversity Information Facility (GBIF) to target these gaps in a call for proposals that resulted in the funding of two of these taxonomic gaps, for the Compositae (<http://compositae.landcareresearch.co.nz/>) and Melastomataceae (<www.melastomataceae.net/>; GBIF, 2005).

Although Target 1 for the GSPC in 2010 can be viewed as a success from a global perspective, the need for stronger implementation at a national level has been noted (CBD, 2008; Paton & Nic Lughadha, 2011). Capacity building at national levels as identified in the Global Taxonomy Initiative (GTI; <http://www.cbd.int/gti/>) and covered under Target 15 of the GSPC (CBD, 2010a) is important to ensure that a working list or online flora can be maintained to ensure that it supports national-level support and implementation of the CBD. Different countries will have different priorities and require different foci of taxonomic research and service. Capacity building is likely to remain a priority in the next 10 years of GSPC implementation, but such capacity-building initiatives need to have clear goals to support implementation of the convention (Paton & Nic Lughadha, 2011).

National-level input is vital for the long-term compilation and maintenance of a global working list or online flora. For this paper, an analysis (Paton, unpubl.) of the distribution of species covered by Kew's WCSP underlying database, which covers 173 families and 123,000 species (WCSP, 2012), was carried out. The WCSP provides Taxonomic Database Working Group (TDWG) level 3 distributions (Brummitt, 2001) for the species covered. This level corresponds to countries or parts of large countries such as the United States or China. The analysis found that 58% of seed plant species are only found in one TDWG level 3 area and, therefore, endemic to one country (WCSP, 2012). Thus, for the majority of seed plants, a national treatment will also be a global treatment. Generally, within the GSPC, there needs to be a stronger interplay between global resources, such as The Plant List, and national level resources (CBD, 2010b). This interplay will facilitate long-term maintenance of global resources and will ensure that national level resources maintain up-to-date knowledge concerning more widely distributed species that may cross national boundaries.

The GSPC Target 1 set in 2002 (CBD, 2002) provided a vision that extends well beyond 2010. Going forward to 2020, The Plant List and any other system used to support the assembly of an online flora needs to consider its long-term maintenance. Currently, The Plant List (Version 1, 2010) can be regarded as only a single picture at any given time. It is not maintained as a dynamic online resource, although this is a possibility in the future. At the moment, corrections are fed back to the collaborating

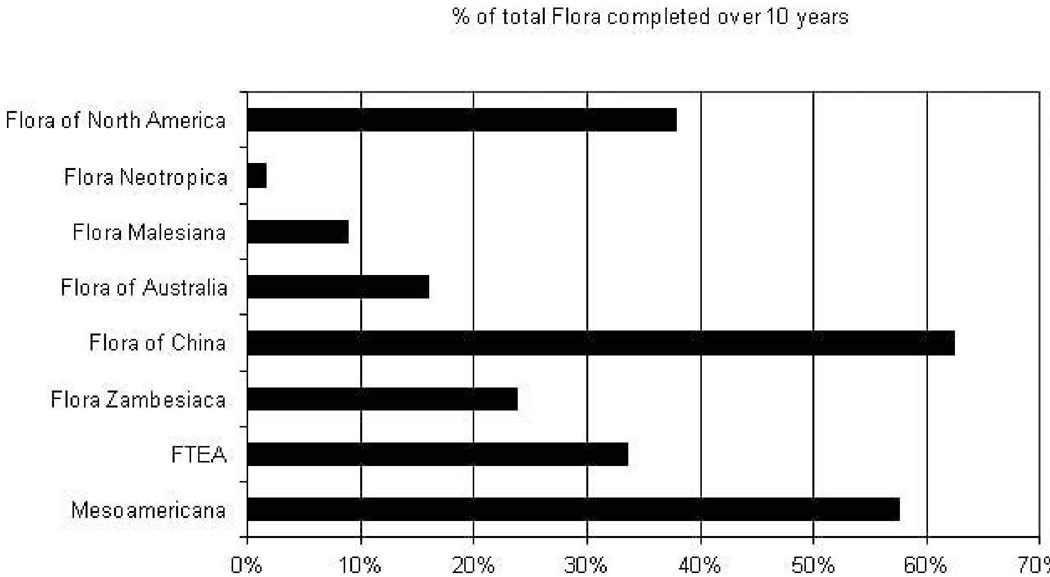

Figure 1. Progress in a selection of flora projects over the last 10 years. Totals from 2001 are taken from Heywood (2001). Results from 2012 come from the editors of regional or national flora projects asked to give totals for the number of species completed (see acknowledgments and Table 1 for details). Numbers reflect progress as of July 2012.

partner databases, and a planned new version of The Plant List will incorporate changes originating from these source databases. The lesson for GSPC implementation is that the processes used to achieve Target 1 on time may not be the most sustainable or efficient mechanisms to support implementation in the long term. Nevertheless, achieving the target of a working list for plant taxa worldwide is a vital first step toward an online flora.

The 2020 Target 1: An Online Flora of All Known Plants

It is important to clearly define what this online flora represents. This will enable potential partners to understand how best they can support work toward the current GSPC Target 1, and it will also facilitate monitoring and identification of gaps in implementation, which can then help further focus activities. For the 2010 Targets set by the COP Decision X/17 (CBD, 2010a), the definition of the first Target was initially provided by a rationale and description, which was then used as a basis for broader stakeholder consultation. Although the 2020 Target 1 has been agreed upon, with all 16 targets discussed at this workshop and the following liaison group meeting in St. Louis (CBD, 2011a), there is still opportunity for broader input from the scientific community who might implement the GSPC and policymakers. The aim here is to look at progress in large regional- or country-level floras to date in conjunction with lessons learned from the first 10 years of GSPC implementation and to identify factors that might assist implementation of Target 1 over the next 10 years.

Progress has been made in several large regional- or country-level floras over the last 10 years (Fig. 1; Table 1). Despite some impressive achievements, resulting in many species accounts being available for incorporation into an online global flora, none of these floristic projects were completed in a 10-year period. Nonetheless, the most impressive rates of progress were seen over the past decade for The Flora of China text series with 70% completion, Flora Mesoamericana with 57% completion, and the Flora of East Tropical Africa (FTEA) with around 34% of the known plant taxa treated. It is apparent that progress in larger regional areas, e.g., the Flora Malesiana and Flora Neotropica, tends to be slower than that in large country-driven projects such as Australia and China or in smaller regions such as the FTEA and Flora Mesoamericana; although, it should also be noted that monographs play an important role in covering plant groups from larger areas such as the Neotropics (Thomas, 1999). However, there is an important difference in the information content of traditional floras or monographs as contrasted with an online flora that meets Target 1 of the GSPC and supports the other 15 specific targets as well as the implementation of the CBD, generally. An online

Table 1. Progress in a selection of regional or national flora projects over the last 10 years. Totals from 2001 are taken from Heywood (2001). Results from 2012 come from editors of the flora projects asked to give totals for the number of species completed (see acknowledgments). Numbers reflect progress as of July 2012. In the New World, the Flora of North America treats plant taxa from the United States and Canada; the Flora Mesoamericana considers plants from Mexico south through Panama, and treatments in the Flora Neotropica extend to the south through Peru, Bolivia, and Uruguay. Plants of the African continent are investigated by the Flora of East Tropical Africa and the Flora Zambesiaca (Botswana, Malawi, Mozambique, Zambia, Zimbabwe, and the Caprivi Strip). The remaining projects treat plant taxa in China and Australasia, with the Flora Malesiana, which includes the following countries: Indonesia, Malaysia, Singapore, Brunei Darussalam, the Philippines, and Papua New Guinea in southeastern Asia.

	Species completed 2001	Species completed 2012	% Complete 2001	% Complete 2012	% Completed since 2001	Estimated total number of species
Flora Mesoamericana	3249	13,412	18%	76%	57%	17,683
Flora of Tropical East Africa (FTEA)	12,104	12,104	66%	100%	34%	12,104
Flora Zambesiaca	5960	8417	57%	80%	23%	10,528
Flora of China	9642	29,232	31%	93%	62%	31,360
Flora of Australia	6369	9452	33%	49%	16%	19,306
Flora Malesiana	8000	11,750	19%	28%	9%	42,500
Flora Neotropica	6237	7715	7%	9%	2%	90,000
Flora of North America	3249	11,004	16%	54%	38%	20,500

world flora that supports CBD implementation will need to present or link to broader information; otherwise, the Target will not support the implementation of the convention (Table 2). Given current rates of completion and requirement for additional information, clearly floristic writing as usual will not provide an online global flora that fully supports the implementation of the GSPC and the CBD by 2020.

Looking Ahead with Hindsight

The GSPC implementation has been reviewed at different times and from different perspectives. Such reviews include the Third National Reports of Parties to the CBD (<http://www.cbd.int/reports/analyzer.shtml>); an in-depth review of the implementation of the GSPC was considered by the Subsidiary Body on Scientific, Technical, and Technological Advice (SBSTTA) at their 12th meeting in Paris in June 2007 (CBD, 2007); and by the Conference of the Parties to the CBD at their ninth meeting (COP IX) in Bonn, Germany, May 2008, as reflected by the decisions arising there (CBD, 2008). This was followed by the CBD Plant Conservation Report issued by the Secretariat of the CBD (SCBD, 2009); and an online consultation and recent review of implementation in botanic gardens (Williams & Sharrock, 2010). The findings of these reviews were compared and contrasted by Paton and Nic Lughadha (2011). The factors found to be associated with successful implementation of the GSPC included: (1) the targets having a clear focus with identified outcomes and a degree of flexibility in how these outcomes were achieved; (2) a core group of stakeholders acting as a community and sharing similar business aims; and (3) a mechanism for monitoring progress and identifying gaps. How might these factors influence development of the online flora of all known plant species?

Focus and Flexibility

As seen in Table 2, a flora traditionally covers a broad range of taxonomic, geographic, and nomenclatural information, yet an online flora that supports other targets of the GSPC (Targets 2, 7, 9–13; cf. Table 2) would cover an even broader range of information. One way to speed up the production of significant regional and country floras as well as The Plant List is to ask what is the minimum requirement for floristic treatments? This might be as simple as the provision of an accepted name of a taxon and its synonymous names to clarify what species exist and then what names have been used historically to recognize the taxon. As the CBD is implemented at a national level, it would be important to include, in a minimal view, country-level distributions so that country inventories could easily feed into and receive information from such an accepted plant name and distribution backbone. Such a minimal backbone for names of known plant taxa and their country-level geography would provide a clear focus for the GSPC Target 1, but also the flexibility to link and add further information to it. A similar approach was recently discussed at the 16th meeting of SBSTTA (CBD, 2012a). Existing descriptions, illustrations, and distributional detail could be linked to a taxon's record without the need for standardized text or

Table 2. Summary of the taxonomic information found commonly in traditional floras. This is contrasted with taxon information required to support implementation of other Targets (2, 7, 9–13)[1] of the Global Strategy for Plant Conservation beyond Target 1, which seeks "an online flora of all known plants" (Convention on Biological Diversity [CBD], 2010a).

Taxon information for traditional floras and Target 1	Additional taxon-level information supporting other targets
Accepted name	Conservation status (Target 2)
Synonyms	Genetic diversity (all Targets)
Description	Economic Use (Targets 11–13)
Identification key	Medicinal use (Targets 11–13)
Illustrations	Invasive potential (Target 10)
Distribution	Trade statistics, nondetriment information for CITES implementation (Target 11)
Relationships	
Phylogeny	Traditional uses (Targets 7, 9, 13)
Literature citations	Common names (all Targets)
Specimen and type citations	

[1] Additional Targets (CBD, 2010a). Target 2: An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action. Target 7: At least 75 per cent of known threatened plant species conserved in situ. Target 9: Seventy per cent of the genetic diversity of crops, including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge. Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded. Target 11: No species of wild flora endangered by international trade. Target 12: All wild harvested plant-based products sourced sustainably. Target 13: Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care.

descriptive language as required by an established, traditional flora format. Other information integral to conservation, such as threat assessment, harvesting information, or a plant's invasive potential, could also be linked to such an initial backbone toward a global flora. An important element of any flora is a key to aid identification. However, keys to plant taxa do not need to operate at a global level. Existing country- or regional-level keys could be linked to a family and genus hierarchy. New and existing keys could be contributed to IdentifyLife (<www.identifylife.org>), thus benefiting from existing information and facilitating other key-building activities.

These elements could build directly on a backbone of scientific names for accepted, known plant taxa such as The Plant List, although a more sustainable system would have to be developed in order to keep the data and links up to date, and an inclusive system of editors would have to be developed to help maintain the system. Currently, The Plant List is static and cannot be edited online. There are successful examples of plant specialist communities maintaining data in online taxonomic systems, for example, the Solanaceae Source (<www.solanaceaesource.org>) and eMonocot (<http://e-monocot.org/>). Not every taxonomic group will have such a broad-based community to support its e-taxonomy, but more open, community-based collaborations will greatly facilitate taxonomic progress (Knapp, 2008) and achievement of the GSPC Target 1.

