Biocultural conservation as a botanic garden conservation strategy

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Abstract

Concerns continue to mount regarding potential impacts of global climate change, habitat loss, and other environmental changes on the world's biota and peoples, especially in island systems. Just as floristic diversity is impacted by environmental change, so too are cultural and linguistic diversity. It is not enough to consider just the effects of environmental change on plant life within the context of the Global Strategy for Plant Conservation and the Convention on Biological Diversity. Rather, botanic gardens should actively engage in understanding the broader impacts of environmental change to biocultural diversity.

Key words

Biocultural diversity, botanic gardens, CBD, endangered languages, GSPC, hotspots, islands

Introduction

Historically, botanic gardens have focused primarily on aesthetically appealing displays, plant exploration and collecting, and taxonomy. The social relevance of gardens to the general public has been largely recreational and aesthetic. Until the mid-20th Century, many botanic gardens and arboreta offered little else to public users and visitors.

As a result of well-documented threats to the world's biological diversity, many botanic gardens now consider conservation as a key component of their programmes and mission. In addition to biological conservation, botanic gardens have new opportunities to increase their relevance, importance, and appreciation by embracing biocultural conservation.

Global plant conservation

Attention to plant conservation and biodiversity is an important way for gardens to regain social relevance (Maunder *et al*., 2001). It is well-documented that a large proportion of plants and animals are at risk of extinction, with the magnitude of risk varying by region of the world (Myers *et al*., 2000; Thomas *et al*., 2004) (Table 1). Thomas *et al*. (2004) estimate that up to 30% of all species will face serious extinction risks by 2050. In the Hawaiian Islands, for example, 90% of the 1200 native flowering plant taxa are endemic to the islands, with more than 30% listed by the US Fish & Wildlife Service as threatened or endangered. Given continued threats from land use change, urban development, invasive species, climate change, and sea level rise, the threats of extinction are likely to increase.

Table 1. Extinction risks for plants in four world regions (from Thomas *et al*., 2004)

Region	% of plants at risk
Amazonia	53-87
Cerrado (Brazil0	40-50
South African Protaceae	24-34
Europe	4-17

As threats to plants escalate, other organisms within their ecological setting are also threatened. Recognition of the broader threats to entire ecological systems has lead to the identification of "biodiversity hotspots" (Myers *et al*., 2000); namely, regions of the world that face particularly grave threats to ecosystems and ecosystem integrity. Recognition of such hotspots (most of which are concentrated in the tropics, island systems, and Mediterranean) has been useful in shaping conservation priorities and strategies.

Hawai'i is included in the Polynesia/Micronesia hotspot (Myers, 2000). Because of the high extinction risks to plants and the high endemism in these islands, the efforts of many conservation organizations and government programmes are needed to meet the extinction challenge. To avoid redundancy of effort, many organizations focus on some specific aspect of the larger conservation imperative. Lyon Arboretum in Honolulu, Hawai'i, for example, specializes in *ex-situ* conservation using micropropagation, or tissue culture. Of the 400 threatened or endangered Hawaiian plant taxa, 200 are now in tissue culture; five of these are extinct in the wild.

Climate change presents considerable challenges for the natural world, botanic garden management, and home gardening. Studies at the Royal Botanic Gardens, Kew (UK) and the Arnold Arboretum (Harvard University, USA) clearly demonstrate the changing phenology of plants during the past century. At RBG Kew, for example, many spring flowering plants now bloom 1–3 weeks earlier than 20–30 years ago (Bell, 2007; Royal Botanic Gardens Kew, 2008). Such phenological data are readily obtained from plant collections and curatorial records at botanic gardens and herbaria. Thus, the critical importance of botanic garden resources, data, and scientific programmes to better understanding global environmental issues cannot be overstated. Yet, few botanic gardens and botanic gardens associations have developed clear strategies to adapt to climate change. Notable exceptions include BGCI and Australian botanic gardens (Council of Heads of Australian Botanic Gardens, 2008).

Loss of cultures and languages: the special vulnerability of islands

Largely lost in the discussion of loss of plant diversity is its effect on human cultures. Loss of "cultural keystone species" as a result of environmental changes will severely compromise cultural integrity. In the most vulnerable parts of the world (e.g., Pacific Island nations), the effects of environmental changes (such as sea level rise) threaten to erode biological diversity as well as cultural and language diversity. As botanic gardens (and other plant conservation organizations) develop and implement conservation strategies, they have a unique opportunity to participate in cultural and linguistic restoration.

Concerns about the present and future loss of plant species are considerable. By some estimates, the world could be losing 25-50 plant taxa per year (Peter Raven, pers. comm.), or about 100 times the background rate of 1 extinction per million species per year (Stuart Pimm, pers. comm.). Sutherland (2003) documented threats to birds, mammals, and languages (Table 2) using the IUCN-based threat categories of critical, endangered, and vulnerable (IUCN, 2001). He showed that 12% of birds and 24% of mammals worldwide are at risk. He further attempted to fit IUCN criteria to the world's languages. By his estimation, 25% of languages are at risk. Most linguists who document endangered languages put this number considerably higher. The United Nations Educational, Scientific and Cultural Organization (UNESCO, 2013) estimates that of the *ca*. 6900 extant languages, 50% are endangered and the world is losing, over the long-term, one language every two weeks. Linguists now identify and map "language extinction hotspots" (*e.g*., National Geographic Society's Enduring Voices Project; NGS, 2013). Human culture is at greater risk than other biotic elements. Loss of cultures and languages results in lost knowledge of the plant world, of the uses of plants, and traditional ecological knowledge, not to mention loss of a significant part of our humanity.

Plant and of cultural/language diversity are linked in significant ways. As threats (climate change, sea level rise, land conversion) to Pacific Island nations increase, threats to various "cultural

keystone species" (see Garibaldi and Turner, 2004) also increase. For example, many Pacific cultures rely on *Colocasia esculenta* (L.) Schott (taro) for food and for spiritual purposes, with many such cultures of the belief that their ancestry derives from taro. Thus, if taro (or other culturally significant plants) were to disappear, so too will that people's cultural integrity. Taro is so central to some cultures that, for instance, the Vanua Lavans state, "we do grow taro to live, we live to grow taro" (Caillon and Desgeorges, 2007). Loss of culture and language is not restricted to the Pacific nor to islands.

Table 2. Global threats to three entities of conservation concern (from Sutherland, 2003).

Category	Critical	Endangered	Vulnerable	Extant	% C, E or V
Birds	182	321	680	9797	12
Mammals	180	340	610	4630	24
Languages	43	506	732	6809	25

Because biological diversity and cultural diversity are linked, considerations of "biocultural diversity" (Maffi, 2001, 2005; Dunn, 2008) and conservation should be key elements of any restoration and recovery strategy. Awareness of this link between erosion of biological and cultural integrity has lead to the suggestion of hotspots and indices of biocultural diversity (Loh and Harmon, 2005). It is no coincidence that hotspots of biological and biocultural diversity overlap considerably, and is a useful reminder of the interdependence of natural and human communities. As early as the 1980s, the French 1965 Nobel Laureate in Medicine, Francois Jacob (1982), noted that "in humans, natural diversity is further strengthened by cultural diversity."

Botanic gardens conservation and biocultural diversity

Acknowledging threats to both biological and cultural aspects of the world has been incorporated into important global strategies. Article 8(j) of the Convention on Biological Diversity (CBD, 1992) encourages all nations to "…respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities…for the conservation and sustainable use of biological diversity." As important a statement as this is, it places primacy on conserving biological heritage, rather than on cultural and human heritage (Dunn, 20008). Nonetheless, it does recognize the link between biological and cultural diversity.

More satisfying is Target 13 of the *Global Strategy for Plant Conservation* (BGCI, 2012) which states "Indigenous and local knowledge, innovations and practices associated with plant resources, [be] maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care." Here plant life and cultures are considered equally.

Botanic gardens are taking an increasingly prominent role in local and global plant conservation efforts (Maunder *et al*., 2001; Miller *et al*., 2004; Blackmore *et al*., 2011; Wyse Jackson and Sharrock, 2011). Given that erosion of biological diversity can lead to erosion of cultural diversity, botanic gardens with a strong conservation mission have an opportunity to play a key role in biocultural conservation (Dunn, 2008). This role can take any number of forms, from training indigenous peoples in conservation methods to learning from indigenous peoples regarding traditional ecological knowledge, and learning local languages. The Lyon Arboretum (University of Hawai'i) has incorporated the concept of biocultural conservation into its mission statement and is leading an effort to establish a new Center for Biocultural Studies at the University of Hawai'i. The Center brings together faculty and students who are concerned about threats to biocultural diversity from the viewpoints of anthropology, ethnobotany, ethnoecology, ethics, law, linguistics, political science, and other disciplines. In addition, the arboretum is developing memoranda of agreement with other institutions in the Pacific (University of Auckland, University of the South Pacific) and has signed a formal Memorandum of Agreement with the Smithsonian Institution (National Museum of Natural History) to facilitate exchange of information, faculty, and students.

For gardens without international activities, increasing awareness of threats to biocultural diversity can be incorporated into education programmes and special events. Many gardens are located in regions with diverse cultures and ethnicities. The Queens Botanical Garden (New York City) has a rich tapestry of events that encourage residents to express their cultural heritage within the context of a metropolitan botanic garden. The Garden's mission statement (2013) directly interrelates "people, plants, and culture…innovative educational programs and demonstrations of environmental stewardship" (Queens Botanical Garden, 2013).

For new gardens in the process of developing a conservation strategy, incorporating biological and cultural diversity is much simpler than for long-established gardens, and will immediately raise their profile on the global conservation stage. As a new arboretum is being established on the west coast of South Korea (Dunn, 2012), a great opportunity exists to take a leading role in biocultural conservation and in implementing the resolution (M041) passed at the 2012 IUCN World Conservation Congress in Jeju, which explicitly addresses biological and cultural diversity in Korea and East Asia.

Conclusions

As botanic gardens and arboreta position themselves for the future, they should not lose sight of their core mission. However, it is necessary that conservation science at gardens consider ways in which cultural diversity can be incorporated into broader conservation programmes and strategies. Partnerships with other organizations is one way to more efficiently and effectively develop strong and meaningful initiatives. As threats to biological diversity intensify globally, threats to cultural diversity also intensify. Thus, there is a dual imperative for all gardens engaged in plant conservation to consider innovative ways in which they can enhance and increase awareness of cultural diversity as part of their conservation mission.

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Seeds of Success: seed banking and native plant materials for a changing climate

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Abstract

Seeds of Success (SOS) is the United States' national native seed collection program, led by the Bureau of Land Management (BLM) in partnership with other federal government agencies and numerous non-federal organizations. As the first step of the Native Plant Materials Development Program (NPMDP), SOS's mission is to collect wildland native seed for research, development, long-term germplasm conservation, and ecosystem restoration. Each year, 65 collecting teams across the country collect native seed for SOS, all following the SOS Technical Protocol. SOS collections are divided into a working collection which is made available for research, and a long-term conservation storage collection which is stored at partner institutions throughout the United States. Seed collection is an efficient and cost-effective way to conserve the diversity of plant species into the future. Partnerships make a national large-scale conservation effort like SOS possible.

Keywords

Bureau of Land Management, Collection, Germplasm, Native Plants, Restoration, Seed Banking, Seeds of Success, United States.

Introduction

Healthy ecosystems provide the essential ecological services upon which all life depends, including our own. Native plants create oxygen, food, and medicines. They have broad, extensive root systems that reinforce soils and increase penetration of water and reduce erosion and flooding. Native plant communities provide the foundation for fish and wildlife habitats such as the sage-grouse. In the United States, these communities are affected by increasing wildfires, urban expansion, climate change, increased demand for energy resources, expansion of recreational areas, and non-native plant invasion. There is an increasing awareness of the importance of local plant materials for successful restoration projects. However, there are still shortcomings with respect to the availability of geographically and genetically appropriate native plant materials for restoring the American landscape. Seeds of Success (SOS), the national native seed collection program coordinated by the Bureau of Land Management (BLM), provides the initial seed collections that are used for research and long-term storage. SOS relies on partners, such as botanic gardens and native plant centers, to achieve nationwide restoration goals.

The BLM is the largest purchaser of conservation seed in the Western Hemisphere, purchasing as much as 7.4 million pounds of seed in a single year. After the 1999 wildfire season, when 5.6 million acres burned, the US Congress recognized that there was a need to develop genetically and geographically appropriate native plant materials for restoration and rehabilitation. In 2001, the United States House of Representatives' FY 2001 Conference Report directed "…the agencies to develop a long-term program to manage and supply native plant materials for various Federal land management restoration and rehabilitation needs" thus forming the Native Plant Materials Development Program (NPMDP).