COMMUNITY SUPPORT: STAKEHOLDERS ACTING AS A COMMUNITY AND SHARING SIMILAR BUSINESS AIMS

The Plant List provides a names backbone, as discussed above, and includes detail from both regional datasets and global datasets. Monographic datasets that treat taxa globally have the advantage of providing a logically consistent view of the taxonomy for any area, whereas regional datasets may differ in their treatment of particular taxa, creating problems when these regional datasets are combined. It is likely that a flora of all known species would be composed of elements derived from both regional and monographic databases. Relatively few new data resources covering single large plant families have been developed over the last 10 years, the exceptions being the Compositae and Melastomataceae as previously mentioned. Ten large plant families that lack comprehensive or global species treatments or a database are shown in Table 3. Several of these larger families with significant taxonomic gaps have portions completed, e.g., in Apocynaceae, but global communities of plant specialists have not yet committed to the support necessary to maintain comprehensive databases for these families. This may be because the involved scientists have narrower taxonomic interests, as in the case of Apocynaceae where the subfamilies Apocynoideae and Rauvolfioideae have been reasonably, completely treated, but Asclepiadoideae, Periplocoideae, and Secamonoideae lag behind (WCSP, 2012). For other large families (cf. Table 3), funding or available specialists

Table 3. Families of vascular plants with over 2500 species that are not yet covered by a global species checklist.

Plant family	Estimated species number
Apocynaceae	4552
Malvaceae	4225
Ericaceae	3995
Apiaceae	3780
Acanthaceae	3500
Boraginaceae	2740
Urticaceae	2625
Ranunculaceae	2525
Amaranthaceae	2500
Lauraceae	2500

have not been available to complete treatments comprehensively across the family, e.g., Amaranthaceae. In other instances, taxonomists may be more interested in geographic or generic levels rather than family ones, as in Ericaceae. In both instances, energy necessary to pull the community together to produce this list has not been provided. Recent experience suggests that there are two means whereby global communities have been catalyzed to come together to produce a global checklist: (1) external funding as in the case of GBIF-funded projects (e.g., GBIF, 2005); and (2) draft electronic checklists being compiled from the literature and existing resources with expert communities then reviewing the list product, as in the case of those families covered by the WSCP (Paton et al., 2008; WSCP, 2012).

Regional- or national-level input into an online world flora will be important not only to fill the gaps among global species databases for particular families, but also to help maintain them and improve their quality. Broad participation will be vital for the long-term success of the GSPC. In terms of the GSPC Target 1 and the production of an online flora, those contributing to it must receive professional recognition for their efforts. The lack of accreditation for those compiling global checklists has been and still is a major barrier to completing a working list of known species (Paton et al., 2008). However, research councils are now considering such impacts as part of their research assessments. Projects such as the European Union–funded Virtual Biodiversity Research and Access Network for Taxonomy (ViBRANT; <http://vbrant.eu/>) focus on the development of virtual research communities involved in biodiversity science and must consider ways in which such online contributions can be recognized by the broader scientific community and funding sources. Objective measures of research impact and the value of contributions to an online flora will be easier to provide if the online flora connects to conservation and sustainable use information essential to those implementing the convention on the ground. Such linkages will boost the use and citations of the online flora and any associated data contributions.

MEASURING SUCCESS

As noted above, having a mechanism to monitor progress toward the target and to identify taxonomic gaps was an important factor in progress toward Target 1's working list prior to 2010. For the GSPC, such general monitoring of progress needs to be linked to the Aichi Biodiversity Targets (<www.cbd.int/sp/targets/>), both to demonstrate how the GSPC supports the strategic plan of the CBD and also to integrate monitoring and reporting with other environmental initiatives (CBD, 2011a). Otherwise, the report burden from different conservation or sustainable management initiatives constitutes a barrier to the acceptance and fulfillment of the targets (CBD, 2010a). The ways in which GSPC Targets support the Aichi Biodiversity Targets have been outlined by the Liaison Group on the GSPC (CBD, 2011a). The GSPC Target 1 is most relevant to the Aichi Biodiversity Target 19: "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied." Just as Target 1 underpins the other 15 GSPC Targets, it is also relevant to many of the other Aichi Biodiversity Targets, and a process is underway to develop indicators for the Aichi Biodiversity Targets. A set of headline indicators has been developed, under which operational indicators or metrics are then organized. The most relevant headline indicator to the GSPC Target 1 being "trends in accessibility of scientific/technical/traditional knowledge and its application" (CBD, 2011b). Underneath this, operational indicators apply at both global and subglobal levels, the most relevant to Target 1 address: (1) "trends in coverage of comprehensive policy-relevant sub-global assessments including related capacity building and knowledge transfer, plus trends in uptake into policy"; and (2) "number of maintained species inventories being used to implement the Convention." This second indicator reflects discussion within the Coordination Mechanism (CBD, 2011d) for the GTI concerning the need to have an indicator that reflected the importance of taxonomy underpinning the CBD and other environmental agreements (CBD, 2011c).

The Aichi Biodiversity Targets and their suggested indicators provide a mechanism for monitoring the implementation and impact of the environmental agreements such as the CBD, and to a less precise extent, to components programs such as the GSPC or GTI. However, to monitor progress and identify gaps in the implementation of the 16 GSPC Targets, more granular measures will be required. Such measures of progress for individual targets should be part of the GSPC tool kit (CBD, 2012b; <http://www.plants2020.net/>) to be developed to support implementation at both national and regional levels (CBD, 2010a). For Target 1, measures to help monitor progress will need to be developed. Such measures should cover:

(1) Taxonomic completeness. Unresolved scientific names should steadily decrease over time and, concomitantly, confidence should build in those names as peer-reviewed taxonomic decisions similarly increase. For example, in The Plant List, there should be a decrease in the number of unresolved names and an increase in the confidence ratings on the placement of names as accepted or synonyms over time.

(2) Links to additional information. As the online global flora develops, the numbers of accepted names with links to additional information necessary to implement the CBD should increase. Such additional information could include plant images, description, geographic distributions, and common names and coverage in taxonomic keys to aid identification. The number of linkages to support other targets of the GSPC could also be measured, e.g., an increasing number of conservation assessments, which would link to the GSPC Target 2, which notes "[a]n assessment of the conservation status of all known plants species, as far as possible, to guide conservation action."

(3) Support and participation. Measurable assessments toward progress of a global flora could be demonstrated by an increase in the number of countries supplying information to an online flora. Also pertinent would be the broadening distribution of contributing taxonomists and other committed individual scientists. As elsewhere in the scientific community, the number of citations of the online flora content would offer measureable progress toward widespread acceptance of the 2020 goal for the GSPC Target 1 toward the accomplishment of an online global flora.

Conclusion

If the online flora is to support GSPC implementation, then this Target 1 must also support conservation and sustainable-use projects at national and local levels, beyond providing or acting as a link to information concerning global plant diversity. To fulfill these functions, the online global flora should be complete and of sufficiently high quality such that information about plants can be found with confidence. Target 1 must link to information of use to those working in conservation and sustainable use at national and regional levels, and an online global flora must be supported by a broad range of stakeholders who can help to maintain and to update its taxonomic and other essential databases. Previous reviews have demonstrated that being able to monitor progress has assisted implementation of the GSPC Target 1 (Paton & Nic Lughadha, 2011), and it will be important to monitor progress using measures such as those detailed above.

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IN VITRO METHODS AND THE CHALLENGE OF EXCEPTIONAL SPECIES FOR TARGET 8 OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION[1]

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ABSTRACT

For the majority of plant species of conservation concern, seed banking and traditional propagation methods are the most efficient ways of meeting the ex situ and recovery conservation goals of Global Strategy for Plant Conservation (GSPC) Target 8. However, there are estimated to be 5000 or more endangered species for which these methods will not be adequate conservation tools. These "exceptional" species are those with recalcitrant seeds or those that produce few or no seeds. In vitro methods can provide alternative procedures for propagating and preserving germplasm in the long term for these species. Research at the Center for Conservation and Research of Endangered Wildlife (CREW) with several U.S. endangered species has shown the potential of these methods. In vitro propagation can provide plants for reintroduction and research when traditional propagation methods are not adequate. Phytotissue banking can be used for long-term ex situ conservation when seed or embryo banking is not possible. In vitro methods are also needed for recovery when embryo banking of recalcitrant seeds is possible. The full implementation of in vitro methods is constrained by information, scientific, and economic challenges, but the need for its use in meeting the needs of exceptional species should provide impetus for overcoming these challenges and making these methods an integral part of an overall ex situ conservation strategy.

Key words: Cryopreservation, ex situ conservation, Global Strategy for Plant Conservation (GSPC), in vitro, tissue culture.

Ex situ conservation has become a major tool for plant conservation. As such, it is one of the major targets of the Global Strategy for Plant Conservation (GSPC). Target 8 states: "At least 75 per cent of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes" (Convention on Biological Diversity [CBD], 2011). This goal is primarily accomplished through seed banking, which, for most species, provides the most efficient method for long-term preservation of multiple genotypes. However, there is a subset of endangered species for which seed banking is not workable, including species with recalcitrant seeds (desiccation-sensitive seeds that cannot survive traditional seed banking protocols) and a significant number of species that produce few or no seeds, or for which seed collection is not practical. Combined, these form a group of unbankable or "exceptional" species that may comprise an estimated 5000 to 10,000 plant species of conservation concern (Pence, 2011a). Because exceptional species are fewer in number than species with available, bankable seeds, and because they require more costly approaches to ex situ conservation, they are more likely to be overlooked as a group. However, these exceptional species are just as likely, if not more so, to hold potential value, since many are components of species-rich and ecologically complex tropical rainforests. Thus, it is important to consider the challenges posed by this group for conservation biologists and to evaluate what is needed for dealing with them.

IN VITRO TOOLS IN EX SITU CONSERVATION AND RESTORATION

Many of the tools available for dealing with the ex situ conservation and propagation of exceptional species include at least some aspects of in vitro culture, and the extent to which this biotechnology is needed will influence the labor and resources required for a particular species (Pence, 2011a, 2011b). For example, excised embryo axes from recalcitrant seeds, such as the endangered Texas wild-rice *Zizania texana* Hitchc. and the common horse chestnut, *Aesculus hippocastanum* L., have been shown to survive rapid freezing in liquid nitrogen (Wesley-Smith et al., 2001; Walters et al., 2002). This allows the cryobanking of multiple genotypes in one sample, as is the case with intact

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seeds. However, this requires the excision of embryos prior to banking followed by the recovery of the embryos using in vitro systems, thereby increasing the input of labor and resources compared with seed banking. Another approach is the cryopreservation of dormant buds in woody taxa, which has been demonstrated with cold-hardy and cold-acclimated tissues (Towill & Ellis, 2008). With some plant species, such as willows (*Salix* L.) and apples (*Malus* Mill.), recovery can be accomplished through bud grafting or direct rooting (Forsline et al., 1998; Towill & Widrlechner, 2004), while in vitro methods have been used in persimmon *Diospyros kaki* Thunb. for post-freezing recovery growth (Matsumoto et al., 2001). If embryo axes or buds of an exceptional species cannot be cryopreserved, tissue banking using in vitro methods may be the more effective route for securing germplasm ex situ.

In vitro tools for conservation and restoration are based on the growth of plant tissues in tissue culture, a flexible technique that can adapt to a variety of needs (George & Debergh, 2008). The primary requirement for ex situ conservation is that plants can be recovered for restoration needs. Shoot propagating cultures and somatic embryo cultures are both capable of producing plants in vitro that can be acclimatized to soil and used for restoration. Shoot tips and embryogenic cultures have also been used for cryopreserving tissues long term in liquid nitrogen (Lombardi et al., 2008; Reed, 2008a), and thus, these have been the primary types of cultures used in conservation efforts.

In vitro propagation protocols have been described for hundreds of plant species, many of which are of economic importance, but some protocols have been developed for endangered taxa, such as several from Australia, Spain, and Hawaii (Bunn, 2003; Gonzalez-Benito & Martin, 2011; Sugii, 2011). In vitro methods can assist plant conservation starting at the point of a taxon's collection. The technique of in vitro collecting can be used to initiate tissue cultures in the field, when seeds or cuttings are unavailable or unworkable (Pence & Engelmann, 2011). In vitro propagation can be used to maintain ex situ collections, as is being done for native Brazilian vascular taxa (Pilatti et al., 2011) and for European bryophytes (Rowntree et al., 2011). Tissue culture can also be used to produce plants for restoration, as has been done with the Autumn buttercup *Ranunculus aestivalis* (L. D. Benson) Van Buren & K. T. Harper and the Cumberland sandwort *Minuartia cumberlandensis* (Wofford & Kral) McNeill. Both are two endangered species in the United States that have been propagated through tissue culture and outplanted in Utah and Kentucky, respectively (Pence et al., 2008a, 2008b). By using in vitro propagated plants, restoration experiments can be conducted without loss of genetic material, since back-up material of each clonally propagated line can be maintained in the lab, either as an active culture or as cryopreserved tissue. This may be particularly useful in seeking out new habitat if assisted migration experiments are undertaken with exceptional species (Vitt et al., 2010).

In vitro cultures can also provide material for cryopreserving tissues for long-term ex situ storage (Engelmann, 2011). While fewer species have been cryopreserved, compared with those propagated in vitro, liquid nitrogen storage has been a valuable tool for maintaining germplasm of rare plant taxa, particularly those classified as exceptional species. Tissue cryopreservation has been vital for the ex situ conservation of the federally listed Todson's pennyroyal, *Hedeoma todsenii* R. S. Irving, from New Mexico, for which seed production has never been observed (Pence et al., 2009). Species management utilizing long-term storage in liquid nitrogen has been effectively used across major plant groups ranging from European bryophytes (Rowntree et al., 2011) to vascular plants under threat in the native Australian flora (Kacmarczyk et al., 2011). Several basic methods are available and cryopreservation appears to be adaptable to a wide range of plant species (Reed, 2008a), although methods often need to be adjusted for particular species and genotypic variations. As with in vitro propagation, work with a related but common species can often facilitate protocol development for rarer species (Turner et al., 2001).

Challenges for the Application of In Vitro Methods

It is clear that in vitro tools allow us to go beyond the limits of traditional seed banking to include exceptional species in conservation efforts, making it possible to include, in theory, almost all plant species within the focus of Target 8 of the GSPC. Work in translating this theory into practice, however, faces at least three challenges.

The information challenge

Fundamental to addressing the needs of exceptional species is the challenge of identifying those species and determining the most effective and efficient methods for their conservation. While it is possible to develop a rough estimate of the number of exceptional species that may exist (Pence, 2011a), identifying them for specific conservation efforts will require at least three levels of information. The first requirement is the comprehensive listing of all plant species set as Target 1 of the GSPC. This has been largely completed with ongoing updates by the Missouri Botanical Garden and the Royal Botanic Gardens, Kew, and can be accessed online (The Plant List, 2010). Second, within this list, species that are of conservation concern must be identified, as defined in Target 2 of the GSPC. Work on this has been conducted on many fronts, as Red Lists have been compiled, often at regional or national levels. The global effort is spearheaded by the International Union for Conservation of Nature and Natural Resources (IUCN, 2011) and is in progress.

Finally, the third need is to define for each endangered species the most appropriate methods for achieving the ex situ conservation and restoration goals of Target 8 of the GSPC. This is the most challenging level of information to acquire, since this requires an evaluation of whether the species can be stored conventionally or is an exceptional species. Some of this information is becoming available as species are described in national or regional lists of endangered plants, such as in the Plant Profiles for the Center for Plant Conservation's (CPC) National Collection of Endangered Plants (CPC, 2012). Information on seed characteristics for both endangered and non-endangered species is also being compiled in the Seed Information Database (Royal Botanic Gardens Kew, 2008). However, because this will depend on having a completed list of endangered plant species and will require the individual evaluation of each of those species, a full listing of endangered exceptional species is not yet available.

Despite this lack of information, many species are already known that fall into the exceptional category, and some of these are known to be endangered (CPC, 2012). Methods for tissue banking have been applied to several exceptional species in this laboratory to examine the logistics and costs of dealing with cryopreserving multiple genotypes for ex situ conservation (Pence et al., 2009; unpubl.). These species include three federally endangered exceptional species: the fourpetal pawpaw, *Asimina tetramera* Small, and Avon Park rattlebox, *Crotalaria avonensis* DeLaney & Wunderlin, which are both found in the state of Florida, as well as Todsen's false pennyroyal, *Hedeoma todsenii*, from New Mexico. Species that are already known as exceptional can serve as models for evaluating and refining methods that can then be applied to the larger group of species, yet to be identified.

SCIENTIFIC CHALLENGES

Plant tissue culture, while firmly based in the science of plant physiology and development, still encompasses a wide range of variability between species and often among genotypes. Developing protocols for species new to tissue culture is normal for those wishing to use in vitro methods for plant conservation. Some species respond easily to commonly used protocols (George & Debergh, 2008), while other taxa may prove recalcitrant to one or more of the steps necessary to culture the plant and return it to ex vitro conditions. Species may be difficult to initiate into culture due to internal contamination, excessive production of phenolic compounds, or unusually slow growth. Shoots may be difficult to root; somatic embryos may not develop into normal plants in vitro; and plants may not acclimatize easily from culture to soil substrates (Benson, 2000; Bunn, 2003; Bunn et al., 2011). All of these may be points of challenge, depending on the species. Even closely related species and genotypes within a single exceptional species can be more or less amenable to the various steps of culture (Reed, 2008b; Uchenda & Reed, 2008). The goal of any in vitro work with an endangered taxon is to efficiently and effectively move it into culture, to preserve plant tissue, and ultimately to propagate plants from in vitro cultures for restoration projects. While this is rarely achieved with ease, there are species that can serve as models for directions that researchers might explore in dealing with more difficult species.

Species of *Saintpaulia* H. Wendl., or African violets, are endangered in their native habitat of southern Kenya and northern Tanzania (Eastwood et al., 1998), despite the fact that *Saintpaulia* hybrids are common worldwide as houseplants. *Saintpaulia* is easily propagated, even without tissue culture intervention, but in vitro propagation can provide plants free from pests and diseases that might be more suitable for restoration projects than conventionally propagated plants. In vitro cultures can also provide material for tissue cryopreservation and banking when seeds are not available at the time that a wild habitat site is visited. *Saintpaulia* leaves will survive several days of common postal transport or courier, and thus, leaves can be collected and sent to a distant lab for culture. *Saintpaulia* shoots can be regenerated from leaf tissue using several media formulations. These shoots root easily in culture and the resulting plants acclimatize readily (e.g., Cooke, 1977; Mithila et al., 2003; Khan et al., 2007). Shoot tips from in vitro cultures of commercial cultivars of *S. ionantha* H. Wendl., originally native to Tanzania and Kenya, have been shown to survive three of the standard cryopreservation protocols (Moges et al., 2004). Normally, one of the most labor-intensive steps in shoot tip cryopreservation is the dissection of the many small shoot tips needed. However, with *Saintpaulia* on some hormonal combinations, many small buds form as clusters on the cut margins of cultured *Saintpaulia* leaves. We have found that shoot clusters can be scraped from the leaf surface with a scalpel, cut into smaller pieces, and then subjected to cryopreservation procedures. While each meristem is not completely delineated in this system, the growing points are small enough and numerous enough to provide material that can survive liquid nitrogen exposure and later regrow (Fig. 1). Such a system greatly reduces dissection time and, consequently, the labor involved in cryopreservation protocols. The ability to manipulate growth in vitro in other species to provide similar tissue for cryopreservation could help facilitate the ex situ conservation of exceptional species.

An approach that has been commonly used when dealing with new species in culture is to use information from the culture of related, but non-endangered species to guide the development of new protocols. This approach was used in recent work with four endangered oak (*Quercus* L.) species from the United States. Methods used in other laboratories to initiate cultures and produce shoots and somatic embryos with several nonthreatened species ultimately proved successful with three of four species tested that were new to culture, *Q. arkansana* Sarg., *Q. boyntonii* Beadle, and *Q. georgiana* M. A. Curtis (Kramer & Pence, 2012). However, this approach may not always be possible, as many endangered species do not have congeners that have been grown in vitro, and families with high numbers of endangered species have not always been prioritized for in vitro studies (Pence, 2011b). Other avenues could also prove helpful. Natural adaptations have been recognized as an important consideration in developing cryopreservation protocols (Benson, 2008), and these may also prove to be important in developing in vitro propagation protocols for species new to culture.

The Challenge of Costs

The third major challenge for efforts directed at meeting Target 8 for exceptional species is the cumulative cost, a factor closely linked to the information and scientific challenges described above. This subject has been discussed in more detail elsewhere (Pence, 2011a), but in general, labor is the primary cost for protocols involving in vitro methods. While the costs are always likely to be higher than seed banking and traditional propagation methods, the more readily a species is initiated into culture, cryopreserved, and propagated, the less expensive those efforts will be. Information on the requirements of individual species is also critical, as different exceptional species will require varying levels of attention. For example, species that can be banked as isolated embryos will avoid the costs of initiating an in vitro culture before cryopreservation and will include multiple genotypes in a single banking exercise. Species requiring tissue banking must be initiated into culture, cryopreserved as multiple genetic lines, and recovered in vitro, thereby increasing efforts and costs. However, once banked, maintenance costs for tissues or embryos in liquid nitrogen are lower than maintaining species as active in vitro cultures or in living collections and do compare favorably with seed banking (Epperson, 1997; Reed et al., 2004; Keller et al., 2008; Li & Pritchard, 2009).

Meeting the increased costs of propagating and preserving exceptional species will benefit from multiple levels of collaboration and coordination. Academia, nonprofit organizations, government, and industry all have expertise and infrastructure that might be utilized in meeting Target 8 for exceptional species by contributing to basic research, protocol development, and actual banking or propagation activities. Over the long term, the cost of banking and maintaining endangered exceptional species ex situ will be significantly lower than the costs of comparably maintaining ex situ living collections of endangered animals, but the costs for exceptional species as a group will likely be measured in millions of dollars (Pence, 2011a). The challenge of these costs will best be minimized by creatively using multiple partners, coordinating information and effort, harnessing basic research, and leveraging monetary funding with in-kind support.

Conclusions

Exceptional species, or those without bankable seeds, pose a significant challenge to meeting Target 8 of the GSPC. Representing perhaps 5% or less of all endangered species, the goal in Target 8 of "at least 75 per cent of all threatened plant species in ex situ collections," and "at least 20 per cent available for recovery and restoration programmes" (CBD, 2010; Sharrock et al., 2010) could be met by not including any exceptional species. However, the worth of a species to humankind and to the environment cannot be determined by its ability to conform to traditional ex situ conservation methods.

Figure 1. —A. *Saintpaulia* plant growing in Tanzania. Photo by Johanna Kolehmainen. —B. Adventitious buds of *Saintpaulia ionantha* H. Wendl. subsp. *rupicola* (B. L. Burtt) I. Darbysh. forming on leaf cultured in vitro. —C. Cryopreserved buds of *S. ionantha* subsp. *grandifolia* (B. L. Burtt) I. Darbysh. growing into small plants on recovery medium. This culture was from African violet stock that originally came from Tanzania. Images taken by V. C. Pence at the Center for Conservation and Research of Endangered Wildlife (CREW).

Thus, consideration needs to be given to what resources and approaches are needed to include highly threatened exceptional as well as conventional species in efforts to achieve Target 8.

This challenge needs to be met by the use of alternative tools, including in vitro methods, but will require information that identifies the needs of particular species for these tools. The effective use of in vitro methods will also require further research into the basic science of manipulating plants in tissue culture as well as the development of coordinated collaboration between multiple partners with complementary skill sets, in order to most effectively and efficiently utilize existing expertise and infrastructure. These challenges are significant, but the need for conserving all endangered plant species mandates that they be addressed. By identifying and understanding these challenges, they will be more easily evaluated and integrated into strategies for the ex situ conservation and restoration of all rare plant species into the future.

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LESSONS FROM THE CONSERVATION ASSESSMENT OF THE SOUTH AFRICAN MEGAFLORA[1]

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Abstract

South Africa has the world's richest temperate flora, with 20,456 indigenous vascular plant taxa recorded. With the current estimate of the global flora at 379,881 taxa, 5% of the world's plant diversity is represented within South African borders. Between 2004 and 2008, South African botanists completed a comprehensive assessment of the status of the South African flora using the International Union for Conservation of Nature and Natural Resources (IUCN) Red List categories and criteria, version 3.1. South Africa is the first floristically megadiverse country to fully assess the status of its entire flora and to achieve Target 2 of the Global Strategy for Plant Conservation (GSPC): "[a]n assessment of the conservation status of all known plant species, as far as possible, to guide conservation action." Herein, we discuss the critical success factors that allowed an assessment of such a megadiverse flora within five years. Establishing a centralized team of ecologists to develop Red Lists, collaborating with a wide range of botanical experts, streamlining the assessment process via automation, and establishing a data management system that served local conservation needs were crucial to the success of the project. Utilizing the IUCN categories and criteria proved to be, and is suggested as, the most cost-effective measure for other megadiverse countries wanting to achieve Target 2. Quantitative assessments can be done with minimal data, and comprehensive assessments of all known taxa ensure conservation attention for a greater proportion of a flora. The example of South Africa demonstrates that conservation assessments can be done relatively cheaply in developing megadiverse countries (less than $30 per taxon for South Africa). As megadiverse countries have high numbers of endemic plant taxa, it is well worth the investment by IUCN and conservation donors to support continued and future assessment projects.

Key words: Conservation assessments, Global Plant Conservation Strategy Target 2, IUCN Red List, South African flora, threatened species.

There is a global imperative to assess the conservation status of plant species to improve and measure conservation efforts. Currently, vascular plants worldwide are poorly represented on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species (Krupnick et al., 2009; Stuart et al., 2010), and only 15,190 or 4% of the estimated 379,881 vascular plant species worldwide (Paton et al., 2008) have been included in the list. Such low representation makes it difficult to use plant assessments as meaningful indicators of biological diversity. There is an increasing need for such measurable indicators in order for Red Lists to assess national and global targets for conservation and sustainability. The United Nations Environment Programme (UNEP) utilizes the IUCN Red List to measure progress toward its Millennium Development Goal 7, which is tasked to ensure environmental sustainability and thereby reduce biodiversity loss. Similarly, Target 12 of the Aichi Biodiversity Targets (2011–2020) of the Convention on Biological Diversity (CBD) also depends on conservation assessments, with the goal that by 2020 the extinction of known threatened species has been halted and their conservation status, particularly of those most in decline, has been improved and sustained (CBD, 2010a).

The Global Strategy for Plant Conservation (GSPC), which was adopted by Parties to the CBD in 2002, and revised in 2010 for a further 10 years (2011–2020), lays out a strategy for plant conservation. One of the 16 quantitative targets to be achieved by 2020 is Target 2: "[a]n assessment of the conservation status of all known plant species, as far as possible, to guide conservation action" (UNEP, CBD, 2010b; Wyse Jackson & Sharrock, 2011). To date, relatively few parties have made progress toward achieving this target (Secretariat of the CBD, 2009). A number of the other targets for the strategy depend on knowing which plants are threatened,

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especially Target 5, "[a]t least 75 per cent 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 7, "[a]t least 75 per cent of known threatened species conserved in situ," and Target 8, "[a]t least 75 per cent of threatened plant species in ex-situ collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes" (UNEP, CBD, 2010b, <http://www.cbd.int/gspc/targets.shtml>). Greater progress is needed in plant assessments in order to approach and to achieve the GSPC targets.