The BLM leads the NPMDP, whose mission is to increase the quality and quantity of native plant materials available for restoring and supporting resilient ecosystems. As the first step of the NPMDP, the overarching goal of SOS is to collect and store native seed for long-term conservation, as well as provide material for research on native plant materials development. SOS

seeks to collect high quality, accurately identified, genetically representative, and well documented native plant seed from multiple wild populations across the US. SOS has also contributed to international seed banking efforts.

Beginning in 2000, a partnership was formed between the BLM and the Royal Botanic Gardens, Kew (RBG), the leader of an international seed collecting effort known as the Millennium Seed Bank Project (MSB). The goal of the MSB is to collect all bankable species in the world. This effort also relies on partnerships to reach its goal. Throughout the 10-year partnership, SOS provided collections to the MSB, thus helping RBG reach their goal of preserving 10% of the world's flora.

In 2008, a Memorandum of Understanding was signed between the BLM and the Chicago Botanic Garden, the Lady Bird Johnson Wildflower Center, the New England Wildflower Society, the Greenbelt Native Plant Center of the New York City Department of Parks and Recreation, the North Carolina Botanical Garden and the Zoological Society of San Diego. As the lead agency for SOS, the BLM works to facilitate cooperation and coordination of SOS in the collection of native seed for conservation and restoration. The non-federal partners collaborating with SOS provide collections in areas where there is little federal land.

The collection focus of SOS is on species needed for restoration and rehabilitation projects. Teams may make multiple collections of species on their restoration target list as long as they are capturing unique populations in each collection. Collecting teams are encouraged to work with local federal land managers and the BLM National Coordinating Office to develop and execute priority target lists. Rare, threatened or endangered species are not collected by SOS, instead these fall under the purview of the Center for Plant Conservation. In order to achieve the goal of banking most of the US flora, SOS has prioritized the collection to include:

- Species of high restoration value
- Species most at risk from climate change and associated threats such as increased wildfire and invasive species
- Species representative of key ecological communities.

More specifically, there is a goal for each species: to have a minimum of 20 accessions throughout that species' range, so that a high percentage of the genetic diversity can be preserved. Each collection is to include 10,000 – 20,000 seeds from a minimum sample size of 50 plants without taking more than 20% of the available seed on a given day. This protocol was established to collect 95% of the genetic alleles while ensuring collections do not exceed sustainable harvest levels.

As of October 2013, SOS has collected a total of 14,500 accessions representing 4,700 different taxa. Within the National Collection, 52 species are represented with 20 or more collections. The most frequently collected species include *Poa secunda, Achnatherum hymenoides, Artemesia tridentata, Elymus elymoides, Hesperostipa comata*, and *Allium acuminatum*; these represent some of the workhorse restoration species used by the BLM.

In addition to banking species for long-term conservation storage, SOS has established a working collection of native plant germplasm available for research on plant materials increase. It is not sufficient to simply bank seed; in order to be useful, species need to be developed for restoration use. This entails research on seed transfer zones (geographic areas in which seed can be used without danger of maladaptation), research on propagation, harvest and storage methods, and production of large quantities of source-identified seed for restoration. There are more than 500 partners engaged in the entire NPMDP.

The BLM has contributed over US$70 million, which has been leveraged by partners to more than US$100 million. Partners are critical for the success of the NPMDP and SOS. In the US, interns and volunteers from botanic garden partners enhance the work of federal agencies. One example of enhancing botanic capacity is the Conservation and Land Management Internship Program coordinated by the Chicago Botanic Garden. Additionally, partners are critical for carrying out the research, much of which is species specific, to determine the appropriate conditions and techniques for growing wild species in an agronomic environment.

Ecoregional partnerships in the Colorado Plateau, Great Basin, Mojave Desert, and Pacific Northwestern United States are carrying out research to answer questions related to how to grow native species as crops, how to harvest and clean the seed, methods for diversifying monocultures of invasive plants, and how to restore the plant communities in their unique ecosystems across the western US. The NPMDP also works with private industry to improve the equipment needed for successful native plant seedings.

In 1999, the BLM spent US$52 million on 6.5 million pounds of seed; 70% was non-native. Since the establishment of the NPMDP the tide has turned, and today the BLM uses more natives than not. SOS continues to make collections of US native plants and the NPMDP is involved in dozens of projects to expand the research and use of native plants.

Conclusion

There is a need for continued partnerships to focus on using genetically and geographically appropriate materials, so that restoration projects are successful and funds are spent wisely. Native species **do** work in restoring native plant communities for native wildlife such as sage-grouse. They take more time to establish and require continued research and development, but in the end resilient healthy ecosystems will result.

Current status and challenges of Chinese plant taxonomy

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Abstract

With a consideration of the history of plant systematics in China, a detailed analysis of the current status of plant taxonomy in China was undertaken, with particular focus on the literature, specimen accumulation, research personnel, and compilation and quality of published floras, in relation to the Convention on Biological Diversity Protection Strategy, the China Plant Protection Strategy and Cataloging Chinese Native Species requirements. The analysis demonstrated that a large gap exists between the taxonomic knowledge of China and that of western countries. A critical factor underlying this is the knowledge gap in the evaluation and guidance of basic research. The lack of basic data on Chinese plant species has seriously affected the quality of efforts to catalogue all plant species, as well as establishment of both Red and Black Lists based on species classifications. Consideration of the future developments and direction of plant taxonomy in China suggests that China's advantages in geography and resources should be fully utilized in order to participate in international collaborations and to produce high-quality research that conforms to the country's overall image and national strategy requirements. Additional objectives should be to provide a sound foundation for providing consultation to officials on the conservation of national biodiversity, an inventory of species, the assessment of academic research, resource protection, scientific and technological development, policy determination, and the management of species.

Key Words

Plant taxonomy, status, challenges, China

Introduction

The Tenth Meeting of the CBD (Convention on Biological Diversity) held in October 2010 in Nagoya, Japan, set a target (Target 1) for the completion by 2020 of a global online flora (CBD, 2015). The XVIII International Botanical Congress held in July 2011 at Melbourne identified this goal as the common task of global botanists (Science in Public, 2011). In April 2012 the Missouri, New York, Edinburgh and Kew botanic gardens released a guideline document about the iimplementation of GSPC Target 1 by 2020 (Missouri Botanical Garden, New York Botanical Garden, RBG Edinburgh and RBG Kew, 2012). In 1992 China became a Party to the Convention on Biological Diversity. At the sixth Conference of the CBD Parties in 2002 the Global Strategy for Plant Conservation was unanimously adopted. China has actively participated in the work of the Global Strategy for Plant Conservation. The China Wildlife Conservation Management Department of the State Forestry Administration has organized experts to compile the Chinese Wild Plant Conservation Action Plan. It has cooperated with the Chinese Academy of Sciences and other organisations, on the basis of GSPC Target 16, to further the preparation of the China Plant Protection plan.

China's Strategy for Plant Conservation (China's Stategy for Plant Conservation Editorial Committee, 2008) is the authoritative contemporary Chinese statement of policy in the field of biodiversity conservation. Current problems in the surveying and cataloging of native plant species in China are summarized as follows:

- The cataloguing of plant collections has been in process for a relatively short time; many recently discovered species are not included in existing lists; the naming of many plants is inconsistent.

- There are few digital herbarium records, and the network for sharing data is imperfect.

- There is a serious shortage of researchers engaged in taxonomy and the study of plant diversity. There is also a shortage of professional training and of funds for the construction of facilities.

Since *Species Plantarum* was published, plant taxonomy has continued to develop. From 1959 to 2013 an inventory of China's flora has been completed in two versions: *Flora Reipublicae Popularis Sinicae* (FRPS), a Chinese-language version compiled between 1959 to 2004, and *Flora of China* (FOC), an English-language version developed between 1994 to 2013. So to what extent are China's plant species now clearly catalogued? Are plant protection lists (Red Lists) and invasive alien plants lists (black lists) complete? What is the state of plant taxonomy in China? What are the problems? This article attempts to conduct a comprehensive analysis, to address academic research scholars, government policymakers, to catalogue biodiversity basic reference data about rare and endangered species, in order to assess the protection that these species need.

The Basic Data

China is known as "the mother of gardens", with more than 30,000 species of vascular plants, about the total for Europe and North America combined (North America about 20,000, and Europe only about 12,000). China is recognized as the country with the world's richest plant biodiversity in northern temperate zones. In 1916, a plant taxonomy article by Chien Chong Shu marked when the Chinese people began to describe their own plants using a non-traditional taxonomy. Since then, botanists have overcome many difficulties to continue this work. Over the past half-century four generations of Chinese organizations have, despite gaps in the literature, inadequate specimens, lack of experience, and the Cultural Revolution period, finally completed 80 volumes of the projected 126 volumes of the *Flora of China* (FRPS, 1959–2004). This needed the training of several generations of staff.

In specialized areas of plant taxa, Chinese scholars have done a lot of good work and results achieved quite an influence in the world: the discovery of the Dawn Redwood and some silver firs have not only greatly enriched Chinese plant diversity and the world flora; but have been recognized as major achievements in plant taxonomy. Ching's study of ferns in 1993 was awarded a National Natural Science First Award. Many floras and academic works have been produced, including *Northeast Woody Illustration* (1955), *Northeast Herb Flora* (1958–2005), and *Hainan Flora* (1964). China has completed floras for dozens of provinces, municipalities, autonomous regions and natural geographic regions. These works include the second edition of the *Inner Mongolia Flora*, *Beijing Flora, Flora of Taiwan* (in English), and the first versions of *Flora of Tibet*, *Yunnan Flora* and *Guangdong Flora*. The publication of the *Flora of China* played a positive role in promoting and complementing the publication of local floras and promoting local plant resource utilization and protection.

In parallel with the completion of local floras, the *Flora of China* has been completed (Flora of China 1994–2013). It comprises 25 volumes of text and 24 volumes of illustrations (available at http://flora.huh.harvard.edu/china/). This is an important work in the history of contemporary Chinese plant taxonomy and a landmark, in particular in the description of taxa, in the research involved, and other aspects of the revisions and changes from the original Chinese-language version. These changes have resulted in a lot of progress, the protection and utilization of plant resources in China; these changes have been of epoch-making significance to the world of botany. Recently, the English-language version of the *Flora of Pan-Himalayas*, completed by a team led by Prof. Hong Deyuan of Peking, has marked a new chapter of the history in the preparation of overseas floras by Chinese botanists. This work involved training teams, cultivating talents and accumulating experience. More importantly, it is a sign of the rising recognition of the importance of plants to the world.

The 21st century ushered in an age of 'information taxonomy', offering both unlimited potential applications but bringing more severe challenges. In China, more than 20 national main botanical digital sites have been set up, including the National Specimen Information Infrastructure (http://www.nsii.org.cn/), the Species 2000 China Node (http://www.sp2000.cn/joaen/index.php), the Biodiversity Heritage Llibrary China node (BHL-China, http://www.bhl-china.org/cms/ -page=page-1), the China Digital Herbarium (CVH, http://www.cvh.org.cn/), and the Chinese Field Herbarium (CFH, http://www.nature-museum.net/). These facilities not only provide a very modern way to manage the protection, use and management of natural resources, but more importantly, they provide a solid foundation for Chinese botany research Contemporary developments of digitalisation and networking in the development of taxonomy undoubtedly offer a golden opportunity to provide more complete background information to help in the urgent task of recording China's plant species. . But to see current achievements in context, we must also face the following realities:

- Many historical data collections have a serious shortage of corresponding literature, and a lack of systematic collation. There is limited amount of specimen collection, and their management is seriously lagging behind.

- There is a worrying shortage of young classical taxonomists. Much descriptive work is of poor quality and difficult to follow up. There are poor evaluation systems and insurmountable competitive mechanisms.

- There is a big dichotomy between the size and variety of the country's plant communities and the manpower available to research them.

Conclusion

A world online flora is due for completion in six year's time (2020). China has one tenth of the plant resources of the world, and to record it is clearly an extremely difficult task for the Chinese people. At the same time, the popularization of science and education for the more than 1.3 billion population of China will improve the quality of people's appreciation of the academic community, including various types of experts and scholars as well as all levels of managers and policy makers. Classical plant taxonomy at the national level must be forward-thinking and strategic decision-making, especially top-level design and overall layout. China does not lack talent, and there is also no shortage of botany enthusiasts, so the key is how to promote and guide, how to attract talent and cohesion to the task. To this end, the following recommendations are made:

- An emphasis on infrastructure, the speeding-up of plant rescue and storing background information. Completing taxonomic literature and its digitisation, networking the results and improving the efficiency of its use. To finish reviewing the historical data on Chinese plants collections as soon as possible, including not only China's domestic collection cases, but also including foreign collections made over the past 300 years; also collections not only of the less surveyed areas of China but also of neighbouring countries; better management of existing collected specimens and digitalization of records of specimens collected from overseas.