Between 2004 and 2008, South African botanists completed a comprehensive assessment of the status of the South African flora using the IUCN Red List categories and criteria (IUCN, 2001; Raimondo et al., 2009). South Africa is among 17 floristically megadiverse countries that collectively hold 70% of the world's species diversity (Mittermeier et al., 1997). South Africa is the first among these countries to comprehensively assess its vascular plant flora and to achieve Target 2 of the GSPC.

South African Plant Conservation

South Africa has the world's richest temperate flora, with 20,456 indigenous vascular plant taxa recorded (Raimondo et al., 2009). With the current global estimate of 379,881 taxa (Paton et al., 2008), 5% of the world's plant diversity lies within South African borders. In addition, the extraordinary level of vascular plant endemism, with ca. 13,265 taxa representing 65% of the flora, is singular and internationally recognized. South Africa is one of only two countries in the world that has three of the world's 34 biodiversity hotspots within its borders, namely the Cape Floristic Region (6210 endemics), the Succulent Karoo (2439 endemics), and the Maputaland-Pondoland-Albany Region (1900 endemics; Mittermeier et al., 2005). South Africa is indisputably a custodian of a significant store of the world's flora, both in terms of diversity and endemism. Monitoring the threat status of this extraordinary flora and ensuring its effective conservation is, therefore, a high priority.

South Africa has a centralized institution for biodiversity monitoring in The South African National Biodiversity Institute (SANBI), which is an independent entity linked to the Department of Environmental Affairs. SANBI is responsible for generating and disseminating information on the nation's biodiversity, and its findings are used to guide national conservation legislation and policy. As part of its mandate under the National Environmental Management: Biodiversity Act (NEMBA, 2004), SANBI must monitor and report on the conservation status of species and ecosystems. As a result, SANBI coordinates assessments of the conservation status of South African plant and animal species using the IUCN Red List categories and criteria. This builds on a long history of using the IUCN Red List system, where assessments of plant taxa date back to 1980 (Hall et al., 1980). Subsequent updates (Hilton-Taylor, 1996a, 1996b, 1997; Golding, 2002; Raimondo et al., 2009) have all utilized the IUCN Red List criteria of the time.

South Africa is fortunate among megadiverse countries to have a disproportionably high level of capacity in terms of taxonomic expertise and field botanists. The majority of the flora has received taxonomic treatment, with 62% of plant taxa having been revised since 1970 (Von Staden et al., 2013). In addition, a network of 20 local herbaria across the country house a representative sample of plant specimens, with the majority of specimens (90% of the country's ca. 3,263,200 plant specimens) concentrated in only six herbaria (BOL, GRA, NBG, NH, NU, PRE; National Research Foundation [NRF], 2011), three of which are managed by SANBI. Good electronic data in the form of digitized herbarium specimens and spatial layers for vegetation classification and national land use exist (Mucina & Rutherford, 2006), and 44% of South Africa's plant specimens have been electronically encoded (NRF, 2011). Most of these specimens are georeferenced to at least a quarter-degree square grid. This richness of taxonomic literature and electronic specimen and land-use data, combined with expert knowledge, enabled assessments to be carried out that satisfy the data requirements of the IUCN Red List categories and criteria.

Critical Success Factors

Critical success factors that allowed a large flora of over 20,000 plant taxa to be assessed within five years include a core team to coordinate and conduct Red List assessments, extensive collaboration with the local botanical conservation community, and the development of a data management system that serves local conservation needs.

Establish a Red List Team to Conduct Assessments

South Africa is one of a few countries with a team employed specifically to conduct IUCN Red List assessments. This team collaborated with an extensive network of 169 professional and amateur botanists from across the country to obtain information for plant taxa. While conducting the threat assessments between 2004 and 2008, the team consisted on average of one project manager, three ecologists, and two support staff (e.g., student interns). A dedicated Red List team is considered essential for processing a large number of assessments as it reduces the need to train a large number of expert contributors in the use of the IUCN Red List system, which is complex and takes time to master. A small team of experienced staff can process a large number of assessments far faster than a large group of botanical experts dedicating their time toward threat assessments on a voluntary and part-time basis. The South African strategy delegated the core IUCN Red List team to host workshops and conduct interviews with taxonomic experts to efficiently obtain information not available in the literature or in electronic datasets. Although the IUCN Red List system is quantitative and objective, giving the responsibility of completing threat assessments to many different expert contributors results in inconsistent assessments, due to variation in precautionary and evidentiary approaches to listing among experts. A dedicated IUCN-trained team ensures consistency in the way the criteria are applied across different taxonomic groups. As with any large flora, at any given time there are many plant groups that are not receiving taxonomic attention, and, therefore, no botanical experts are available to do assessments for these groups. In such cases, the available botanical literature and taxonomic revisions need to be processed. Dedicated IUCN-trained Red List staff can focus on such plant groups. It is essential that scientists employed to do Red List assessments understand plant life histories and the response of plants to prevalent threats in different ecosystems. Field experience and a sound understanding of ecological characteristics of different habitats are also essential. IUCN Red List assessments are often undertaken by taxonomists, but in the South African experience, having a team of mostly ecologists working with taxonomists provided greater consistency in the interpretation of the environmental and biological parameters used to determine Red List status.

Although all South African assessments were done by SANBI Red List staff, it was absolutely vital to the success of the project that assessments were not done in isolation, and extensive collaboration with the local botanical conservation community was necessary. The Red List team acted as a central point through which the South African conservation community was involved in the listing process. The data informing the South African Red List were compiled with input from 169 professional botanists, taxonomists, conservationists, as well as amateur plant enthusiasts. These experts contributed a large volume of vital information not otherwise available in literature or spatial datasets. Whether or not the experts had extensive and recent field experience made the greatest difference to the value of the data they were able to contribute. Experts were consulted via workshops that focused either on plant families, particular plant groups, taxa of special interest (e.g., succulents, medicinal plants), or regional floras. Individual interviews were also held with experts throughout the duration of the assessment process. Collaboration with botanists based at local herbaria and academic and conservation institutes not only resulted in obtaining valuable IUCN Red List data, but also led to significant and widespread acceptance of the Red List as an important conservation tool. The IUCN Red List has subsequently been applied in many conservation initiatives, including the 2012 update of important legislation such as the list of Threatened and Protected Species on South Africa's Biodiversity Act (NEMBA, 2004).

STREAMLINE THE ASSESSMENT PROCESS VIA AUTOMATION

Electronically accessible herbarium specimens have been widely recognized as a useful resource whereby to conduct assessments of plant species (Schatz, 2002, 2009; Hernández & Navarro, 2007; Brummitt et al., 2008; Krupnick et al., 2009). Typically for countries with large floras, many plant taxa will be widespread and not threatened and the time spent assessing such common species should be minimized. In order to efficiently assess the large number of plant taxa that occur in South Africa, the assessment process was automated for widespread and common species. Electronic specimen data were used to automatically assign 9387 widespread taxa into the IUCN category of Least Concern (LC). Electronic specimen data were also used to prioritize 6000 taxa of restricted distributions that had never been assessed before, and these were targeted for further investigation. Based on this experience, the use of electronic specimen data is recommended as a first step in threat assessment to distinguish those species that are clearly widespread, abundant, and unlikely to be in danger of extinction from those species of lesser extent that need further investigation. This process focuses assessment resources on those plant species for which there is a greater likelihood that they could be threatened.

DEVELOP A DATA MANAGEMENT SYSTEM THAT SERVES LOCAL CONSERVATION NEEDS

When assessing a large number of species, a well-designed data management system can be a vital time-saving device. The IUCN promotes the use of their Species Information Service (SIS) as a suitable data management portal for conducting assessments. This SIS system was developed at the same time that South Africa was assessing its flora, and one of the consequences is that South Africa developed its own relational database purposefully compatible with the SIS. Thus, we can compare the relative benefits of the IUCN SIS system from the time of the 2009 South African assessment with the local database in order to assess a large number of plant taxa from any area within the flora of a megadiverse region. The SIS system was developed to facilitate online assessment by IUCN specialist groups, where scientists working simultaneously on assessments may be based in a wide range of locations. In contrast, the South African assessments were conducted by a centralized team so the database did not need online capabilities and was constructed to interface with existing data sources in the country. For example, taxonomic information, such as scientific names, plant life history traits, and countries of occurrence, were automatically imported from South Africa's National Herbarium Computerized Information System (PRECIS), which saved significant time. Speed of data capture and ease of navigation are critical factors for allowing rapid completion of threat assessments. The SIS system allows for a large amount of data to be captured as part of the assessment process that may be relevant to species conservation but not necessarily critical in justifying categorization. Not only is completing the many data fields time consuming, but navigating through the associated forms can also significantly delay the completion of assessments. The South African approach was to select only a very limited number of critical data fields that could be displayed on a single form or screen view, and complete only those data fields for each species assessed, thereby allowing the completion of a large number of assessments within a short timeframe. SIS has recently made available the option to construct custom data views according to users' preferences and has improved ease of database navigation; however, allowing bulk data importing is still under review consideration.

The online SIS system constrains data held by the IUCN, such that this information is accessible only through IUCN-defined query protocols and is thus either not available or adaptable to answer novel and evolving local conservation questions. South Africa's threatened species database is more flexible, having been designed to serve local conservation needs, e.g., to provide the lists of species requiring protection from national and provincial conservation legislation as well as informing which species and even subpopulations to include as biodiversity targets in conservation plans.

The IUCN SIS is an international system, and, therefore, data capture options to support threat assessments are generalized and not adaptable to local data needs. In South Africa, not all data were captured as specified by the IUCN; instead, what was nationally required took precedence. For example, the IUCN's habitat classification system is too coarse for local requirements. Three of South Africa's nine major vegetation biomes comprise the Succulent Karoo, the Nama Karoo, and the Albany Thicket, which all fall under the IUCN's classification of Subtropical/Tropical Dry Shrublands. Data more locally appropriate for South Africa were captured, yet compatibility with SIS was maintained so that data could still be provided in the required format to the more globally relevant IUCN Red List.

Spatially georeferenced data for subpopulations of threatened species in South Africa turned out to be the single most useful dataset generated as part of the assessment process. It allowed for subpopulation distribution information to be intersected with other spatial information, such as vegetation maps or maps of protected areas, and this facilitated the automation of a large volume of the supporting data required by the IUCN. Other assessment projects for plants, including threat assessment of Madagascan and Hawaiian endemic plant families, have also relied heavily on georeferenced data (Schatz, 2002; Krupnick et al., 2009, respectively). In addition, spatial data associated with subpopulations is highly useful for informed conservation planning (Hoffman et al., 2008). The South African Red List database has been designed to capture spatial data associated with subpopulations. However, the IUCN SIS system does not currently have this capability.

Lessons Learned

(1) *Invest in using the IUCN system.* The latest version of the IUCN Red List categories and criteria is a quantitative, objective system that can be consistently applied across a range of taxonomic groups worldwide. The quantitative criteria are based on scientific studies of populations among many different species; these criteria also apply to the biological conditions under which they are highly likely to go extinct (Mace et al., 2008). The quantitative nature of the system demands that assessments be justified by supporting data that indicate how a species meets the conditions for inclusion in the threat category in which it is listed. This results in a high degree of transparency in the listing process. South Africa has found it valuable to

use the IUCN system because the Red List assessments for a number of species under threat have been legally challenged. This typically occurs when infrastructure, agriculture, or other developments are halted as part of the Environmental Impact Assessment process due to the presence of threatened species. The fact that the IUCN system is objective and scientifically based and is widely used internationally has meant that assessments for threatened plant species have been successfully defended. For example, a development that would have destroyed a subpopulation of the orchid *Brachycorythis conica* (Summerh.) Summerh. subsp. *transvaalensis* Summerh., an Endangered Red List taxon, was halted in 2011 in Gauteng Province, South Africa.

Further, the quantitative nature and transparency of the IUCN system enables more meaningful conservation decisions that are based not only on the threat category a species is listed under, but also on the different reasons a species may qualify as being in danger of extinction. In using the IUCN Red List, South African conservationists were able to consider how the threat criteria under which a species qualified could be used to recommend conservation actions or to set conservation targets. In conservation plans, for example, biodiversity targets for species vary by the threat category and also by criteria under which a species has been listed (Pfab et al., 2010). Similarly, guidelines dealing with threatened plant species in Environmental Impact Assessment reports are based not only on species status, but also on the qualifying criteria (Driver et al., 2009).

One of the perceived disadvantages of the IUCN system is that it is data intensive and, therefore, too time-consuming to complete large numbers of threat assessments for taxa within a reasonable time (Brummitt et al., 2008; Schatz, 2009). However, the quantitative and data-intensive nature of the IUCN Red List process was for South Africa one of its greatest advantages. The value of the data obtained as part of the threat assessment process for strategic, informed conservation decision-making outweighed the effort in capturing it. It became apparent that the problem with evaluating a plant species against the IUCN Red List criteria was not necessarily the amount of data required, but rather that resources were required to comply with the IUCN documentation requirements, i.e., the documentation required when an assessment is lodged with the IUCN. Many of the current documentation requirements for the IUCN have been developed to support analyses of the Red List database and are not necessary for reporting on the state of biodiversity at the international level, or for guiding conservation at the local level. South Africa has not submitted a full set of data for all species to IUCN, but instead has submitted only a minimum set of supporting data justifying the classification of plant species against threat criteria. A strict focus on a minimum set of supporting data is one of the main reasons it has been possible to assess 20,456 plant taxa within five years. The IUCN is currently reviewing the minimum data requirements partly on the basis of lessons learned from the South African plant assessment process.