- Increasing classical taxonomy expertise and numbers to ensure that the needs of the country are met..

- On this basis, to find out as much detail as possible about Chinese plant resources, and lay a solid foundation for the country's overall science and the popularization of science. To implement further revisions of the *Flora of China* and the local floras and related types of directories and manuals, not only to provide an academic reference base for research, but also help in the popularization of science, public education and improving the quality of taxonomic data, which is China's core mission of plant taxonomy.

- To establish China's geopolitical and resource influence in East Asia, so that China, as a country with an enormous variety of plant life, can full advantage of its geography and resources. To accelerate specialist dedicated research work to East Asia as a main aim, while developing investigation and research resources in neighboring countries and regions (especially South Asia, Southeast Asia and Central Asia and West Asia). This is also to lay a firm foundations for the development and use of national strategic resources.

- To speed up the construction of information networks, make full use of various resources sharing platform integration, enhance taxonomic infrastructure (specimens, images and documents) and other digital networks' speed and level with a variety of resources, not only for the overall scientific and comprehensive production out , in order to improve the efficiency of scientific research and lay the foundation level of resource utilization, while providing the basic data for the Conservation and Utilization of plant resources, and to provide authoritative information to the strategic decision-making core national interests.

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Tracing a path for plant conservation in central Mexico: the evolution of the Cadereyta Regional Botanical Garden

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Abstract

The Cadereyta Regional Botanic Garden (CRBG) is actively contributing to the conservation of the Mexican flora. It focuses on the arid zone of the State of Queretaro, which is a small state with less than 1% of Mexico's land but with a remarkable plant richness of nearly 4,000 species. The CRBG collections include 82 endangered species, according to the Official Mexican Standard, 46 species are in the risk categories of the IUCN Red List and 185 in the CITES Appendices. Propagation tasks include the development of propagation protocols and the cultivation of more than 100 native plant species, which are available for reforestation and restoration activities. The Garden has an active environmental education programme, oriented to elementary school pupils, with an increasing audience in the recent years. Its scientific work supports the correct assessment of extinction risk for endemic species. In the last three years, new species have been described or reviewed. This paper is summary of the recent advances by, and challenges to, the CRBG, which is working to meet the definition of a botanic garden as defined by BGCI.

Keywords

Botanic Garden, Cadereyta, conservation, flora, Mexico.

Introduction

The Cadereyta Regional Botanic Garden is a public institution that depends on the Queretaro State Council of Science and Technology (CONCYTEQ, in Spanish). The Council is part of the Ministry of Education of Queretaro State.

The Garden is located in the municipality of Cadereyta de Montes, in the State of Queretaro, central Mexico, at 20º41'12" N, 99º48'15" W. It is close to the semi-arid zone of Queretaro and Hidalgo States (Figure 1), which is considered to be the southern end of the Chihuahuan Desert (Hernández-Oria *et al*., 2007), and is known world-wide due to its big number of desert flora endemics (Hernández & Bárcenas, 1995, 1996). The State of Queretaro is one of the smallest in Mexico. It represents less than 1% (0.59%) of Mexico's territory but its number of plant species is a little over 4,000 (Rzedowski *et al*., 2013).

The surface of the Garden belongs to an *ejido*. An ejido is land expropriated from large private holdings and redistributed to communal farms. The land is owned by the government, the usufruct by *ejidatarios*. In 1989, members of the Ejido of "Fuentes and Pueblo Nuevo" signed an agreement of bailment with the CONCYTEQ for the Botanic Garden establishment.

The CRBG has developed an integrated scheme of tasks, based on BGCI's definition: "Botanic gardens are institutions holding documented collections of living plants for the purposes of scientific research, conservation, display and education". It also works with other Mexican botanic gardens to participate in the Mexican Strategy for Plant Conservation (EMCV). To achieve these goals, the principal areas at the Garden are *ex situ* Conservation, Scientific Research and Environmental Education. Its main features and achievements are described below.

Figure 1. Location of the CRBG

Ex situ conservation

The botanical collection of the CRBG serves as a repository for 303 taxa of 27 botanical families. In recent years, field work and plant collecting have been enhanced, and today four main sections of the Garden keep an important contingent of plants. These sections are:

Cactaceae of Queretaro, the main section. This section represents the diversity of Cacti in the centre and north of Queretaro; it includes both cacti and specimens of allied families.

Mammillaria in Mexico, a specialized collection of this genus, almost endemic to Mexico. It has more than one hundred of species.

Agavaceae of Queretaro is a collection with 38 taxa of the Agavaceae family, including *Agave, Manfreda, Polianthes, Prochnyanthes, Beschorneria* and *Yucca* genera.

Trees of Queretaro Valley, an interesting group of tropical dry forest trees, whose remains still can be found in the south of the State of Queretaro. Botanical collection sections preserve threatened and microendemic species from the semi-arid zone of Queretaro and Hidalgo.

Specimens at the botanical collections are used as a source of germplasm for the propagation programme, which has propagated more than one hundred species to increase the stock available for replacement, donation, reforestation, and sales.

The CRBG offers advice and training in plant propagation. An interesting example of this was the advisory given to the “Xitales”, a confraternity of persons in charge of the celebration of religious feasts in the municipality of Tolimán. The feast includes the erection of a special structure named “Chimal”, adorned with thousands of leaf bases of sotol (*Dasylirion acrotrichum* (Schiede) Zucc.) (Figure 2). *D. acrotrichum* is listed in the Mexican NOM-059-SEMARNAT-2010 as “threatened” (A), and permission from the Mexican Ministry of Environment and Natural Resources must be obtained in order to collect it. In 2009, the permission was conditional on the establishment of a propagation place of the species, and the “Xitales” received advice and training at the CRBG for

Figure 2. A “Chimal”, made of leaf bases of *D. acrotrichum*

the legal propagation of *D. acrotrichum*. Recently, they began to reintroduce young plants in their habitat (Figure 3).

Environmental education

The main goal of the garden’s educational programme is to educate individuals to become aware of and take care of the environment and its problems, and to provide them with appropriate tools. This education programme has three essential elements: to promote the Botanic Garden as an attractive place for study, exhibition and cultivation of plants, the Environment as the system where plants and humans coexist, and the sustainable development as a guiding concept.

The education programme is based in a conceptual framework that proposes constructivism as its pedagogic approach (Sánchez & Galindo, 2009). Individuals live and experience real situations and activities, and learn directly from their interactions with the environment. The interaction becomes a unique phenomenon for every single individual, who should change his behavior towards the environment after information process. An essential part of the programme is the “37 concepts” list, an integrated learning scheme to guide pupils towards nature interpretation and social awareness (Sánchez *et al*., 2012) (Figure 4).

The programme is oriented to elementary schools pupils from the municipality of Cadereyta de Montes. The sessions are developed outdoors, in an informal atmosphere, and pupils take the leadership of activities. At the end of each session, a time for reflection and interchange is given, and students are encouraged to analyze their behavior and attitudes, to identify the learning achieved. The programme started in 2009; since then, an increasing number of elementary school pupils have come every year to participate. In 2013, 4 419 pupils participated.

Figure 3. Reintroduction of *D. acrotrichum*, propagated by the "Xitales" (Photographs courtesy of the Cadereyta de Montes municipality).

Scientific Research

Since 2003, the CRBG has been developing scientific research. The objective of this area is to generate and disseminate scientific knowledge about plant resources, with the main emphasis on flora and vegetation of the semi-arid zone of Queretaro and Hidalgo.

The main lines of scientific research are: the study of useful plants, optimization of growth factors of useful plants inside a greenhouse, documentation of regional plants collections, the study of conservation status of key species and ecological restoration.

The CRBG is enhancing this area, establishing key partnerships with local, national and international educational institutions. The Autonomous University of Queretaro, the National Autonomous University of Mexico, the Autonomous Metropolitan University and the Université Laval in Canada are some examples of these partners.

A brief resume of the Scientific Research at the CRBG is summarized in the following list, including the project name, date, source of funds and main results, besides scientific and divulgation papers:

- *In situ* ecological evaluation and propagation of threatened species of the Cactaceae family at the semi-arid zone of Queretaro. (2003-2006). Funded by the FOMIX (acronym for "mixed funds") Programme, with participation of the National Council of Science and Technology (CONACYT) and the CONCYTEQ. (FOMIX-QRO-2003-CO1-10152). A book was published (Sánchez *et al*., 2006) and nineteen propagation protocols were standardized. Mother plants collected during this project are sources of germplasm at the Garden.

- Technical notes about the conservation status of the Cactaceae species in Queretaro. (2004-2006). Funded by the National Commission for Knowledge and Use of Biodiversity (CONABIO). (CONABIO-CK016).

- "The three R's that you are." Cacti conservation with participation of local communities. (2005-2006). Funded by HSBC, through BGCI. A prototype of a 'training' greenhouse was installed at the small town of El Arbolito, in a key location of the municipality of Cadereyta, in terms of cactus biodiversity. Five local boys and girls were trained in the appreciation of endangered species, and its sustainable propagation.

- Evaluation of the conservation status of *Echinocereus schmollii* (Weing.) N. P. Taylor, at Cadereyta de Montes, Queretaro. (2005). Partially funded by the National Autonomous

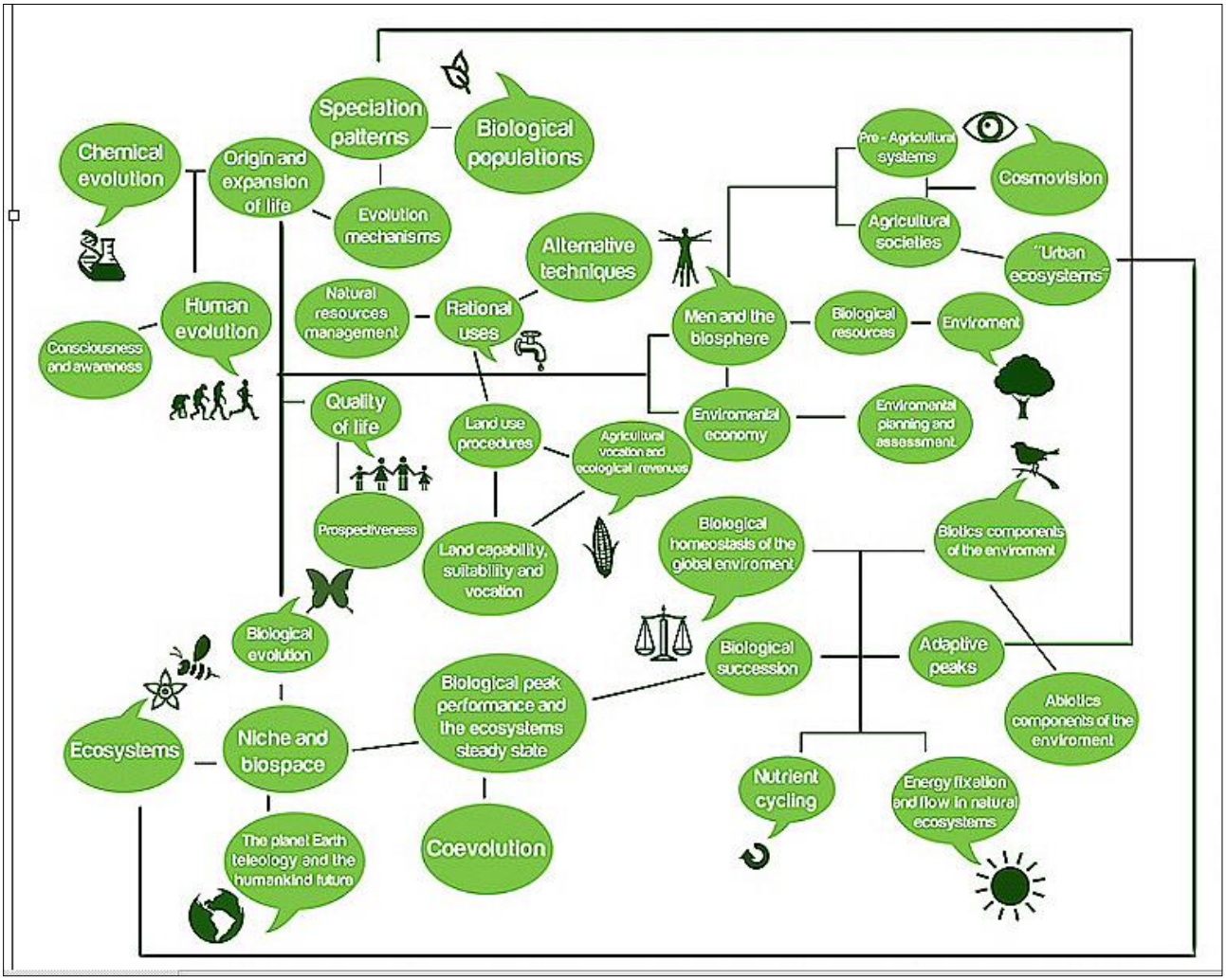

Figure 4. “37 key concepts”, foundation of the Educational Programme

University of Mexico (UNAM). A special issue of the Mexican journal *Cactáceas y Suculentas Mexicanas* was published with the information of this project.

- Key species propagation, for their use in reforestation and restoration in the municipality of Queretaro, and its area of influence. (2007-2011). Funded by the FOMIX Programme (CONACYT-CONCYTEQ). (FOMIX QRO-2006-C01-54300). A book was published (Sánchez *et al*., 2011). Thirty five propagation protocols for key species of the tropical dry forest were developed. A pool of 3,000 young plants was delivered to the Queretaro Trust for Environment (FIQMA). The CRBG has participated in regional workshops for the use of native flora in urban areas.

- *Mammillaria herrerae* Werderm. A conservation project at Cadereyta de Montes, Queretaro. (2009-2011). Funded by the British Cactus and Succulent Society (BCCS). An inventory of this extremely threatened species was made. It was possible to collect seeds. A plot for the propagation of the species was established at the CRBG.

- Evaluation of the conservation status, uses and threats of *Yucca queretaroensis* Piña (Agavaceae). Evaluation of its relevance for inclusion in the CITES Appendices. (2011-2013). Funded by the CONABIO. (CONABIO-JE005). The species was listed in the Appendix II of CITES during 2013, thanks to the information generated.

A colophon

The Cadereyta Regional Botanic Garden has evolved, increasing its tasks, commitments and responsibilities. However, much work is still needed to enhance key areas. The administration of the Garden is aware of this and is strengthening new partnerships and seeking creative ways to ease educational and research activities, and to collaborate with national and international organizations for the conservation of flora.

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New Zealand botanic gardens and the Global Strategy for Plant Conservation

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Botanic gardens are remarkable places! We are institutions with a unique mix of skills and infrastructure, and our 'botanical gardeners' are much more than professional gardeners; potentially involved with a mix of horticultural displays, education, scientific research and conservation (Blackmore *et al*, 2011).

To successfully champion this esteemed title, botanic gardens need to be active in a wide range of plant-related issues – including plant conservation. Sir Ghillean Prance hit it on the head: "*A botanic garden that does not emphasize plant conservation in its mission programme… is not adequately responding to the challenges of today's world*" (Guerrant *et al* 2004).

The Global Strategy for Plant Conservation (GSPC) provides a framework for botanic gardens to participate in and can help shape how New Zealand meets its obligations to the Convention on Biological Diversity (CBD). A major initial call for the CBD to adopt a strategy for plant conservation came from the heads of several botanic gardens (Wyse Jackson, 2011) and now botanic gardens worldwide are embracing the GSPC to achieve conservation action actions at global, national and local levels.

The GSPC includes 16 targets grouped into five objectives to help guide plant conservation activities and there are five targets which New Zealand botanic gardens are in a position to really contribute toward – targets 3, 8, 14, 15, and 16.

New Zealand botanic gardens could adopt these GSPC targets into their work programmes to help fulfil our obligations to the CBD and work proactively together, and with others, to help conserve plants and halt the continuing loss of New Zealand's indigenous plant diversity. Not only do we have an obligation to contribute to the GSPC, but it's to our advantage to do so. Working toward the targets of the GSPC gives significance to our work and is a very meaningful contribution to our community.

We are lucky in New Zealand that the scale of the issue is reasonably apparent and well documented. We have a good understanding on what species are present and how many are threatened (de Lange *et al*, 2013). Currently New Zealand botanic gardens hold nearly 40% of New Zealand's indigenous vascular plant species that are considered to be threatened. This is on par with international averages for target 8 of the GSPC (Secretariat of the Convention on Biological Diversity, 2009). Having already achieved this percentage without a targeted attempt to do so places New Zealand botanic gardens in a very positive position.

So how do botanic gardens fit into conservation work in New Zealand? Most gardens are funded by a city or local authority (district or regional council). Many are relatively old by New Zealand standards, some even predate the start of centralised government, most predate events that have shaped how conservation work happens in New Zealand today such as the enactment of the Treaty of Waitangi Act 1975, the formation of the Department of Conservation (DoC) in 1987 and of Crown Research Institutes in 1992. However, there is no act of government that defines what a New Zealand botanic garden does, so we depend on our individual management plans.

With the setting up of the GSPC we have gained a valuable international tool. The GSPC sets a framework to work within. However there are some issues:

(1) Botanic gardens in New Zealand receive no contact at all from the GSPC national focal point. A situation that is also reflected in our national statement on the website of the Convention on

Biological Diversity (CBD): "*The Government's primary focus is on indigenous biodiversity, particularly endemic species, and for conservation work in situ rather than ex situ*." (Secretariat of the Convention on Biological Diversity), so botanic gardens, seen largely as *ex-situ* practitioners, are not supported;

(2) Our botanic garden management plans, while clearly stating our role in conservation, mostly do not include any mention of the GSPC or the CBD;

(3) The recent formation of Botanic Gardens Australia and New Zealand (BGANZ) has allowed much stronger networking and collaboration between botanic gardens, but BGANZ meetings in New Zealand generally do not address progress on the GSPC.

Practical steps we can take towards the GSPC are as follows:

- Contribute our living collection names to the national service, the New Zealand Organism Register (NZOR) and ensure that supporting herbarium voucher specimens are made where appropriate (target 1).

- Record and share horticultural and propagation methods; explore methods of publishing about our work; and explore a framework for assessing, enabling and sharing the results of research involving botanic garden-sourced plant material (target 3).

- Form partnerships to assist with germplasm storage; enable plant use for conservation – for example by sharing information about what we grow; make collection records accessible to DoC staff and appropriate researchers (target 8).

- Explore methods to record and share weediness data; participate in weed surveillance programmes; support sentinel plant research for pests and diseases (target 10).

- Explore appropriate and sensitive recording of plants with local customary use – for example, record only what is appropriate and supportive to local community use of plants; Work appropriately with the Treaty of Waitangi Act 1975 including the treaty claim WAI262 relating to indigenous flora and fauna (target 13).

- Explore the role of the BGANZ network in conservation; relationships with agencies such as the DoC, non-governmental organisations (such as the New Zealand Plant Conservation Network (NZPCN), and various ecosanctuaries), and with universities and crown research institutes; develop a relationship with BGCI that is more relevant to our national situation – in particular, encourage contact with the New Zealand member of the BGCI scientific advisory board; at present we receive no contact from this person (target 16).

Many of these changes require some persistent effort on the part of botanic gardens and enthusiastic individuals, as well as the support of partnerships. The beginning of such can perhaps be seen in some on-the-ground collaborations. The following example of from Wellington illustrates a willingness at the local level to work together:

Otari Native Botanic Garden (Otari) in Wellington has grown several local species in partnership with the DoC and the Wellington Regional Council. One such species that staff have been working with since 2009 is *Brachyglottis kirkii* var. *kirkii* (kohurangi, or Kirk's tree daisy).

Kohurangi is a forest-dwelling epiphytic daisy considered to be at risk and to be declining nationally; it is under critical threat in the Wellington region. Herbarium records and historic plant lists place it in the Wellington City area as late as 1908, but unfortunately it is now considered extinct in the Wellington City area. The DoC and the Regional Council have identified several sites

on their estate that kohurangi grows in the wider Wellington region, but this amounts to only a handful of plants in all.

The intention is to reintroduce kohurangi back into the forest next to the Otari Garden and two nearby areas to bring back a viable population to Wellington city. Once established, we can also begin to build the existing populations of plants *in-situ*.

Otari staff have taken both seed and cuttings from plants, but unfortunately seed has had a zero percent strike rate. Is it the technique used, or is the seed not viable? Possibly because of the small population sizes, between 1 to 10 plants depending on site, the seed is not viable. If the seed is not viable, what is the future of those plants out in the wild?

No matter what protection they are afforded, the likelihood of successful recovery of the small populations seems remote. Without the collaboration of the organisations involved and the use of *ex-situ* facilities, the future of this species in the wider Wellington area is undoubtedly bleak.

So what could the future look like for New Zealand botanic gardens involved in plant conservation? Here are several further opportunities to consider:

- The GSPC provides a great framework for us to participate in. Let's start incorporating the GSPC into our everyday business and culture. Put plant conservation on the agenda at meetings and conferences. When considering management plans, interpretation, education policy, or staff development plans, have them reflect the GSPC targets.

- Build your threatened species collections in a targeted, meaningful way. Find out what species you might be able to contribute to the survival of, and with whom. Build your collection and make it available for recovery programmes. (target 8)

- We need to partner with others to be successful in recovery programmes. National and local governments, universities, the New Zealand Plant Conservation Network (NZPCN) and the Royal Forest and Bird Society are good examples. Private landowners too, whether on a 1000-hectare farm or a quarter-acre section can be interested in biodiversity conservation on their properties. (target 16)

- One of the ways to build partnerships is to demonstrate success. It may be the case that people and organisations we might consider partnering with don't know what resources we have and what we are capable of. Show others that botanic gardens are valuable and we can really help them carry out conservation work.

- Build our capacity to work in this space. We have the facilities and knowledge at our disposal that makes us ideal candidates to help with plant conservation work, but conservation hasn't historically been our core business. We need to learn more about how *ex-situ* conservation can best support *in-situ* conservation. (target 15)

- Send staff to NZPCN conferences, network with your local Botanical Society and attend their field trips. The Royal Botanic Gardens Kew offers an International Diploma in Plant Conservation Strategies; the NZPCN offers two plant conservation-related courses that botanic gardens have perfect facilities to deliver: Introduction to Plant Life in New Zealand and Plant Nursery Management and Propagation. (target 15)

- Start recording what we do with threatened plant species, good propagation protocols, their phenology in cultivation, and their cultural requirements. (target 3)

- Share our knowledge, publish it in our newsletters and magazines, put in on our websites, and present our successes (and failures) to our colleagues, so that we increase our collective knowledge. (target 3)

- Develop visitor interpretation and educational messages that express the work we do and provoke thought about plant conservation. (target 14)

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Partnerships for plant conservation: seed banks in Australia

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Abstract

The Australian Seed Bank Partnership (the Partnership) is a national effort to conserve Australia's plant diversity through collaborative *ex situ* conservation, research and knowledge sharing. Through shared efforts the partnership is working to bridge the gap between policy makers, researchers, land managers and on-ground conservation and restoration activities. The establishment of the Partnership has required an evolving process to ensure it is an effective venture that actively contributes to national and international plant conservation priorities. This paper discusses the work of the Partnership and outlines its areas of collaboration for plant conservation. This case study highlights the importance of a government framework for conservation partnerships and illustrates the value of such partnerships in effectively leveraging resources to make significant contributions to conservation efforts. The challenges and benefits presented through working across a federation of states are highlighted, and the social and philosophical shift required to expand functional boundaries of partnership members beyond their traditional 'turf' is discussed. From these insights, consideration is given as to what is needed to maintain a successful national partnership.

Keywords

Partnerships, conservation, plant diversity, seed banks.

Introduction

With the rapidly reducing resources available for plant conservation in countries, including Australia, partnerships are seen as a key way to do business and deliver a conservation mandate (Trauger *et al*. 1995: 114; Toupal & Johnson 1998: 4) and so deliver societal change (Glasbergen 2007: 4). While partnerships are not always be the solution or be appropriate for every situation, they can be critical to advancing plant conservation programmes and accomplishing goals (Trauger *et al* 1995: 115). Moreover, partnerships can pave the way for opportunities within botanical institutions to diversify how they undertake their conservation efforts, as well as result in necessary change to widen the perspective taken by these institutions.

This paper presents a case study on the Australian Seed Bank Partnership (the Partnership) and attention focuses on its establishment and ways in which this stakeholder partnership is working on national plant conservation priorities. It also reflects on what makes a successful national partnership and considers some of the challenges and lessons learned to date.

Context and governance for the Australian Seed Bank Partnership

At a continental scale 87% of Australia's native vegetation remains; however, there has been substantial loss of vegetation since European settlement and native vegetation loss continues at a rate of nearly 1 million hectares per year (State of the Environment, 2011: p.586). Changing climates, new biological security issues and increasing natural disasters, such as fire and flood, are also challenges facing Australia's plant conservationists.