Where the IUCN Red List system does not meet all local conservation needs, it is possible to augment it for national purposes without compromising its capability to be an effective international biodiversity monitoring tool. Because the IUCN system is focused entirely on determining a taxon's risk of extinction, it is less effective for prioritizing all taxa in need of conservation action. South Africa has a high number of range-restricted or rare endemics that are of high national conservation priority. However, if populations of such taxa are not declining, then the IUCN system would classify them with widespread and abundant taxa as Least Concern (LC). To address this, additional categories for highlighting taxa of conservation concern that were not detected by the IUCN system were developed for use in national conservation (Raimondo et al., 2009). For example, plant taxa known from only one subpopulation in South Africa but which face no threats were listed under the national category Critically Rare. Species that are listed according to this additional category appear on the South African national Red List but are classified as LC when the threat assessments are submitted to the IUCN Red List.

(2) *Quantitative assessments can be done with very little data.* Like many megadiverse countries, South Africa has many plant taxa that are poorly known. An estimated 38% or ca. 7000 taxa have outdated or no taxonomic treatment (Von Staden et al., 2013), and 26% or 5505 taxa have fewer than five specimens represented in the National Herbarium. Despite this lack of good data, it was possible to assign all South African plant taxa to one of the IUCN categories. Most assessments were desktop assessments done with only three basic information resources: taxonomic literature, electronic herbarium specimen data, and spatial land cover data. In South Africa, threatened plant species tend to be concentrated in specific areas where high levels of endemism coincide with high levels of threat, especially impacts of land use. Many plant species with similar distribution ranges and habitats are thus facing similar threats. Experienced assessors were able to

use their knowledge from assessing well-known species to infer the status of poorly known species from similar regions and habitats. Understanding the impact of local threats on particular life histories and ecological processes was central to this process. Because there is no monitoring data or recent field information available for most South African plant species, a civil society volunteer programme was established to gather information for the Red Listing process. This volunteer programme (the Custodians of Rare and Endangered Wildflowers) worked synergistically with the assessment process by prioritizing threatened, but poorly known species for field surveys (SANBI, 2012). Field data collected by volunteers were successfully used to either confirm the Red List status or to correct erroneous classifications of these previously poorly known species.

Brummitt et al. (2008) note that the majority of species listed on the IUCN Red List have been conducted by IUCN specialist groups with extensive field knowledge. They promote an approach to increase the number of plant taxa on the Red List, similar to that used in South Africa, in which non-experts conduct desktop assessments. Brummitt et al. (2008) specify that assessors need to have a thorough understanding of the IUCN categories and criteria, access to a database of georeferenced specimen collections, and some basic geography information system (GIS) knowledge. Our experience supports this approach as a practical way to assess large floras. However, a vital addition is that assessors need to have a sound understanding of the interactions between local threats and plant life histories and ecological processes in the region of assessment. In the South African assessment, this understanding was gained largely through extensive interaction of Red List staff with botanical experts, ably supplemented by the practical field experience of threatened plant surveys obtained through the Custodians of Rare and Endangered Wildflowers Programme.

(3) *Costs and cost-saving recommendations.* The South African Red List cost $593,291 to assess 20,456 taxa, at an average cost of $29 per taxon. This is relatively inexpensive when compared to other regional assessment projects. The Pan-Africa Freshwater Biodiversity Assessment that assessed 5000 taxa from a range of taxonomic groups cost $383.87 per taxon (W. Darwall, unpubl. data), whereas the European Red List, which assessed 5600 taxa also from varying taxonomic groups, cost $239 per taxon (M. Biltz, unpubl. data). Other estimates of the cost of conducting plant assessments have been as high as ca. $440 per taxon (Stuart et al., 2010), but the cost of the South African assessment was closer to the costs typically incurred when there is a large volunteer contribution. For example, the Global Cycad Conservation Status assessment, conducted by the IUCN Species Survival Commission (SSC) Cycad Specialist Group, cost ca. $26 per taxon (J. Donaldson, unpubl. data). In the case of the cycad assessment, the volunteer contribution has not been estimated, which emphasizes the low real cost associated with the South African Red List assessment. An assessment of selected plant families in Madagascar cost under $30 per taxon (Schatz, 2009). We thus predict that assessments of plants in other developing countries with megadiverse flora and fauna could also be done at a similar, reasonable cost. As megadiverse countries have high numbers of endemic plant taxa, it is worth the IUCN and conservation donors investing in supporting assessment projects in these countries in order to cost effectively increase the number of plant taxa on the IUCN Red List.

The approach adopted in South Africa meant that threat assessments of widespread and common species were automated, and only taxa that were of potential conservation concern were assessed in detail. In total, 12,044 South African plant species received focused attention. The cost of assessing these taxa of potential conservation concern decreased with time (Table 1), changing from $158.25 in the first year of assessment (2004) to $39.72 in the final year (2008). This change in cost was due to experience gained by assessors over the course of the project, which decreased the amount of time needed to assess each species. There is, therefore, a financial incentive to invest in a team of assessors when assessing a large number of taxa that may take several years to complete.

Consultation with experts was pivotal to the success of the South African Red List project and involved a combination of workshops and interviews. It was financially more efficient to assess species via interviews with individual experts than via workshops (Fig. 1), because in a large flora botanists tend to have specialized knowledge either of a certain region of the country or of a particular taxonomic group. As a result, there was little or no added value gained from bringing experts together, as expert knowledge seldom overlaps. However, some groups, such as medicinal plants, did require assessment via workshops because the impact of harvesting on populations needed to be debated with a range of the knowledgeable experts.

(4) *Comprehensive assessments ensure conservation attention for greater proportion of flora.* All previous Red Lists conducted in South Africa evaluated only a small proportion (less than 20%) of the indigenous

Table 1. Break down of staffing and costs of the South African Red List programme.

	2004	2005	2006	2007	2008
No. of support staff (e.g., student interns)		2	3		
No. of junior ecologists employed	1	3	5	1	1
No. of ecologists with over five years experience	1	2	1.5		1
Project manager	1	1	1	1	1
No. of expert consultants contracted	1		2	1.5	0.5
Total number of staff	4	8	12.5	3.5	3.5
Financial cost of staff	$80,506.33	$156,708.86	$206,075.95	$59,493.67	$76,708.86
Workshop expenses	$0	$3037.97	$2911.39	$1012.66	$1265.82
Expert interviews	$835.44	$278.48	$2227.85	$1392.41	$835.44
Total cost (U.S. $)	$81,341.77	$160,025.32	$211,215.19	$61,898.73	$78,810.13
No. of assessments conducted	514	3462	4537	1547	1984
Cost per assessment	$158.25	$46.22	$46.55	$40.01	$39.72
Total cost of project	$593,291.14				

flora. As a result of the first comprehensive assessment of all 20,456 taxa, 10% or 2045 taxa of conservation concern were added to the Red List for the first time. Of these, 942 were taxa threatened with extinction. The majority of these were historically of conservation concern but were never previously assessed (Fig. 2A). Many threatened taxa and other taxa of conservation concern are overlooked when only selective assessments are done. For example, one of South Africa's most threatened plant genera is *Marasmodes* DC. (Asteraceae). The six cryptic species in this genus were never all evaluated in a South African plant Red List before, even though they are all restricted historically to extensively transformed habitats and are all on the brink of extinction. The urgent conservation needs of the majority of the species in this genus were identified for the first time through this comprehensive assessment and resulted in an annual monitoring effort for the six described *Marasmodes* species as well as the discovery of four undescribed species. An argument often used against comprehensive threat assessments for plant conservation is that it is a waste of effort to try and assess all species when most are too poorly known to obtain enough data to measure against the criteria. Conducting a comprehensive assessment has allowed South Africa to identify the major gaps in botanical knowledge and has led to the prioritization of taxonomic research (Von Staden et al., 2013).

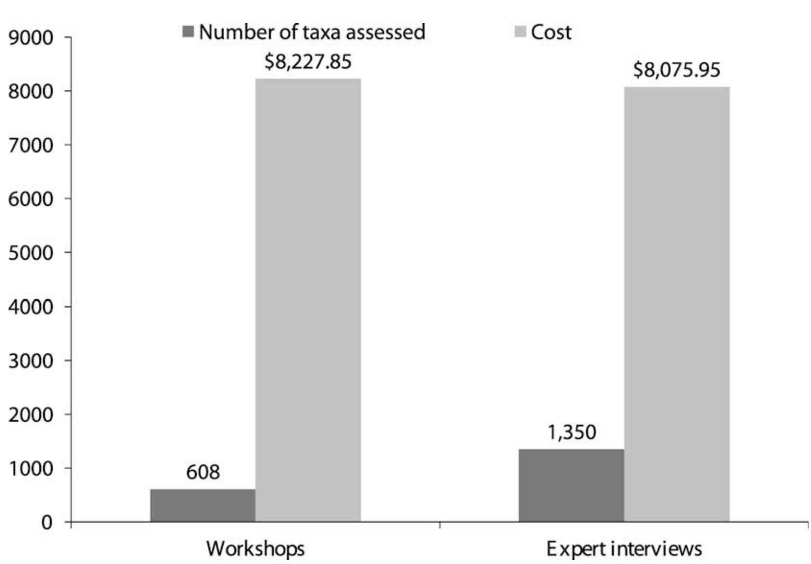

Figure 1. The total relative costs of conducting workshops or expert interviews are compared to the number of plant taxa assessed for South Africa via each of these approaches.

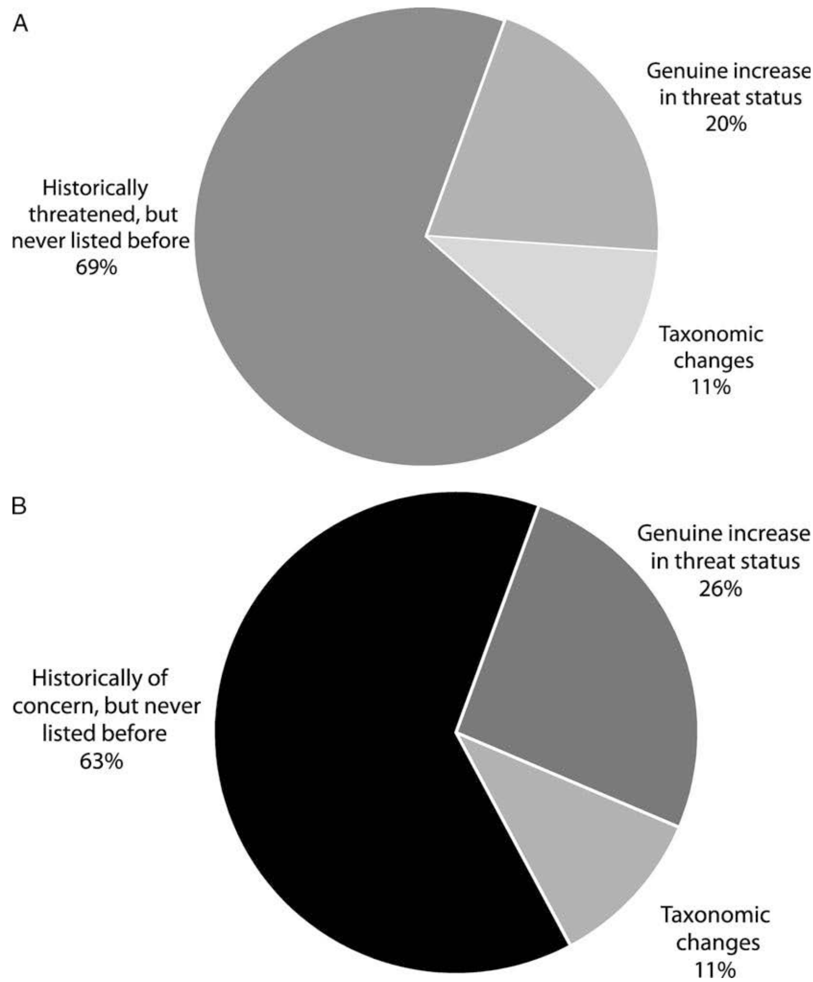

Figure 2. —A. Rationales for the addition of 942 taxa to categories of threat on the South African Red List for the first time. —B. Rationales behind the addition of 2045 taxa of any conservation concern to the South African Red List for the first time. Assessments follow the IUCN categories and criteria, version 3.1.

When comparing the proportion of threatened taxa in South Africa to those in other megadiverse countries, the impact of substantive assessment programmes becomes clear. South Africa, like other megadiverse countries that have conducted IUCN assessments of endemic taxa, has a high proportion (greater than 10%) of taxa that are threatened (Fig. 3). Other megadiverse countries such as Australia (20,148 plant taxa) and Brazil (35,107 plant taxa) that have not yet undertaken substantive assessment programmes have identified far lower proportions of their floras as threatened, only 4% and 6%, respectively (see Fig. 3) (Griffin & Hilton-Taylor, 2008; Chapman, 2009; Forzza et al., 2010, <http://floradobrasil.jbrj.gov.br>).