Considering all these challenges to the maintenance of biodiversity, the Australian Seed Bank Partnership has an ambitious vision of a *'future where Australia's native plant diversity is valued, understood and conserved for the benefit of all'.* The Partnership works towards achieving this vision through collaborative efforts in seed banking, research and knowledge sharing. This stakeholder partnership (Leach *et al* 2002: 646) consists of representatives from fourteen leading

botanic gardens, state environmental agencies and academic institutions, as well as non-government organisations. In addition, there are several Associates who work with the Partnership on a project-by-project basis.

The Partnership has complex beginnings and it builds on a legacy from phase one of the Royal Botanic Garden Kew's Millennium Seed Bank Partnership. The Australian Seed Bank Partnership has been established as the principal conservation programme and a trading name of the Council of Heads of Australian Botanic Gardens Inc. (CHABG). CHABG was originally an informal network of executives formed in the early 1990s; it has recently evolved into a legal entity through its incorporation and registration as a charitable organisation. In addition, an executive role and secretariat are provided by the Australian Government, through the Australian National Botanic Gardens.

Establishing this governance structure was crucial for the long-term management of the Australian Seed Bank Partnership programme. Particular governance arrangements are required to enable fundraising from such sources as trust and foundation grant programmes and philanthropic and public donations. Furthermore, creating a board with strong connections to environmental agencies within Australia's state and territory governments, as well as the Australian Government, enables the Partnership to access established communication channels that can support the promotion of the role of *ex situ* conservation in integrated conservation management.

Scope of collaboration

The challenge for any conservation partnership is determining what needs to be done as a collaborative effort and how it needs to be done; this process requires a team with expertise in leadership, strategic thinking and negotiation. The current scope of collaboration by the members of the Australian Seed Bank Partnership is outlined in Table 1.

Progress to date

Leach *et al* (2002: 650) explain that 'Critics assert that partnerships consume excessive amounts of time and effort, create new and unnecessary layers of bureaucracy, divert attention away from important problems, [and] give false legitimacy to parochial deliberations when regional and national interests are at stake'. There is little doubt that partnerships require significant resources to provide leadership and manage the communications, negotiations, projects, fundraising and administration, just to name a few. The Australian Seed Bank Partnership is trying to address national plant conservation interests through its collaborations and thereby, encourage a national perspective and challenge parochial jurisdictional thinking within *ex situ* conservation.

There is an array of issues that a partnership like the Australian Seed Bank Partnership can address through its collaborative national approach, particularly within a federated system of states and territories. To measure the multiple dimensions of success one needs to consider measures of outputs, actions and perceived values of the partnership by its members. It must be highlighted that the evaluation of the three year old Partnership programme is in its early stages. This paper will initially draw on quantitative data from recent reports on partnership projects to measure actions and outputs, as well as using qualitative data from participant observation and a focus group conducted with key stakeholders to assess the perceptions of the value of the Partnership.

The first two and a half years of the Partnership's development saw the establishment of its governance arrangements, negotiation of its ten-year strategic business plan, creation of its brand (including a web presence) and the growth of stakeholder relationships. By the third year, the Partnership began to deliver on various agreed plant conservation-related priorities. It is noteworthy that these timelines for establishment are along similar timelines to those experienced by other conservation partnerships. For example, in the United States, studies have found that the majority of watershed management partnerships often took more than four years to achieve

several benchmarks of success (Leach *et al* 2002: 662 and 665). Consequently, caution must be taken with prematurely judging early stage partnerships as failures. It typically takes between four to six years '…*to educate participants, overcome distrust, reach agreements, secure funding, and begin implementation*' (Leach *et al* 2002: 666). The development of the Australian Seed Bank Partnership is observed to be following similar timelines to those described by Leach *et al* (2002). For example, in its third year of operation the Partnership is beginning to secure project funds and deliver outputs that contribute to achieving two of its main goals.

Key areas of cooperation	**Defining the cooperation**
Collections	Prioritising seed collection and banking of national priority species including threatened, endemic ones and those of known or anticipated economic importance.
Influencing national policy	Full cycle of influence from defining the problem, planning, lobbying and raising awareness of the role of *ex situ* conservation in the conservation of biodiversity to influence government policies and strategies and their implementation.
Enhancing scientific opportunities	Collaborative mentoring and postgraduate supervision.
	Sharing scientific resources and facilities at a country-level to support efficient use of resources.
	Collaborative research to assist in the efficient use of resources and expertise, enhancing research quality through engaging a range of experts, as well as reducing the likelihood of duplication.
Leveraging resources	Sharing resources and undertaking collaborative fundraising for *ex situ* conservation that addresses national plant conservation priorities.
Sharing knowledge	Sharing collection information for the benefit of researchers and the conservation and restoration sectors.
Training and capacity building	Bringing national expertise together to build capacity and offering training for the conservation and restoration sectors.

Table 1 Scope of collaborative efforts by the Australian Seed Bank Partnership

One of the Partnership's' goals is to collect and store seed in secure seed banks as long-term insurance against loss of plant diversity (so contributing to GSPC Target 8). Efforts to achieve this goal are currently being made through the *1000 Species Project*. This project has involved partners developing a national priority list for seed collections of 1000 endangered, endemic or economically significant species. As a result of Australia's federated system of states, the process to create a priority list has required careful consideration of State, Territory and Australian Government biodiversity conservation legislation.

Through a three-year fieldwork fund, generously provided by the Royal Botanic Gardens Kew, and a collective 82% in-kind contribution from the eight participating partners, the collecting work for the 1000 Species Project commenced in the 2012/2013 financial year. In its first year, 155 new taxa were added to conservation seed bank collections. The Partnership also received funding from the Australian Government, and 70% in-kind contributions from the two participating partners, to build provenance collections of 20 threatened species susceptible to 'dieback' (infestation by the fungus *Phytophthora cinnamomi*) in areas of national concern.

Both of these collecting activities are a valuable illustration of how partnerships can leverage resources effectively for conservation activities, which address national concerns such as the impact of biosecurity threats in the maintenance of plant diversity. Furthermore, these projects also encouraged a wider perspective to be taken by the partner organisations beyond their tradition jurisdictions to ensure resources were directed to national priorities.

A second goal of the Partnership is the sharing of knowledge and engaging the public, private and charity sectors, as well as community members, in the work of the Partnership (contributing to GSPC Targets 14, 15 and 16)

The *Australian Seed Bank Online* is a project that builds an accessible seed information resource. The projedct hub operates as an aggregator of data supplied directly by member institutions. The hub gives these collections a 'common' presence on the web and enables extended information sharing and collaboration, as well as ease with reporting to governments and the Convention on Biological Diversity. The project is being delivered through the *Atlas of Living Australia* (ALA), which has been demonstrating significant success in coordinated planning and delivery of digitised content from Australia's biological collections, including Australia's herbaria. Stage one of the *Australian Seed Bank Online* has been realised solely through in-kind contributions from the Partners and the *Atlas of Living Australia* (a contribution conservatively valued at A$350,000).

There is evidence of a growing attitudinal shift among the Partners through working collaboratively on these projects over the past two to three years. Ongoing exposure of the Partners to different individual and institutional ways of thinking is increasing their ability to deal with Partnership matters from a national perspective and expand the functional boundaries beyond traditional 'turfs'. There is a growing vision of plant conservation beyond the member's jurisdiction and core business, and there is a cultural shift from inward-looking perspectives that consider the institution's immediate need for funds, to outward-looking approaches that prioritise resource allocation in terms of national priorities. It is also fair to say, that the national perspective can waiver from time to time and be challenged when institutional resources continue to decline, experts are lost from an institution and/or there are mounting institutional pressures through restructuring and changing priorities.

In the context of the Australian Seed Bank Partnership, we need to keep investing and supporting this cultural shift within botanical institutions, to provide the necessary backing for us to have real collaborations that result in national and international plant conservation benefits.

What makes a successful national partnership?

- Key ingredients for strengthening and maintaining partnerships have been discussed by others in case study literature (e.g. Toupal & Johnson 1998; Siebert & Smith 2004). Several limitations have been highlighted that affect the development of models for successful conservation partnerships. These limitations mean that the structure of a partnership needs to be tailored to enable a specific partnership to be successful, particularly over a large geographical area.

- Within an Australian context, consideration of Australia's large geographic area and its federated system of states is critical. This federated system means that the Partnership's work operates under a variety of legislative instruments. This has implications for undertaking truly collaborative projects with cross institutional collaboration. Particular areas effected are i) securing resources for its work because of jurisdictional funding frameworks; and ii) practical operations such as arranging seed collecting permits, negotiating priorities with three levels of government, and the ability to duplicate collections across states/territories for risk management.

The recent focus group with ASBP members revealed some key perceived values of the Partnership:

- Where there are limitations in capacity [of member institutions], the partnership has been beneficial in providing staff with opportunities to work with other partners and develop their experience and increase skill levels.

- …a national partnership assists in discussions with government and other funding bodies, providing a powerful case for demonstrating the rationalisation of funding for shared infrastructure and research goals.

The main issues that the partnership is successfully addressing are:

- Seed banking has been mainstreamed in host institutions

- Seed banking has become more visible due to national undertaking.

Importantly, individual efforts are recognised as contributing to the whole:

- While participation in research projects has been difficult, contributing to collaborative projects such as the development of [ASBP] web pages has been a valuable contribution to the whole partnership.

- While aspects of measuring partnership success can be subjective, there are characteristics of success common to partnerships that can provide the basis for assessment (Toupal & Johnson 1998: 5). Many of the ingredients of success identified with the Australian Seed Bank Partnership have been highlighted in other partnerships (e.g. Siebert & Smith 2004; Agranoff 2005) including:

  - **Executive leadership in mobilization:** Dedicated champions with a commitment to collaboration are critical to the development and promotion of a partnership. For example, champions within government have enabled the Partnership to have a seat at the table to contribute to national discussions and debate on the transition to management of myrtle rust (Puccinia psiddii). Furthermore, due to the Australian Government hosting the Partnership's Secretariat through the Australian National Botanic Gardens, communications on the partnership are sent to the Minister for the Environment, Parliamentary Secretary and Australian Government Senior Executive when appropriate. In addition, it has enabled the Partnership's work to be featured in international reporting such as briefs presented at the recent Convention on Biological Diversity's SBSTTA meeting in Montreal. Executive leadership is also provided by the Committee members of the governing body CHABG and member representatives on the Partnership's Strategic Steering Committee. All these champion efforts help to profile and enable the work of the Partnership at both a national and international scale.

  - **Brokering the collaborative:** A supported secretariat is crucial to the functioning of a national partnership. Secretariat staff need to take a broad national, and at times international, perspective and be high-level strategic thinkers. This is particularly important because a secretariat provides a key point of contact for new organisations and individuals wanting to collaborate. Furthermore, it provides resources and leadership to create opportunities for action, as well as bringing stakeholders together and conducting team building to strengthen collaborations across organisations.

  - **Monitoring and flexibility**: Taking a flexible approach to collaborative work is essential. The ASBP business plan provides a framework for achieving the Partnership's vision and goals; however, the agreed plan needs to allow flexibility to enable the Partnership to

respond to changing national priorities. Recent examples of changing national priorities in Australia include a new government elected with different conservation approaches, and new biosecurity risks through the establishment of myrtle rust (*Puccinia psiddii*) in 2010. Furthermore, flexibility is essential at times when partners are not 'ready' to tackle some of the agreed tasks and a stalemate results if things are pushed. An adaptive approach allows for project timeframes to be modified while still maintaining a commitment to the overall agreed priorities.

- **Financial mechanism:** A financial mechanism is essential for the success of a conservation partnership addressing national priorities. While the Partnership relies on its members to have a sustainable base to undertake their core business in *ex situ* conservation, the efforts needed to successfully deliver a visionary national collaborative programme in plant conservation require the creation of a sustainable financial mechanism. The process of working towards a sustainable financial model takes time and involves integrating a complex range of components to diversify funding sources and reduce vulnerability to changing political and financial climates. One key component of this mechanism for the Partnership includes the contribution of a national coordinator and secretariat services and facilities by the Australian Government, through the Australian National Botanic Gardens. In addition, voluntary in-kind contributions by members of the Partnership provide significant resources for strategic planning, project development, marketing and communications. These resources, combined with various grants and funds, have enabled the Partnership to develop its governance, agenda and commence work on 16 of its 32 identified priorities in its business plan within three years of operations.