Conclusion

The South African experience shows that it is possible to assess a large group of plant taxa, such as the flora of a megadiverse country, using the global standard of the IUCN Red List system. The lessons learned from this process should inform the approaches adopted by other megadiverse countries as these will confer cost savings on similar projects and can help to make the Red Listing process more meaningful for local conservation action. Overall, the Red Listing process has had a positive impact on conservation efforts and is enabling South Africa to report against global targets for conservation and sustainability, such as those required by UNEP (Millennium Development Goals) and the CBD. As a

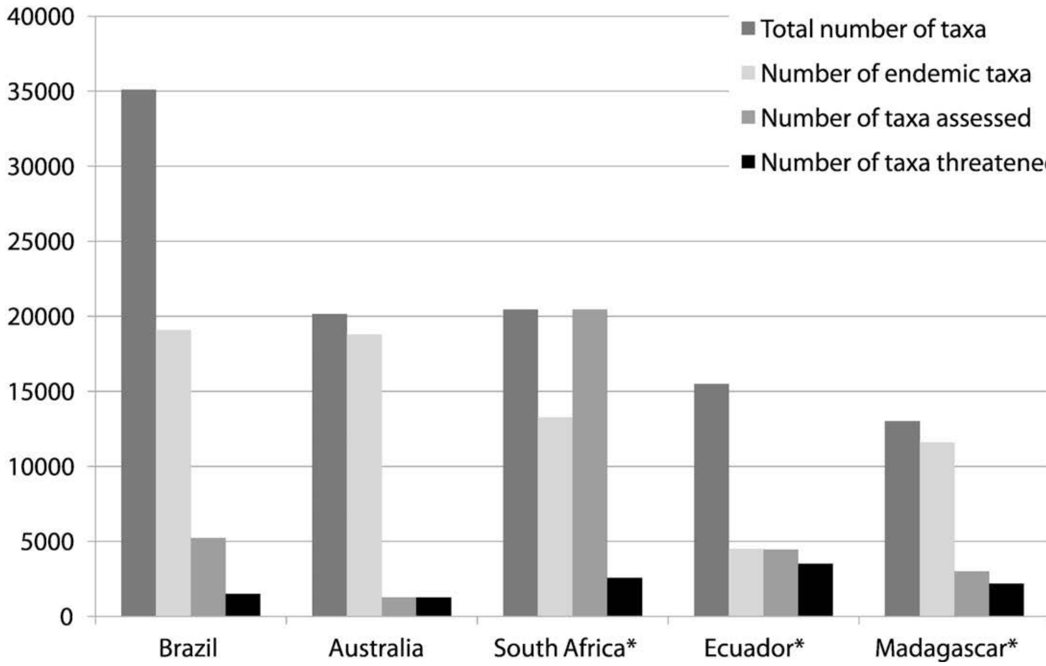

Figure 3. Taxonomic comparison of the five megadiverse countries: Brazil, Australia, South Africa, Ecuador, and Madagascar. Assessments in South Africa, Ecuador, and Madagascar (marked by asterisks, *) follow the IUCN categories and criteria, version 3.1. Data were obtained from Chapman, 2009 (Australia); Floradobrasil, 2010 (Brazil); Griffin & Hilton-Taylor, 2008 (IUCN); Groupes des spécialistes des Plantes de Madagascar (Madagascar); León-Yánez et al., 2010 (Ecuador); and Raimondo et al., 2009 (South Africa).

result, we encourage other megadiverse countries to conduct comprehensive conservation assessments, particularly of plants, using the IUCN system. As one step toward this goal, Red List training and experiences are currently being shared between Brazil, Colombia, and South Africa.

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A NETWORK APPROACH TO PLANT CONSERVATION IN NEW ZEALAND[1]

John Sawyer[2]

New Zealand has long been regarded as one of the world's biodiversity hotspots (Myers et al., 2000); therefore, the country's flora represents a global priority for plant conservation action. Factors influencing this significance are the high degree of endemism, the evolution of its species in a largely mammal-free environment dominated by birds, and the threatened status of its species and ecosystems. New Zealand has 60 endemic vascular plant genera, comprising 13% of New Zealand genera, and 1984 vascular plant taxa are endemic at the species and infraspecific level, representing 82.2% of these taxa (de Lange & Rolfe, 2010). In addition, 38% of New Zealand's indigenous vascular plants have been recognized as Threatened or At Risk (de Lange et al., 2009).

For the last two decades, plant conservation in New Zealand has been led by the New Zealand Department of Conservation (DOC; the central government agency charged with the protection of indigenous species) and local government (charged with environmental management under the Resource Management Act 1991), with participation from botanic gardens, nongovernmental organizations such as the Royal Forest and Bird Protection Society, the World-Wide Fund for Nature, as well as regional botanical societies. Numerous scientific institutions have researched New Zealand's flora, including most New Zealand universities and Crown Research Institutes (such as Landcare Research, National Institute of Water and Atmospheric Research, and AgResearch). From Sir Joseph Hooker's *Handbook of the New Zealand Flora* (1867) to Thomas Cheeseman's *Manual of the New Zealand Flora* (1906), there has been a long history of botanical research in New Zealand that culminated in the *Flora of New Zealand* nine-volume series (Allan, 1961; Moore & Edgar, 1970; Healy & Edgar, 1980; Galloway, 1985; Webb et al., 1988; Edgar & Connor, 2000; Galloway, 2007 [Vols. 1 and 2]; Engel & Glenny, 2008). All these organizations and agencies have demonstrated a strong desire to describe, understand, and protect New Zealand's unique plant life as part of a wider conservation movement that has existed in New Zealand for more than 100 years.

At the time New Zealand adopted the Global Strategy for Plant Conservation (GSPC) in 2002, there was limited coordination of national efforts, and no single agency appeared to be successfully championing the cause of New Zealand plant life. New Zealand needed a greater degree of coordination, advocacy, and action amongst the many governmental, nongovernmental, community, and research organizations involved in plant conservation in New Zealand.

Biodiversity Declines in New Zealand

The ongoing global decline in biodiversity has been documented widely and is caused by environmental changes such as climate change, habitat destruction, unsustainable harvesting, and the impact of invasive pests and naturalized plants (Butchart et al., 2010). In New Zealand, vascular plant populations and ecosystem structure and functioning are threatened by a broad suite of animal pests, including possums, rats, mice, mustelids (stoats, ferrets, weasels), goats, rabbits, pigs, deer, and stock. Bird and egg predation has impacted plant populations through loss of plant pollinators and seed dispersers (Anderson et al., 2011). Naturalized plants compete with native species; adventive species now outnumber native species in the wild (Howell & Sawyer, 2006). Humans continue to destroy intact indigenous plant communities and to intensify agricultural production in landscapes once dominated by indigenous plants. A lack of understanding of ecological declines has exacerbated the situation, with approximately 60% of New Zealanders believing the natural environment to be in good or very good condition (Hughey et al., 2008).

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This suite of environmental threats has conspired to increase the number of critically threatened vascular plant species by 60% over the last five years (de Lange et al., 2009). The most recent assessment of the conservation status of the flora occurred in 2009; 180 vascular plant taxa were listed as Threatened, which included 91 as Nationally Critical, 45 as Nationally Endangered, and 44 as Nationally Vulnerable, with an additional six taxa considered Extinct (de Lange et al., 2009). A further 651 plant taxa were listed as At Risk and comprise 83 Declining, six Recovering, 20 Relict, and 542 Naturally Uncommon taxa. In total, 38% of New Zealand's total indigenous vascular flora has been recognized as Threatened or At Risk (de Lange et al., 2009). Those declines precipitated a need for improved coordination to halt the decline in New Zealand's indigenous plants.

A Networked Approach, the New Zealand Plant Conservation Network

The New Zealand Plant Conservation Network (<http://www.nzpcn.org.nz/>) was formed in 2003 as a response to the GSPC (Convention on Biological Diversity [CBD], 2002) and the New Zealand Biodiversity Strategy as developed through the DOC and the Ministry for the Environment (MfE) in 2000. The New Zealand Plant Conservation Network came into being against a backdrop of a nationwide decline in native plants and was founded with support and advice from the Australian Network for Plant Conservation (<http://www.anbg.gov.au/anpc/>), which was established in 1991. The New Zealand Plant Conservation Network's vision is that: "No indigenous species of plant will become extinct nor be placed at risk of extinction as a result of human action or indifference, and that the rich, diverse and unique plant life of New Zealand will be recognised, cherished and restored." The New Zealand Plant Conservation Network is now composed of a collective of people and agencies reflecting all walks of New Zealand life (see Table 1). It is engaged in a wide variety of projects mostly stemming from the 16 targets of the GSPC including training, seed banking, research, and provision of information.

Table 1. Members of the New Zealand Plant Conservation Network, <http://www.nzpcn.org.nz>.

Botanic gardens
Plant nurseries
Researchers from New Zealand universities and Crown Research Institutes
Ecologists and land managers from central and local governments
Landowners
Gardeners
Botanists
Teachers
Business people

An Online Flora for New Zealand

The Network's first initiative in 2003 was the establishment of a web site to provide information about New Zealand's threatened vascular flora (<http://www.nzpcn.org.nz/page.asp?flora_vascular>). The overall Network web site (<http://www.nzpcn.org.nz>) has since grown to become a central repository for information about New Zealand's flora including all native and naturalized vascular plants, liverworts, mosses, and some fungi. It is now the central hub for the New Zealand Plant Conservation Network in all its communications and is used by Network members to communicate with each other using the online forum, to learn about plants and ecosystems, to buy publications, to test their knowledge of the flora using an online quiz, to read the news or newsletters, and to download species factsheets and plant photographs. The web site now receives more than 450,000 visits annually (cf. Table 2). Site visitors can download species information as PDF files automatically created by harvesting information from online databases or can make personalized plant books of up to 20 species. The web site provides links to other botanical resources such as New Zealand herbaria, the New Zealand digitized flora (<http://floraseries.landcareresearch.co.nz/pages/Index.aspx>), and plant nursery web sites.

Online Phenology Recording in New Zealand

A phenology recording system was built in 2010 and installed on the New Zealand Plant Conservation Network web site to allow recording of observations of plant flowering, fruiting, and dieback. This feature was intended to complement other international initiatives such as Project Budburst in the United States. (<http://neoninc.org/budburst>) and Nature Detectives in the United Kingdom (<http://www.naturedetectives.org.uk>). Both provide citizen scientists with a tool to document local changes in phenological events over time and to compare regional results with those from other parts of their respective country and with historically documented flowering and fruiting times. This also provides plant nurseries and community groups and landowners involved in ecological restoration with valuable real-time information about regional seed collection times.

Table 2. Features and usages of the New Zealand Plant Conservation Network online, <http://www.nzpcn.org.nz>. The web site receives more than 450,000 visits annually.

Features	Daily Usage
More than 23,000 plant photographs	1200 site visits per day
6500 species pages	800 documents downloaded daily (average over six months)
Links to other botanical resources	20,000 images viewed daily (average over six months)
Online quiz	
Make your own book system	
Species factsheet PDF maker	

Since June 2010, more than 8000 phenology records have been made to the New Zealand Plant Conservation Network's phenology recording system.

Plant Advocacy and Public Outreach in New Zealand

Raising public awareness of native plants is a high priority for the New Zealand Plant Conservation Network to prevent further declines in indigenous plant populations and ecosystems. The focus for this advocacy has been to raise awareness of the threats that plants face in the wild and of the actions people can take to sustainably use and conserve vascular plant taxa. This has been achieved through a variety of means (cf. Table 3). An annual award scheme was started in 2005 and is used to identify people and organizations that have made the greatest contribution to plant conservation in New Zealand. Awards have been made to schools, plant nurseries, individuals, local government, and communities. An annual vote to find New Zealand's favorite plant was begun in 2002 by Professor Ian Spellerberg (Lincoln University, New Zealand). The purpose was to discover why New Zealanders love their native plants and to promote the flora. Since 2005, this vote has been conducted via an online voting system on the New Zealand Plant Conservation Network web site. Winners have included: *Lepidium oleraceum* G. Forst. (2005, Cook's scurvy grass, Brassicaceae); *Brachyglottis huntii* (F. Muell.) B. Nord. (2006, Chatham Island Christmas tree, Asteraceae); *Epilobium microphyllum* A. Rich. (2007, willowherb, Onagraceae); *Ficinia spiralis* (A. Rich.) Muasya & de Lange (2009, pingao, Cyperaceae); and *Myosotidium hortensia* (Decne.) Baill. (2010, Chatham Island forget-me-not, Boraginaceae). The New Zealand Plant Conservation Network has published numerous books, reports, and materials that promote plants and include a monthly newsletter (*Trilepidea*), a threatened plant poster, national plant checklists for native and naturalized species (cf. Howell & Sawyer, 2006; de Lange & Rolfe, 2010), and a detailed assessment of the threatened plants of New Zealand (de Lange et al., 2010). These publications are sold via an online shop on the Network's web site (<http://www.nzpcn.org.nz/shop_products.asp>).

Table 3. Advocacy by the New Zealand Conservation Network.

Annual awards scheme
Vote for your favorite plant competition
Publications, including newsletters, promotional materials, plant checklists and books
Submissions on government policy

Plant Conservation through Marae-based Training

To increase plant conservation capacity and capability, the New Zealand Plant Conservation Network has developed a plant training course consisting of four modules. Each module is designed for delivery over a two-day period on a marae (a traditional Maori tribal meeting place). Those modules are: (1) an introduction to plant life in New Zealand (Reid et al., 2009); (2) managing conservation covenants (Reid & Sawyer, 2010); (3) native plant nursery management and plant cultivation (Reid et al., 2011); and (4) streamside and wetland management (Singers & Reid, in prep.) These modules are intended to provide a marae-based learning experience, to increase plant identification, pest control, and plant propagation skills, and to expose an increasing number of people to plant conservation principles and techniques.

Ex situ Conservation in New Zealand

The New Zealand Plant Conservation Network developed the New Zealand Threatened Plant Seed Bank (<http://www.nzpcn.org.nz/page.asp?conservation_seedbank>) as a contribution to the global initiative run by Kew's Millennium Seed Bank affiliated with the Royal Botanic Gardens, Kew, in the United Kingdom (<http://www.kew.org/science-conservation/save-seed-prosper/millennium-seed-bank/index.htm>). Seed banking was identified as a high priority by the Network due to the earthquake-prone nature of the New Zealand landscape. Ex situ insurance populations would be especially significant should wild plant populations be destroyed. Ex situ seed banking was also seen as a relatively cheap way to protect indigenous plants. This work was sponsored by MWH-New Zealand Ltd. (a private engineering and environment company). The seed bank itself was established at the Margot Forde Germplasm Centre in Palmerston North and is managed by AgResearch (<http://www.agresearch.co.nz>), which was originally set up to store agricultural seed.

David Given Threatened Plant Research Trust

In 2007, the Network established the David Given Threatened Plant Research Trust in memory of David Given, who contributed significantly to plant conservation in New Zealand and globally. Given's work in New Zealand was an important building block of the current threatened plant program, including threatened plant listing and advocacy (see Given, 1976, 1981). The trust was established to provide regular scholarships to researchers studying threatened plants and plant communities in New Zealand.

Challenges in New Zealand toward the GSPC 2020 Goals

The New Zealand Plant Conservation Network is a hugely successful product of the GSPC (CBD, 2002). By providing a local, in-country response to the global plant conservation crisis, the New Zealand Network has shown what can be achieved by harnessing the power of individuals and organizations to achieve a common purpose. Despite the notable successes of this national plant network, a number of challenges remain for plant conservation in New Zealand. These can be categorized into four themes, as follow.

(1) In-situ protection of critically threatened species populations. Nature conservation resourcing is not always aligned strongly with the needs of New Zealand's most threatened plant species and ecosystems. Limited funding exists to resource threatened plant species or ecosystems. Many funds support common, more charismatic plant species and ecosystems as a preference. There is no legislation protecting threatened plant species in the wild, irrespective of land tenure. Securing greater funding for threatened species and ecosystems is a New Zealand Plant Conservation Network priority to target active management of important plant areas.

(2) Education and advocacy. Increased public awareness is needed of the role that plants can play in fixing environmental problems. Many challenges facing land managers can be ameliorated through the use of plants. Plants may be used to improve flood prevention, soil conservation, carbon sequestration, coastal and riparian infrastructure protection, and provision of shade and shelter to humans. Advocacy about these roles of plants and the way humans can make use of them will increase the value they attribute to them in the landscape.

(3) Use and appreciation of plants. A key ingredient in the decline in native plants in New Zealand is their invisibility. A critical job is to position native plants at the heart of landscapes, cities, and, therefore, human consciousness. The integration of plant conservation into the management of economically productive land is also a challenge facing New Zealand. A historic dichotomous view of land use has evolved, whereby native species are confined to parks and reserves, and economic production occurs in the areas between which are largely free of native species.

(4) Capacity building. A priority for the New Zealand Plant Conservation Network is to build the Network's training modules into a national Diploma in Plant Conservation to increase the number of people with plant conservation skills. Another challenge is to increase the size of the David Given Threatened Plant Research Trust fund to provide more frequent and larger scholarships. The future expansion of the New Zealand Plant Conservation Network's program to become a partner in a Pacific-wide organization may also be considered. Such an organization could provide opportunities for technology and skill transfer throughout Oceania or the Pacific Oceanic Islands. This may include monitoring, seed banking, propagation, information management, pest control, and habitat protection in places where indigenous plants face similar threats as seen in New Zealand.

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TOWARD THE IMPLEMENTATION OF GLOBAL STRATEGY FOR PLANT CONSERVATION TARGETS 1 TO 3 IN HAWAI‘I[1]

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ABSTRACT

Hawai‘i has a unique natural history, ideal for studying the mechanisms of evolution. With over 90% endemism in its native flora of 1300 species, over half are threatened with extinction. This immense challenge requires working collaboratively, effectively, and efficiently. Despite extensive conservation activity, we do not have a unified strategy, and leaders in Hawaiian conservation are discussing the creation of a Hawai‘i Strategy for Plant Conservation (HSPC) based on the Global Strategy for Plant Conservation (GSPC) targets. Here we analyze the effectiveness of the conservation work taking place in Hawai‘i through the lens of the GSPC Targets 1 to 3 that include: (1) the establishment of an online flora of all known plants; (2) the assessment of the conservation status of all known plant species; and (3) the development and sharing of research and methodology related to on-the-ground conservation.

Key words: Biodiversity, endemism, extinction, Global Strategy for Plant Conservation (GSPC), Hawai‘i Conservation Alliance (HCA), Hawai‘i Rare Plant Restoration Group (HRPRG), Hawaiian flora, IUCN, U.S. Fish and Wildlife Service (USFWS).

The framework of the international Global Strategy for Plant Conservation (GSPC) is an effective way to tie Hawai‘i's conservation programs together and to measure progress toward those updated GSPC goals established at the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity, 18–29 October 2010. As concluded in Nagoya, Japan, Objective I of the GSPC stated that plant diversity is well understood, documented, and recognized. Under Objective I, the GSPC uses three targets that are designed to measure the effective implementation of this objective. Target 1 is an online database for the flora; Target 2 documents the conservation status of the flora; and Target 3 refers to the dissemination and sharing of information.

Hawai‘i is an ideal place to study plant evolution, because its biodiversity developed in the extreme isolation of the mid-Pacific without human interference. The Hawaiian archipelago arose from the central Pacific Ocean floor as a sort of conveyor belt of volcanic activity, emerging from the southeast, moving toward the northwest, beginning some 70 million years ago. From 230 plant colonizations, it is estimated that the archipelago evolved approximately 1345 endemic species of flowering plants (Wagner et al., 1999) and ferns (Palmer, 2003). The steep volcanic topography of the islands, with many narrow mountain drainages and inaccessible habitats, provided many small ecological niches. Taxonomic radiation into these niches led to an extremely high degree of endemism. Ninety-four percent of all dicot species are estimated to be endemic to the archipelago (Wagner et al., 1999) and a large number of those are single-island endemics, often restricted to one valley. Since human colonization only occurred an estimated 1000 to 1200 years ago, and there are no native land mammals apart from one bat species, threats to this flora were, until recently, relatively insignificant.

This contrasts dramatically to the "post-contact" competition from new introductions, be these human, animal, plant, insect pest, or disease. Over half of the remaining endemic flora is now considered at risk of extinction. With an extraordinary assemblage of more than 28,000 native plants and animals, as catalogued by the Hawaii Biological Survey database (<http://hbs.bishopmuseum.org/hbsdb.html>), the Hawaiian archipelago is one of the world's most ecologically diverse locations. A large percentage of these taxa are endemic (cf. Fig. 1). The vulnerability of these unique natural resources makes Hawai‘i a microcosm for the practice and science of global bio-cultural conservation, which should be measured through an international framework like the GSPC.

This immense natural challenge requires working collaboratively, effectively, and efficiently. Despite

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Figure 1. Endemic Hawaiian plants under threat. —A. *Lobelia gloria-montis* Rock, pu‘u kukui or bog lobelia (Campanulaceae). —B. *Scaevola glabra* Hook. & Arn., ohe naupaka or camphusia (Goodeniaceae). —C. *Lysimachia daphnoides* Hillebr., lehua makanoe (Primulaceae). —D. *Polyscias bisattenuata* (Sherff) Lowry & G. M. Plunkett [≡ *Tetraplasandra bisattentuata* Sherff], ohe ohe (Araliaceae). Photos taken by Ken Wood, National Tropical Botanical Garden.

extensive conservation activity, we do not have a unified strategy, and leaders in Hawaiian conservation have discussed the creation of a Hawai'i Strategy for Plant Conservation (HSPC) based on the GSPC targets. An HSPC modeled after the GSPC will focus attention and resources on Hawai'i more effectively than the North American Botanic Garden Strategy for Plant Conservation (<http://www.bgci.org/files/Worldwide/Conservation/north_american_plant_conservation_strategy.pdf>), due to Hawai'i's unique location and natural history. The North American strategy was not written to include Hawai'i, presumably because of the dissimilarity of both the flora and the geography. The following attempts to analyze the effectiveness of the conservation work taking place in Hawai'i through the lens of GSPC Targets 1 to 3. It is important to update the national and international conservation communities on the status of the unique flora that has evolved in this biodiversity hotspot, because while the Hawaiian Islands have been visited by botanists for over 200 years, there have also been many contemporary initiatives by numerous organizations to conserve the native flora.

Target 1, an online database for the flora, has been accomplished, and Hawai'i currently has very good online documentation of its flora. Classification and naming of the Hawaiian flora began with indigenous Hawaiian culture over 1000 years ago. Western documentation based on the Linnaean system (binomial) was begun over 200 years ago, with the arrival of the Europeans. Botanists traveling with early explorers like Captain James Cook (three voyages, 1768–1779) and George Vancouver (1792) made the first known botanical collections and drawings of the Hawaiian flora. Approximately a century later, the first *Flora of the Hawaiian Island* was published by a German physician living in Honolulu (Hillebrand, 1888). Since western botanists began their investigation of the Hawaiian flora, over 100 species have gone extinct. At the same time, due to the rugged nature of the islands, dozens of new species are still being discovered. Since the flora was last systematically revised in 1990, the National Tropical Botanical Garden's (NTBG) field botanists have discovered 45 new species and a further 35 species thought to be extinct, which has expanded the existing flora by a total of 65 species (Wood, 2011).

The publication of the *Manual of Flowering Plants of Hawai'i* by Wagner et al. (1999) was a landmark effort to document the flora using modern systematic methods and remains the reference publication for all botanical research in the Hawaiian Islands, in spite of the fact that taxonomic revisions since its publication have been considerable. A parallel reference for the pteridophytes is *Hawai'i's Ferns and Fern Allies* by Palmer (2003). In collaboration with the NTBG, the Smithsonian Institution (SI) maintains an online version of the *Flora of Hawaiian Islands* (Wagner et al., 2005), which is updated with periodic supplements (<http://botany.si.edu/pacificislandbiodiversity/hawaiianflora/Hawaiian_vascular_plant_updates_1.3.pdf>).

In addition to this online flora, a number of other online resources are available. Collaboration between the Royal Botanic Gardens, Kew, and Missouri Botanical Garden (MO) created an online plant names index (<http://www.theplantlist.org>), which includes Hawaiian species. The Plant List combines multiple checklist data sets held by those institutions and other collaborators, providing the accepted Latin name for most species, with links to all synonymous names by which the taxon has been known.

Extensive collections of plant specimens are deposited in the herbarium at the Bernice P. Bishop Museum in Honolulu (BISH; <http://www2.bishopmuseum.org/HBS/checklist/query.asp?grp=Plant>). A geographical search engine is available through the MO Tropicos database (<http://www.tropicos.org/SpecimenGeoSearch.aspx>) and through the herbarium of the NTBG (<http://ntbg.org/herbarium>). The two Hawaiian herbaria, BISH and PTBG, as well as those at SI, New York Botanical Garden (NY), and MO, extensively document Hawaiian and other Pacific flora. The PTBG's type collections have been digitized and made available online on JSTOR Plants as the result of funding from The Mellon Foundation. Another project, the Consortium for Pacific Herbaria (CPH) funded by the U.S. National Science Foundation, is in progress to database and digitize Hawaiian and Pacific Island herbaria and make them available online through a single web portal hosted by the University of Hawai'i (<http://www.herbarium.hawaii.edu/cph/index.html>).

Other particular lists for the Hawaiian flora or locales corroborate the larger online databases and herbarium collections. These include a checklist of Native and Naturalized Flowering Plants of Hawaii, including the islands of Oahu, Hawai'i, Maui, Molokai, Lana'i, Kaho'olawe, Kaua'i, and Ni'ihau (<http://www.bishopmuseum.org/research/natsci/botany/dbandkeys/Main%20Islands%20Report.pdf>). Another checklist documents the northwestern Hawaiian Islands of Nihoa, Necker, French Frigate Shoals, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes Atoll, Midway, and Kure Islands (<http://www.bishopmuseum.org/research/natsci/botany/

dbandkeys/NWHI%20Islands%20Report.pdf>). Other national databases include Hawaiian plants and can be found through the Botanic Gardens Conservation International (BGCI; <http://www.bgci.org/plant_search.php/>), The Center for Plant Conservation (CPC; <http://www.centerforplantconservation.org/collection/NationalCollection.asp>), and NatureServe (2011; <http://www.natureserve.org/explorer/>). These databases incorporate data from the Hawai‘i Biodiversity Mapping Program. In addition, several other databases maintained by the University of Hawai‘i contain excellent photographic archives of Hawai‘i's flora. The Hawaiian Native Plant Genera database (<http://www.botany.hawaii.edu/faculty/carr/natives.htm>) includes photographs of dicots, monocots, ferns, and fern allies, arranged by family and genus, and to the species level. The Plants of Hawai‘i database contains both native and introduced species as well as indigenous plants (<http://www.hear.org/starr/images/?o=plants>).

Target 2 of the three GSPC targets focuses on the assessment of the conservation status of all known plant species, as far as possible. The U.S. Fish and Wildlife Service (USFWS) has the most complete data on the current status of Hawai‘i's flora. Of all federal listed plants in the United States (760; <http://ecos.fws.gov/tess_public/pub/Boxscore.do>), almost half (357) are Hawaiian taxa (<http://ecos.fws.gov/tess_public/pub/stateListingAndOccurrenceIndividual.jsp?state=HI&s8fid=112761032792&s8fid=112762573902>). With current taxonomic changes, the number of federally listed Hawaiian plant taxa is 370. USFWS estimates that at least half of those taxa are limited to fewer than 1000 individuals each (Table 1).