Challenges and lessons learned from the Australian Seed Bank Partnership

All partnerships present challenges and the Australian Seed Bank Partnership is no exception. Participants in the recent focus group discussion revealed:

- Resourcing levels can make collaboration difficult and core business takes precedence.
- We need to think from a more national perspective…difficult for us to balance institutional core business with national priorities within our resource limits.
- …whether the states/institutions should be collaborative or competitive in applying for funding…

Some of the key challenges and the lessons learned are:

- **Staff shortages / staff turnover**: the small teams across Australian conservation seed banks, as well as staff shortages, staff turnover and contract staff all affect Partnership operations. Consequently, additional human resources need to be included in project proposals to enable Partnership members to participate in larger-scale or longer-term projects.
- **Expertise:** There needs to be diverse expertise in the steering committee and to support the administration of such a partnership. The expertise is needed in such disciplines as fundraising, strategic thinkers, research programme development, and financial and legal management. One of the most challenging aspects is getting research leaders who are able to make a long-term commitment to progressing collaborative research. This is an ongoing challenge where funds are not available to support the development of research ideas and collaborations.
- **Participation:** the participating partner organisations and their representatives need to be open to different views, interests and styles and this requires careful management.

- **Constraints and improvement**: Members of the Australian Seed Bank Partnership do not have equivalent levels of staffing, facilities or resources dedicated to seed science and banking. Consequently, members have different capabilities for achieving the Partnership's objectives and contributing to its overall development and activities. In some situations this has created issues that have needed careful management and consideration of equitability. For example:

  - Expectations that the Partnership will secure resources for an individual institution's core business

  - Advancing collaborative science is reliant on a small number of members who have research leadership skills

  - Varying expertise in project development and management places pressure on those with these skills.

- **Government buy-in** – There are challenges with Australia's federated system, which makes securing government support quite complex and an expectation that funding support for a national programme will come from the Australian Government is unrealistic. Furthermore, the corporate and philanthropic sectors expect government support for plant conservation efforts.

- **Communications** – Effective communication is the cornerstone of any successful partnership effort. There is a challenge to gain recognition as a fledgling organisation and this can affect the likelihood of engaging champions and securing funding. Managing both internal and external communications is one of the biggest ongoing challenges to maintaining a partnership and is resource intensive.

- **Relevance** – There need to be ongoing efforts to promote the value and relevance of a partnership's achievements to wider stakeholders. In the case of the Australian Seed Bank Partnership, these end users include those stakeholders who need access to scientific knowledge to assist with establishment in restoration projects; for example, state environment agencies, regional botanic gardens, land managers, researchers, and the nursery and horticultural industry.

Concluding remarks

The Australian Seed Bank Partnership draws together diverse expertise and offers a political and practical way to address national conservation priorities through *ex situ* conservation and gain momentum for ongoing efforts in the maintenance and sustainable use of plant diversity. In its third year of operation, the Partnership remains challenged to secure sufficient resources to enable the achievement of its strategic plan in a ten year timeframe; nevertheless, it must be highlighted that the governance, strong vision and ongoing good will of committed member organisations and individuals creates a social cohesion that goes a long way to realising national plant conservation priorities. The advantage of a collaborative approach in a federated system of states is that it allows *ex situ* conservation to be considered from a national perspective and through this alliance address those plant conservation priorities that otherwise are overlooked due to a jurisdictional approach taken by individual botanical institutions.

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The North American Plant Collections Consortium as a model for conservation, research and education in botanic gardens

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Abstract

The American Public Garden Association's North American Plant Collections Consortium (NAPCC), in partnership with the United States Department of Agriculture, is dedicated to a continent-wide approach to plant germplasm preservation, promoting high standards of curatorial care. Participants commit to holding and developing collections of documented living plants. These collections are used for germplasm preservation, research, and education. The NAPCC comprises several types of collections, including taxonomic groups, historic groups, eco-regional collections, and thematic groups. These collections may be held by a single institution or coordinated among multiple participants. This program has lead to increased germplasm conservation, increased public awareness, heightened curatorial standards, and easier access to germplasm for researchers, as well as helping to achieve the Global Strategy for Plant Conservation's Target 8, "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."

Keywords

Germplasm, plant collections, curation, NAPCC, APGA, USDA

The NAPCC Program

The American Public Garden Association (APGA) was established in 1940 as the American Association of Botanical Gardens and Arboreta and serves as the primary professional association for public gardens across North America. There are currently approximately 500 member institutions and over 5000 individual members of the organization. APGA's mission is to advance public gardens as a force for positive change in their communities, through national leadership, advocacy and innovation. The North American Plant Collections Consortium (NAPCC) is an initiative of APGA in partnership with the US Department of Agriculture (USDA) dedicated to a continent-wide approach to plant germplasm preservation, promoting high standards of curatorial care. Participants commit to holding and developing collections of documented living plants. These collections are used for germplasm preservation, research, and education.

In the late 1980s, the NAPCC began as an initiative of the APGA Plant Collections Committee, modeled on the UK's national collections program. By 1990 a part-time manager was hired by APGA to head the program. The first six collections applied for NAPCC status and were reviewed in 1996 as a pilot for the program and in 2005 a collaborative, multi-institution application was instituted. There are currently 69 participating gardens holding 63 individual collections and 3 multi-institution collections.

The program is partially funded through a cooperative agreement with the USDA Agricultural Research Service. The USDA operates the National Plant Germplasm System, which is the primary player in the U.S. effort to conserve and use crop germplasm; it is one of the world's largest collectors and distributors of germplasm. Most of this system is dedicated to economic and food crops but the USDA also conserves woody ornamentals in Beltsville, Maryland and herbaceous ornamentals in Columbus, Ohio. The partnership between the USDA and APGA, utilizing the strengths of North American public gardens, helps further the mission of both organizations.

The NAPCC comprises several types of collections including taxonomic groups, historic groups, eco-regional collections, and thematic groups. Most collections are alpha-taxonomic collections concentrating on a single genus, family, or even species and may consist of wild collections and/or horticultural selections. The NAPCC program is open for any APGA member to participate, but all participants must have an active collections management program, an endorsement from and commitment to maintain the plant group from the governing body, an up-to-date collections policy, and a curator for the proposed collection. In addition, participants commit to allowing access to the proposed collection for research.

Applicants to the NAPCC program submit a written application detailing their plant collections policy, letter of endorsement from their governing body, signed conditions for participation, collections inventory, curriculum vitae of key collections management staff, and an application fee. The NAPCC manager reviews the application packet and assigns a peer reviewer for a site visit to evaluate the collection, facilities, key staff, and curatorial practices. The reviewer writes a full evaluation and recommends the applicant receive "Full Status" admission to the NAPCC program, "Provisional Status" for 1–3 years with "Full Status" awarded after the successful completion of recommended improvements, or "Not Recommended at the Time" with a list of activities necessary for completion prior to re-application.

Recruitment for the program is through a continent-wide network of recruiters working with regional organizers to help identify potential collections and work with garden staff to raise curatorial standards to the level that will allow for successful participation in the NAPCC program. Peer site reviewers are trained through periodic workshops which typically include two mock site reviews with different outcomes to ensure standard evaluations.

NAPCC collection holders set their own collections policies and procedures which must conform to accepted curatorial practices. Plant sales and exchanges are governed by the individual institutions, although voluntary codes of conduct and best practices are encouraged. The NAPCC collection holder agrees to make every attempt to distribute the collection to other APGA member gardens if the collection should ever be de-accessioned or participation in the NAPCC program terminated.

Case Studies

- The JC Raulston Arboretum (JCRA) at North Carolina State University holds a NAPCC *Cercis* (redbud) collection consisting of 69 accessions representing 52 taxa including 11 species, subspecies, and botanical varieties. The collection has been utilized in breeding work by Dr. Dennis Werner of NC State University as well as private breeders in the nursery industry. The collection has also been utilized to select superior forms and hybrids including *Cercis* 'Big John', an upright form with vigorous growth and notably large flowers and *Cercis chinensis* 'Kay's Early Hope' (fig. 1) a precocious, exceptionally floriferous, long flowering form. The collection is also used to educate the public on this genus, as an illustration of a group with a distribution scattered across the northern temperate regions, and to discuss the particular attributes of plants in the Fabaceae family through interpretive signage, self-guided tour brochures, staff led tours, and educational articles. Outside researchers utilizing the J C Raulston's redbud collection include the California Academy of Sciences for a phylogenetic study of *Cercis*, the Hungarian Academy of Sciences for a molecular study of the genus, and to help develop a national *Cercis* collection in Somerset, UK.

- The Dawes Arboretum in Newark, Ohio holds a NAPCC *ex situ Metasequoia glyptostroboides* (dawn redwood) collection, consisting of 320 individual trees from 47 wild-collected accessions. The collection represents genetics from across the dawn redwood's native range and represents the greatest genetic diversity of the species outside of China (fig. 2). The collection is being used for genetic analysis and holds the

potential for conservation and restoration of the species in the future. The collection also has considerable potential for horticultural selection of improved forms for landscape use.

- Recently (2005), multi-institution collections have been developed to better capture the broad taxonomic diversity in some of the larger genera. The *Quercus* (oak) collection is held across 20 institutional partners with one partner serving as the coordinator. Collectively, this group holds 2,367 accessions representing 168 species, subspecies, and varieties and over 500 cultivars (fig.3). Forty-one percent of the collection is of known wild-collected germplasm. This is especially important for a group such as the oaks with recalcitrant seed that is difficult to store for any length of time in seed banks.

- Other NAPCC collections are being used in a variety of ways, such as the University of Michigan Matthaei Botanical Gardens & Nichols Arboretum where they are working with the Belarussian Academy of Sciences on DNA fingerprinting of historic herbaceous *Paeonia* (peony) selections. The multi-institution *Magnolia* (magnolia) collection holders are coordinating with the Magnolia Society International to host magnolia study days for public education and using gap analysis of their combined collections to pinpoint collection weaknesses and make concerted efforts to fill those gaps, especially in the case of endangered taxa, in an attempt to work towards the Global Strategy for Plant Conservation's (GSPC) Target 8.

Conclusion

The partnership between the APGA and USDA allows for a much greater degree of germplasm preservation than either entity working alone. The increased coordination and communication between gardens has created a stronger collections conservation environment nationally, and the NAPCC's emphasis on high standards of curatorial care has helped develop the curatorial staff of smaller and less well-funded gardens. Education programs and interpretation have led to a greater public appreciation of the role of botanic gardens in the conservation of plants, and the NAPCC's emphasis on science has led to easier access to germplasm for researchers.

Fig 1 A *Cercis* selection from the J C Raulston Arboretum being sold though the Choice Plants program

Fig. 2 *Metasequoia glyptostroboides* branchlet variation at the Dawes Arboretum

Fig. 3 Interpretive educational sign at the University of California, Davis Arboretum

Efforts in safeguarding China's botanical heritage: the implementation of the CSPC

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Abstract

With 31,362 species of vascular plants, China is home to about 12% of the Earth's known vascular flora. Remarkably swift changes at all levels including fast economic development are rapidly altering natural ecosystems and plant populations; today, the number of threatened species is estimated to amount some 15% of the total Chinese flora. Since China's ratification of the Convention on Biological Diversity in 1993, the country has undertaken tremendous steps to address biodiversity conservation, paying particular attention to safeguarding the country's vast botanical wealth. More recently, spearheaded by the Chinese Academy of Sciences (CAS), the State Forestry Administration (SFA), the Ministry of Environmental Protection (MEP) and BGCI, *China's Strategy for Plant Conservation (CSPC)* was officially launched in 2008. Working with Chinese botanical gardens and forest departments, BGCI has been assisting in the implementation of this national plant conservation strategy including an in-depth review of progress in 2012. A number of other country-wide plant conservation efforts have been initiated recently. SFA launched a '*Five Year Planning Program for the Protection of Plant Species with Extremely Small Populations*', in which 120 species have been identified for priority protection, with Yunnan being the first province for the pilot implementation of this program. In 2012, CAS, SFA and the Ministry of Housing and Urban-Rural Development (MHURD) issued '*Guidance on Enhancing Ex Situ Conservation for Botanical Garden Plant Resources*'. To facilitate the implementation of this scheme, SFA convened national training courses on '*Wild Plants Ex Situ Conservation*' for botanical gardens and forest departments personnel. The three agencies also established the Chinese Union of Botanical Gardens (CUBG) in 2013 to provide a national platform for conserving native plant species. This presentation will provide an overview of these initiatives and discuss progress made in implementation to date.

Key words

BGCI, Chinese Government, conservation, CSPC, efforts, plant species.

Background information

With 31,362 species of vascular plants in 3,328 genera and 312 families (FOC, 2013), China is home to about 12% of the Earth's known vascular flora. Under 50% of these species are endemic to China. Remarkably swift changes at all levels including fast economic development are rapidly altering natural ecosystems and plant populations; today, the number of threatened species is estimated to amount some 15% of the total Chinese flora since the early 1990s (Huang, 2011). The loss of plant diversity has drawn great attention of both at home and abroad. Since China's ratification of the Convention on Biological Diversity in 1993, the country has undertaken tremendous steps to address biodiversity conservation, paying particular attention to safeguarding the country's vast botanical wealth. Based on the model of the *Global Strategy for Plant Conservation (GSPC)* adopted by the Parties to the CBD in 2002, *China's Strategy for Plant Conservation (CSPC)* was launched in 2008 (China's Strategy for Plant Conservation Editorial Committee, 2008) which was spearheaded by the Chinese Academy of Sciences (CAS), the State Forestry Administration (SFA), the Ministry of Environmental Protection (MEP) and BGCI. Since its launch in 2008, The CSPC has served as a practical framework for action for many stakeholders of the Chinese conservation community specifically concerned with preserving China's botanical heritage for generations to come.

BGCI's efforts and achievements in the implementation of the CSPC

In 2007, BGCI established an office at the South China Botanical Garden of the CAS. The BGCI China Program fully supports the implementation of the CSPC and is recognized as having had a catalytic impact on plant conservation in China. The program has developed a focus on the conservation and restoration of globally threatened trees. Selection of species takes into account information derived from tree Red Listing activities and local consultation with botanic gardens and other partners. Working with Chinese botanical gardens and forestry departments, around 40 threatened plant species have been selected for conservation, integrating *ex-* and *in-situ* conservation in collaboration with local communities and authorities (*BGCI's current conservation projects in China*, 2015). In each case, as a result of the projects, the conservation status of the species has been significantly improved. The projects have proved to be catalytic, stimulating matching investment and conservation effort by major botanic gardens in China. A number of habitat conservation activities have been supported in China over the past five years, engaging with local communities and authorities to understand the underlying causes of plant diversity loss and develop sustainable solutions. Over the past five years, ecological restoration has been increasingly recognized as a global environmental priority. BGCI has responded to this challenge by supporting pilot restoration projects and the formation of the Ecological Restoration Alliance of botanic gardens (*Ecological Restoration*, 2015; BGCI acts as the coordinator of the Aliance. Pilot projects on the restoration of degraded tropical rainforest, subtropical forest, dryland ecosystems in China have been supported by BGCI; they all address the key issues of restoring habitats using native species, with a focus on securing the livelihoods of local communities as described in BGCI's *Review of Achievements: 2007-2012* (BGCI, 2013). BGCI has also supported capacity building and training in a range of botanical disciplines by supporting Chinese botanic gardens as major environmental centres for public outreach.

The Chinese government's efforts and achievements in the implementation of the CSPC

The Chinese government has paid great attention to plant conservation in China. To document vascular plants in China, China initiated the *Flora of China* (FOC) in 1988 which was completed in Sept. 2013. The FOC includes 25 volumes text and 24 volumes of illustration, describing 31,362 species of vascular plants in 3,328 genera and 312 families, approximately 12% of the world's flora. The preservation of China's species is of special significance. The FOC will contribute greatly to the conservation of Chinese plants.

The FOC also provides the information needed to facilitate the collaboration of international conservation organizations, especially those dealing with programs on forest restoration and the re-establishment of sustainable communities throughout the country, which have been so extensively devastated by human activities in the past 30 years (the significance of the Chinese flora is described in Harvard University, 2012. To document all known plants as well as recently discovered plants, in 2012 SFA began a large-scale national plant survey, which is a five-year project, called the '*Second survey for National Key Protected Wild Plant Resources*', coming after the '*First survey for National Key Protected Wild Plant Resources*' started in 1999. To ensure the quality and smooth progress of the survey, a survey leading group and an expert group were set up and a series of technical documents and protocols for surveying were developed and trainings on the survey technique were held. At present, the surveys have been carried out in each province of China.

Because of the limited resources available, conservation status assessment is vital for prioritizing plant species conservation. Compilation of the *Red List for China Higher Plants* was started in 2008 by MEP and CAS and published in 2013, using version 3.1 of the IUCN Red List categories (IUCN, 2001) and *Application of the IUCN Red List Criteria at Regional Levels, 2003, V3.0* (IUCN, 2003). The overall result of these assessment activities is shown in Table 1 (Ministry of Environmental Protection and CAS, 2013). This Red List can be used to identify the geographic

priority areas for biodiversity conservation and the target species for *ex situ* conservation in botanical gardens and in seed banks.

Besides the great efforts on the implementation of Targets 1 and 2 of the CSPC, a number of other country-wide plant conservation efforts on the implementation of Targets 7 and 8 have also been started recently and have made great progress. SFA launched a '*Five Year Planning Program for the Protection of Plant Species with Extremely Small Populations*' (PSESP), in which 120 species have been identified for priority protection, with Yunnan being the first province for the pilot implementation of this program. The implementation involves establishing small protected areas or protected sites, *inter situ* (*near-situ*) conservation, propagation and *ex situ* conservation and finally restoring the original habitat by plant reintroductions.

With the rapid climate change, Chinese government has realized the increasing importance of *ex situ* conservation and has strengthened its partnership with botanical gardens. In 2012, CAS, SFA and the Ministry of Housing and Urban-Rural Development (MHURD) jointly issued '*Guidance on Enhancing Ex Situ Conservation for Botanical Garden Plant Resources*', aiming to further standardize the planning, construction, management, conservation and development of botanical gardens; and to strengthen the *ex situ* conservation of plant resources. To facilitate the implementation of this scheme, SFA convened national training courses on '*Wild Plants Ex Situ Conservation'* for botanical gardens and forestry department personnel. The three agencies also established the *Chinese Union of Botanical Gardens* (CUBG) in 2013 to provide a national platform for conserving native plant species. Since its inauguration in June 2013, CUBG has held a series of activities for staffs from Chinese botanical gardens, including environmental education training, horticulture training (Xishuangbanna Tropical Botanic Garden, 2015), and established network information systems for *ex situ* collection training.

Implementation review of the CSPC

The launch of *China's Strategy for Plant Conservation* (CSPC) in early 2008 was a major milestone in the development of guidance for safeguarding the flora of China for future generations. Reviewing the progress made in the implementation of the CSPC is essential to further enhance its impact and inform a future plan of action. Four years after its launch, BGCI and three agencies implemented the review of CSPC implementation progress in 2012. The review results are not only thought to provide guidance to conservation practitioners and policy makers in China on how to enhance coordination and consolidate different conservation approaches; they also aim to provide a basis for discussion to align CSPC with the amended objectives of the GSPC 2011-2020 and CBD's *Strategic Plan for Biodiversity 2011-2020*. The review results were published by BGCI (Gratzfeld, J. and Wen, X. Y., 2012).

Conclusions and recommendations

Tremendous contributions to plant conservation have been made over last few years, including the completion of the multi-volume Chinese Flora (national flora and local flora);a red list of Chinese higher plant species; an enhanced network of sites and people dedicated to *in situ* and *ex situ* conservation; numerous species recovery and ecosystem restoration projects have been initiated; many projects and initiatives to strengthen conservation capacity, education and public outreach; and several new information exchange platforms and networks have beefen created.

To conserve plants more effectively, we recommend that the linkages between *in* and *ex situ* conservation at species and ecosystems, as well as at institutional levels, need to be enhanced; (the coordination of all conservation actors needs to be enhanced); National coordination of *ex situ* collection policies and curatorial efforts to secure conservation and research value needs to be improved; The partnerships between scientists, conservationists and education specialists to promote a new generation of amateur botanists and naturalists need to be enhanced; and the

close linkages of CSPC stakeholders with policy and decision makers who influence and negotiate national and global conservation and development objectives need to be strengthened.

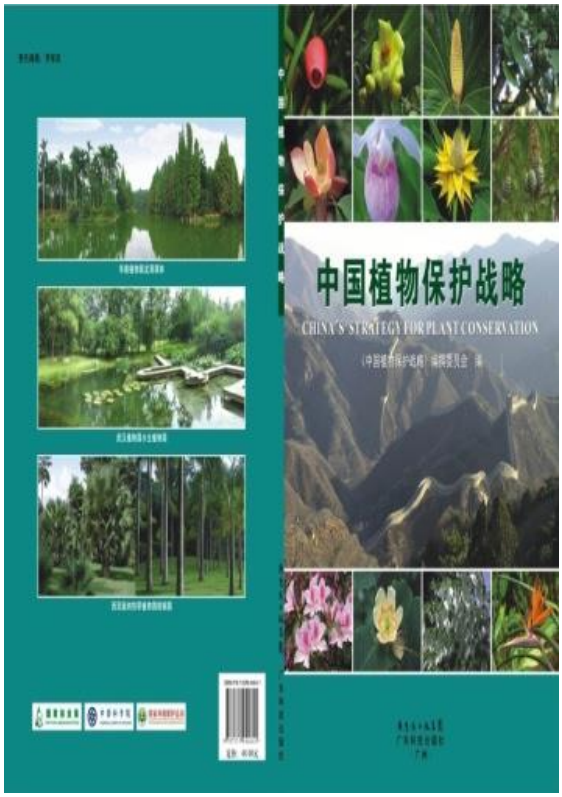

Figure 1 CSPC front page (2008)

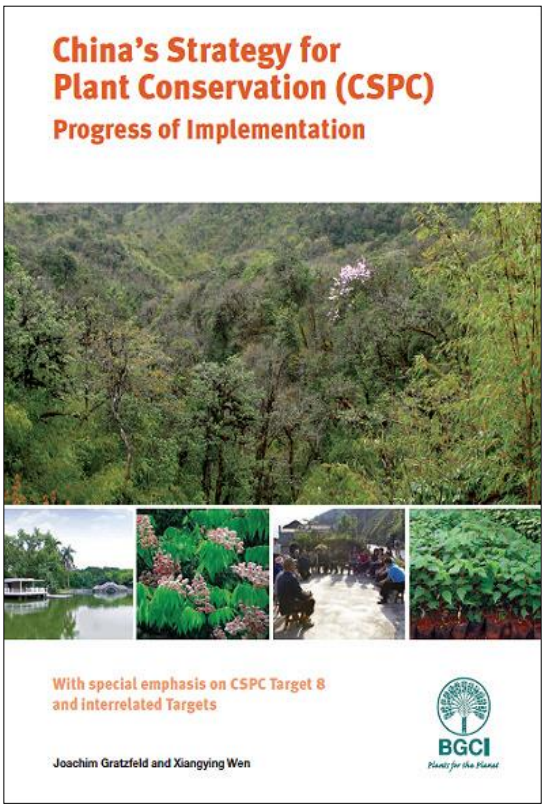

Figure 2:CSPC Implementation review result

Figure 3: *Ex situ* conservation of *Acer yangbiense*

Figure 4: On -site training of farmers

Figure 5: Flora of China

Figure 6: PSESP experience exchange meeting

Figure 7 Group photo of Wild Plants *Ex Situ* Conservation training

Figure 8 Inauguration of CUBG

Group / Category	Bryophytes	Pteridophytes	Gynmosperms	Angiosperms	Total		%
EX	1	5	0	21	27		0.08
EW	0	1	0	9	10		0.03
RE	0	5	0	10	15		0.04
CR	12	28	28	515	583		
EN	44	57	39	1157	1297	3767	10.58
VU	61	66	60	1700	1887		
NT	94	67	12	2550	2723		7.65
LC	1761	1053	93	21389	24296		68.23
DD	584	1122	17	3049	4772		13.4
total	2557	2404	249	30400	35610		

Table 1: Results of the Assessment

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Treasure Of The Four Kings: plant expeditions to the Raja Ampat Islands of West Papua

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Abstract

The Raja Ampat Islands is a group of four large islands and more than 600 smaller islands. The Islands and waters have been known as the most diverse ecosystems on Earth. Despite it being a biologically very rich area, little is known about the Islands' plant diversity. In order to provide important baseline data for conserving the Islands' biodiversity sustainably, an expedition team from Bogor Botanic Gardens had conducted floral collecting trips to Waigeo Island, Salawati Island and Sorong Nature Park. The aims of the expeditions were to collect priority plant species, particularly those of conservation value, and to describe their habitat characteristics in order to understand their ecological preferences for *ex situ* conservation purposes. The exploration and inventory methods used were a combination of random and purposive searchings. Different directions (aspects) were covered in order to comprehensively study the observed forest areas. A total of 719 plant records were collected from the three conservation areas; five species of which are endemic to Waigeo (*Guioa waigeoensis*, *Alstonia beatricis*, *Calophyllum parvifolium*, *Schefflera apiculata* and *Nepenthes danseri*) and all have been regarded as threatened by the IUCN. Sixty one of these species are endemic to New Guinea, while 100 species have been determined as new collections for the Indonesian Botanic Gardens. *Dendrobium* and *Bulbophyllum* were the most diverse orchids both on Waigeo and Salawati.