Under the Endangered Species Act, taxa designated as Threatened (T) or Endangered (E) or candidates for listing are listed in the USFWS's Environmental Online Conservation System, either alphabetically by scientific name at <http://ecos.fws.gov/tess_public/pub/listedPlants.jsp> or alphabetically by common name at <http://ecos.fws.gov/tess_public/pub/stateListingIndividual.jsp?state=HI&status=listed>. On each species page on the USFWS web site, species profile pages for assessed species contain links to documents, including the initial proposed listings, recovery plans, critical habitat designations, and five-year reviews. These describe the conservation status of an individual species, any relevant taxonomic changes, life history research, associated habitats and species, as well as any threat to its survival. Conservation measures are recommended and implemented for species recovery. Five-year reviews have recently been completed for all Hawaiian threatened and endangered plants, with the exception of those most recently listed in 2010. Although not exhaustive, this is the best single source for information on the conservation status of Hawai‘i's rare plants. It is estimated that another 78 Hawaiian plant species will be listed in the next few years (USFWS, 2012a, 2012b, 2012c), according to a new USFWS work plan available at <http://www.fws.gov/endangered/improving_ESA/listing_workplan.html>.

Table 1. U.S. Fish and Wildlife Service (USFWS) population data on the Hawaiian flora.

Abundance	# of taxa
Extinct	115
In captivity only	19
1 in the wild	12
2–20 in wild	95
21–100 in wild	123
101–1000 in wild	205
1001–5000	83
> 5000 in wild	637
Unknown	56
Total	1345

Data taken from USFWS (2011). Taxonomic note: USFWS has listed some entire species, which include a number of subspecies, and in other species only some subspecies. Subsequent to listing some taxonomic revisions have resulted in the listed species being split into a number of new species.

Another 260 Hawaiian plant species are informally designated as species of concern in the USFWS. Species of concern is an informal term not defined in the federal Endangered Species Act, but it commonly refers to species that are declining or may be in need of conservation. Species of concern may be identified as those with some or all of the following indicators:

(1) Magnitude of decline. For the species of concern, the recent rate of decline is compared relative to the historical extent of decline.

(2) Natural rarity. The plant species of concern is known only from a small number of specimens or occurs infrequently and in small numbers because of ecological or evolutionary factors.

(3) Restricted endemism. The species of concern is native to a particular and limited geographical range and is found only there.

(4) Connectivity of populations. The level of possible reproductive exchange among populations of the species of concern is estimated, given the number and distribution of known populations.

(5) Habitat. The species of concern has unique or highly specific habitat requirements that support careful monitoring of its status.

With such species of concern added to those that are officially listed, over 50% of the Hawai‘i flora is considered to be at risk.

Two hundred three species with less than 50 individuals seen in the wild have been identified under the Plant Extinction Prevention Program of Hawai'i (PEP) for priority recovery efforts (<http://pepphi.org/>). The PEP list includes 49 species that are not already listed by USFWS. These additional species are also tracked in a Statewide Rare Plant Database, with regular updates from PEP field botanists on each island.

An earlier version of a statewide database, the Heritage Database, now called the Hawai'i Biodiversity Mapping Program database, contains all the historical occurrences of listed species, but has only been updated through about 2002, due to lack of resources. Additionally, the U.S. Army, Oahu, maintains its own database on those 66 Hawaiian species federally listed as T or E for which it is responsible (U.S. Army, Center for the Environmental Management of Military Lands, Colorado State University; U.S. Army, Oahu Army Natural Resource Program, U.S. Army Garrison Hawaii and Pacific Cooperative Studies Unit, 2010). Regular annual status reports on the conservation status and recovery of these species are available online at <http://manoa.hawaii.edu/hpicesu/dpw_mit.htm>.

Unfortunately, the International Union for Conservation of Nature (IUCN, 2001) Red List, which is considered the international standard for threatened and endangered species, includes only 224 endemic and two indigenous species from Hawai'i (<http://www.iucnredlist.org/>). This is in contrast to the higher number of species federally listed as T and E or on the PEP list. It is interesting that the Red List actually included several species as Vulnerable (VU) that are not listed as rare by either the state of Hawai'i or the USFWS. The Hawai'i Rare Plant Restoration Group (HRPRG), IUCN's Specialist Group for Hawai'i, has requested help in completing the IUCN listing process for additional species but has had no funding for the purpose, and the listings remain incomplete at this time. Until all T and E, PEP, candidate, and species of concern species are listed under IUCN, the global significance of the taxonomic endangerment, indeed extinctions, of the Hawaiian flora is not reflected accurately under the IUCN Red List.

A number of studies have been conducted documenting the diverse plant communities and their distribution in Hawai'i. The composition of Hawai'i's coastal plant communities has been well documented by Warshauer et al. (2009). Another project in 2007 mapped distributional ranges for four plant species, two widespread and two rare, on all the main Hawaiian Islands (Price et al., 2007), and Hawai'i was one of a number of island archipelagos reviewed for conservation priorities by Caujapé-Castells et al. (2010). This last article, however, used the IUCN listings for its statistics on rare plants in Hawai'i, so it provides an underestimate and does not reflect the actual gravity of the extinction crisis in Hawai'i's endemic flora.

The NTBG has over three decades of collection data in both its Living Collections Database and Herbarium Database (<http://www.ntbg.org/herbarium/>). In addition, the Plant Recovery Coordinator for USFWS-Honolulu maintains a database that includes candidate species not yet listed, and species of concern that are assessed to need evaluation as possible candidates for federal listing. Information is maintained on the known status of numbers of populations, individuals, threats, and latest observations. The conservation status of rare plants requires regular monitoring and updating, and more field botanists are needed to collect this information. Staffing also limits IUCN Red listing assessments for many species, so the actual endangerment of the Hawaiian flora is not accurately reflected internationally.

Target 3 of the GSPC is that information, research and associated outputs, as well as the methods necessary to implement the strategy are developed and shared. This has been implemented in many significant directions, but not in the context of the GSPC. Our recommendation is that the conservation and research community establish a mechanism, perhaps through the Hawai'i Conservation Alliance (HCA), that will effectively compile and index progress toward implementing the GSPC targets.

In general, research and conservation efforts in Hawai'i have been collaborative and various groups regularly share information with each other. Perhaps this is because everyone recognizes the magnitude of the problem and agrees that we are working toward a common goal and will need to work together if we are to achieve our goals. One way in which this collaboration has expressed itself is via the HCA, an organization of 19 leading federal and state agencies and NGOs that meet regularly to discuss conservation issues and share information. This target is being met by a wide variety of collaborative projects, database coordination, sharing of on-the-ground restoration techniques, and scientific research, but more science in support of conservation efforts is cogently needed.

The HCA has clearly noted the need for increased research that will inform effective conservation in Hawai'i (<http://hawaiiconservation.org/files/content/activities/effective_conservation/

effectiveconservationoverview.pdf>). Although science in support of conservation has been extensive over the past several decades, the sheer size of the endangered flora dictates that much more needs to be understood about Hawaiian species. More genetic analysis, pollination biology, life history and phenology, soil ecology, and related studies are needed for conservationists to effectively assess and conserve the at-risk species. Very few genera are well characterized across these disciplines, let alone the numerous species that represent Hawai‘i's plant diversity. We still have much to learn in understanding how sympatric speciation, obligate outcrossing, co-evolution, indeed any species interaction, may impact any species' ability to regenerate and maintain themselves in the face of changing ecosystems. Understanding both internal and external reproductive barriers and how they evolved is also essential to long-term management of rare species.

While climate change has now been recognized as an official threat to rare species by the USFWS, the research on what this will mean in Hawai‘i is just beginning. The Pacific Islands Climate Change Cooperative (PICCC; <http://piccc.net>) is a new interagency organization whose purpose is to assist those who manage native species, island ecosystems, and cultural resources in adapting their management to climate change in the Pacific Islands. PICCC coordinates the important research that needs to be done so that appropriate mitigation strategies can be developed. While the need for more research has been identified, a lot of information has already been accumulated and more is being acquired every year. Several key advances have been made to share this information among the members of the conservation and research communities.

Sharing the Science

The HCA (<http://hawaiiconservation.org>) is a coalition of 19 conservation organizations working together to protect and restore the natural resources of Hawai‘i. A list of its institutional members (<http://hawaiiconservation.org/about/alliance_partners>) demonstrates the breadth and depth of cooperative commitment that has been made. Coordinated by the HCA, the Hawai‘i Conservation Conference (HCC) is an annual three-day conference and is the largest conservation gathering in Hawai‘i. Typically attended by ca. 1000 participants, the HCC has become an effective venue that facilitates sharing research results through forums, symposiums, workshops, lectures, and other media (<http://hawaiiconservation.org/activities/hawaii_conservation_conference>). An annual Nahelehele Dryland Forest Symposium is sponsored by Ka‘ahahui O Ka Nahelehele (<http://drylandforest.org>), a Hawai‘i island nonprofit organization. Its participating organizations and projects can be found at <http://drylandforest.org/partners>. In May 2011, SI and NTBG, with support from other organizations, co-sponsored a three-day scientific conference, "Evolution of Life on Pacific Islands and Reefs: Past, Present, and Future," in Honolulu. The conference proceedings are available at <http://botany.si.edu/events/2011_pacific>.

The Hawaiian Ecosystems At Risk (HEAR) website (<http://www.hear.org>) maintains a number of databases, image collections, and listservers that share technology, methods, and information in order to facilitate communication among decision-makers, resource managers, and the general public in support of effective science-based management of harmful non-native species in Hawai‘i and the Pacific. HEAR also provides online discussion forums for a large number of conservation specialist groups, including all invasive species councils, environmental educators, and specialist groups on invasive plant pests and others (<http://www.hear.org/hearlists/index.html>).

The University of Hawai‘i hosts a number of important conservation research facilities including the Center for Conservation Research and Training (<http://www.hawaii.edu/ccrt/CCRTOnline/Programs.html>). Other resources include the Hawai‘i Seed Research facility at Lyon Arboretum, the Hawai‘i Stream Research Center, and the Ecology, Evolution, and Conservation Biology Graduate Program. The University of Hawai‘i Department of Botany also hosts the Hawaiian Plant DNA Library (<http://www.botany.hawaii.edu/faculty/morden/HPDL.htm>), the Pacific-Asia Biodiversity Transect (PIBITRA; <http://www.botany.Hawaii.edu/pabitra>), Weed Risk Assessments for Hawaii and Pacific Islands (<http://www.botany.hawaii.edu/faculty/daehler/wra/>), the HAW herbarium, as well as an Electronic Theses and Dissertations library (<http://www.herbarium.hawaii.edu/collections/etd/>).

Sharing Databases

In the last few years, cooperation between a number of agencies has allowed databases to "talk to each other" through shared data fields. This includes the Hawai‘i State Rare Plant database, the U.S. Army Pohakuloa and Oahu databases, the Hawai‘i Biodiversity Mapping Program, and the NTBG databases. To protect the locations of extremely rare plants, these databases are not available to the public online.

Sharing On-ground Restoration Techniques

The HCC, discussed earlier, is the primary venue where restoration practitioners share their experience, expertise, and new technologies with all levels of the conservation community (<http://hawaiiconservation.org/activities/hawaii_conservation_conference>). Additionally, the HRPRG is a network of practitioners from conservation agencies and organizations, both public and private, that shares information on recovery efforts on all the islands and communicates through meetings, an online listserver, and a web site (<http://www.hear.org/hrprg/index.html>). This web site includes a bibliography for restoration genetics, with guidance on collection and restoration protocols. The group was instrumental in the creation of the PEP and the mid-elevation, rare plant nurseries on several islands. The HRPRG has functioned to develop appropriate procedures and policies for dealing with rare and endangered plants and their recoveries (<http://www.hear.org/hrprg/index.html>).

Close Cooperation and Partnerships between Agencies/Organizations

The mutual sharing of staff, equipment, training opportunities, helicopter time, etc., among organizations in Hawai'i is frequent and essential for accomplishing our goals. Collaboration-coalition types of efforts are almost the rule, rather than the exception, in Hawai'i. We mention just two excellent examples of this. The Hawai'i Association of Watershed Partnerships (HAWP; <http://hawp.org>) comprises watershed partnerships on each island. This organization includes both private and public landowners, conservation groups, and citizen groups, all of whom work collaboratively toward landscape-scale conservation. Also, The Nature Conservancy of Hawai'i (TNC) works to preserve native landscapes and intact habitats for all of Hawai'i's living resources through a system of preserves and collaborations with landowners (<http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/Hawaii/index.htm>). TNC of Hawai'i offers state-of-the-art management tools, achieving substantial results that include the fencing of thousands of acres of native forests. This provides the long-term protection of rare species against the damage caused by feral ungulates. They work extensively with landowners and partners from both the public and private sectors.

Conclusions

While Hawai'i has been recognized for over 200 years as possessing a unique flora, it is only over the past several decades that the level of endangerment has begun to be quantified. Numerous organizations and many dedicated and passionate individuals have been working for years to document and conserve Hawai'i's globally important biodiversity. Although these efforts have yielded results, the continuing trend toward increased endangerment raises concerns locally and nationally. We believe that the GSPC's 2010 Objectives and Targets are an ideal framework for Hawai'i to coordinate and monitor the work currently being done and to bring much needed international awareness to our situation. Based on what other nations have done to create a national strategy for plant conservation, we propose that the HCA should develop an HSPC modeled after the GSPC. This will provide an effective template for our conservation work and tie directly into the global efforts under the United Nations Convention on Biological Diversity. Since the United Nations declared this the Decade of Biodiversity, there is no better time for Hawai'i to do this than now.

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