Keywords

Plant exploration, Raja Ampat Islands, Salawati Island, Waigeo Island.

Introduction

The Raja Ampat Islands is a group of four large islands (namely Waigeo, Batanta, Salawati, and Misool) and more than 600 smaller islands. The Islands are located and scattered off the western tip of the Bird's Head of New Guinea and is administrated by the West Papua Province of Indonesia. The waters around the Islands have been known as the most biodiverse marine area in the world, especially in terms of coral reefs and fish species (Webb, 2005; Pemerintah Kapubaten Raja Ampat & Conservation InternationalI, 2006). However, despite it being a biologically very rich area, little is known about the Islands' plant diversity and terrestrial resources (Bappenas, 2003; Webb, 2005). Detailed plant expeditions and surveys will therefore provide important baseline data for conserving the Islands' biodiversity sustainably (Webb, 2005).

Geologically the Raja Ampat Islands is also very interesting, by having extensive karst ecosystems, alluvium substrates, acid volcanic and ultrabasic rocks (Jepson & Whittaker, 2002; Webb, 2005; Pemkab Raja Ampat & CI, 2006). The flora must be diverse, according to the substrate and biogeographic reasons (Johns, 1997a, 1997b), as well as to the habitat types, which range from submontane forests, via forests on karst and acid volcanics, to sago swamps and mangroves. The ultrabasic scrub of Waigeo Island is unique and widely known for its endemic species (Webb, 2005). On the other hand, the hill forests on volcanic substrates and alluvium lands extensively occur in Salawati Island. Each island has its own characteristics and undoubtedly the Raja Ampat is botanically very important and valuable despite its relatively small size (Johns, 1995, 1997b; Conservation International, 1999; BKSDA Papua II, 2003; Webb, 2005).

The conservation status of the Raja Ampat Islands is also unique, i.e. the population density is very low, the villagers in general are concerned to conserve their lands, and the traditional government system is still highly influential (Webb, 2005). Over the past twenty years, logging has been extensive in a number of areas of the Islands, particularly in the lowlands. However, some of the prior logging was relatively light, searching primarily for large trees of *Intsia bijuga* and *I. palembanica* (Webb, 2005). Hence the potential for the Raja Ampat Islands remains relatively intact. Preventing logging and mining companies from entering and disturbing the Islands' key conservation areas is indeed crucial if we are to sustain their invaluable biodiversity.

Aims

The aims of the expeditions were to collect priority (target) plant species, particularly those of high conservation value (i.e. threatened species, endemics, and ecotypes) from Waigeo and Salawati Islands and to describe their habitat characteristics in order to understand their ecological preferences to enable their *ex situ* conservation purposes.

Materials and methods

Exploration and Study Areas

Mount Nok (Mount Buffelhorn), Waifoi forest (East Waigeo Island Nature Reserve) and Waiyar River (North Salawati Island Nature Reserve) were the main expedition locations. The East Waigeo Island Nature Reserve was established by the decree of the Indonesian Minister of Forestry (no.251/Kpts-II/1996 dated 3 June 1996) comprising a total area of 119,000 hectares, while the North Salawati Island Nature Reserve was established by the decree of the Minister of Agriculture (no.14/Kpts/Um/II/1982) covering a total area of 62,962 hectares. The exploration trip to Mount Nok, Waifoi forest and Sorong Nature Park was conducted from June 11th 2007 to July 9th 2007 while that to Waiyar River was from May 22nd to June 3rd 2008.

The exploration and inventory methods used were a combination of random and purposive searchings (Ludwig & Reynolds, 1988; Krebs, 1989; Cropper, 1993). Waifoi Village of Waigeo Island and Solol Village of Salawati Island were used as the entry points to access the two nature reserves. The camps at Kamtabae River (Waigeo) and Waiyar River (Salawati) were used as the central points to explore the surrounding forests. Different directions (aspects) were covered in order to comprehensively cover the target exploration areas.

Target Species and Habitat Descriptions

The target species to be collected were primarily those of high conservation values, including threatened species, endemics, and ecotypes, but some attractive or promising plants were also collected. The specimens taken were either seedlings, seeds or cuttings. The plant specimens and habitat information were recorded; the records included the scientific and local names, morphological descriptions, abundances, local distribution patterns for selected species (using Ludwig & Reynolds, 1988; Krebs, 1989), phenological events, uses, location coordinates, and habitat characteristics. The habitat characteristic parameters recorded were vegetation types and associations, altitudes, topography/land slopes, soil pH and humidity, as well as air temperature and humidity. The location of each specimen collected was recorded using a Global Positioning System (Garmin MAP 175). Land slopes were measured using a SUUNTO clinometer. Levels of the forest/habitat disturbance were also analysed.

Results and discussions

Waigeo Island and Sorong Nature Park

Records for 554 plants from the East Waigeo Island Nature Reserve and Sorong Nature Park wree made. Five of these species are endemic to the Waigeo Island (*Guioa waigeoensis*, *Alstonia beatricis*, *Calophyllum parvifolium*, *Schefflera apiculata*, and *Nepenthes danseri*) and 42 species

endemic to New Guinea as a whole. The five species endemic to Waigeo have been regarded as 'threatened' by the IUCN (2000). Based on the Indonesian Botanic Gardens' Collection Catalogues (2010), 72 species have been determined as new collections for the Botanic Gardens. Some living seedlings of the palm *Saribus brevifolius* (*see* Bacon & Baker, 2011) were also collected from Bomat Isthmus, Waigeo.

Palms of the karst *Hydriastele costata* and *Livistona brevifolia* were also encountered and collected during the expeditions. *H. costata* and *L. brevifolia* habitat prefer dry karst habitats on particularly ultrabasic rocks. *H. costata* has been regarded as a prominent indicator species of the karst ecosystem. *H. rhopalocarpa*, on the other hand, occurs on inland hill forest on volcanic substrates. Economically potential palms collected were *Sommieria leucophylla, Areca macrocalyx*, *Dransfieldia micrantha*, and *Pinanga rumphianum*. Two variants of *S. leucophylla* have been found showing different leaf colours. This is a taxonomically interesting discovery.

A number of attractive species were also found, including *Maniltoa rosea*, *M. plurijuga*, *Pothos scandens*, and the broadleaf *Dillenia papuana*. Promising species for their potential uses included *Cynometra novoguineensis*, *Piper* spp., and *Raphidophora* spp. Some valuable orchids were also recorded, including *Dendrobium macrophyllum*, *D. lasianthera*, and *D. capituliflorum*. The orchid species that occurred on Mount Nok, Kamtabae River and the surrounding areas were mostly epiphytic (Figure 1). *Dendrobium* and *Bulbophyllum* seemed to be the most diverse genera on Mount Nok and Kamtabae River, indicated by the great number of species (Figure 2). Most orchids occurred on the main part of tree trunks (stems), especially on the upper part (Zone 2) and then followed by the lower part (Zone 1), Figure 3. Johansson (1975) showed a similar occurrence pattern in West African rain forests.

Decaspermum fruticosum, *Planchonella catartea*, *Garcinia altísima*, and *Rhodamnia cinerea* were the most dominant plant species in Waigeo, while the population of the threatened, endemic species *Guioa waigeoensis* tended to clump (Figure 4). Plant species formation at different elevations on Mount Nok of Waigeo is presented on Table 1. Generally, species formations varied with elevation, but no areas of the Raja Ampat are higher than 1,000 m. Interestingly, pseudomontane vegetation occurred on the tops of hills of 100 m to 200 m in altitude. The proximity of Mount Nok (e.g. the forest edges) to the Pacific Ocean might be the driving force, creating a natural phenomenon called the "Massenerhebung" effect. This is shown by the commonly high-inland species *Casuarina rumphiana*, *Decaspermum fruticosum* and *Livistona rotundifolia* that are able to grow at much lower altitudes of the Island. Mountains surrounded by large ranges will tend to have higher tree lines than more isolated mountains (like Mount Nok), due to heat retention and wind shadowing (MacKinnon *et al*., 1996; Monk *et al*., 1997; Mittermeier *et al*., 1999). The pseudomontane areas of Mount Nok seem to be the most suitable habitats of the Island endemic plant species.

Salawati Island

A total of 165 plant collection records (consisting of seedlings, seeds, and cuttings) were collected from Salawati Island, consisting of 50 orchid collections and 115 non-orchid collections, belonging to 51 plant families. Based on the Indonesian Botanic Gardens' Collection Catalogues (2010), 28 species of thses have been determined as new collections for the Botanic Gardens, while 19 species are endemic to New Guinea. Figure 5 shows the number of orchid species of each genus found in the North Salawati Island Nature Reserve of the Raja Ampat Islands. Similar to Waigeo, *Dendrobium* and *Bulbophyllum* were the most diverse orchid genera on Salawati. Valuable and scientifically interesting species found in Salawati Island include the unique palm *Sommieria leucophylla*, the attractive *Cycas riuminiana*, *Maniltoa rosea*, *Bolbitis heterocrita*, *Leea* spp., *Begonia* spp., and *Pandanus* spp.

In general, the island's soil thickness varied significantly from site to site, from very thick (more than 1.5 m) to shallow (16 cm). The shallow soils commonly occurred on the top of hills. Soil

textures generally consisted of clayed-silt and sandy-silt formations. Detailed results of the soil laboratory analysis were reported separately.

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Table 1. Plant species formation (composition) at different elevations on Mount Nok, Waigeo Island, the Raja Ampat Islands.

Elevation (m asl)	Species formation/composition	Dominant species
20 - 100	*Tabernaemontana auricantiaca, Pometia pinnata, Intsia bijuga, Vatica rassak, Artocarpus altilis, Orania regalis, Licuala graminifolia, Pandanus tectorius, Semecarpus macrocarpa, Artocarpus altilis, Syzygium malaccensis, Psychotria tripendumculata, Dillenia papuana*, and *Sommieria leucophylla.* Further inland, *Hydriastele costata* sometimes occurred.	*Tabernaemontana auricantiaca, Pometia pinnata, Intsia bijuga, Vatica rassak, Licuala graminifolia,* and *Orania regalis.*
100-200 Hill tops	*Casuarina rumphiana, Rhodamnia cinerea, Garcinia latissima, Decaspermum fruticosum, Licuala graminifolia, Planchonella catartea, Exocarpus latifolius, Cryptocaria infectoria, Semecarpus macrocarpa, Myrsine rawacensis, Psychotria tripendumculata, Pimeleodendron amboinicum, Intsia bijuga, Artocarpus altilis, Guioa waigeoensis,* and *Livistona rotundifolia* very rarely found.	*Casuarina rumphiana, Rhodamnia cinerea, Decaspermum fruticosum, Planchonella catartea, Exocarpus latifolius,Garcinia latissima.* PSEUDOMONTANE VEGETATION
270	*Calophyllum persemile, C. grandiflorum, Pometia pinnata, Artocarpus integer, Licuala graminifolia, Lasianthus purpureus, Knema* sp.*, Gnetum* sp.*, Actinodaphne* sp.*, Gyrinops* sp.*,* and *Canarium* sp*.*	*Calophyllum persemile, C. grandiflorum, Pometia pinnata, Artocarpus integer,* and *Licuala graminifolia.*
350	*Nagaia wallichii, Schima wallichii, Rhodamnia cinerea, Canarium* sp.*, Gironniera* sp.*, Garcinia* sp.*,* and *Fagraea* sp.	*Nagaia wallichii, Schima wallichii, Rhodamnia cinerea,* and *Canarium* sp.
460	*Castanopsis acuminata, Symplocos fasciculata, Celtis philippinensis, Vatica rassak, Pometia pinnata, Parkia* sp.*, Gironniera,* and *Pandanus tectorius.*	*Castanopsis acuminata, Symplocos fasciculata, Celtis philippinensis, Vatica rassak,* and *Pometia pinnata.*
545	*Celtis philippinensis, Poliosma ilicifolia, Pangium edule, Palaquium* sp.*, Calophyllum persemile, Pandanus* sp.*, Actinodaphne* sp.*, Elaeocarpus* sp.*, Helicia* sp.*, Heritiera javanica, Smilax* sp.*, Inga* sp.*, and Calyptrocalix* sp*.* The orchid *Phalaenopsis amabilis* scattered, small population*.*	*Celtis philippinensis, Poliosma ilicifolia, Pangium edule, Palaquium* sp.*, Calophyllum persemile, Pandanus* sp.*, Actinodaphne* sp.*,* and *Elaeocarpus* sp*.*
560	*Intsia bijuga, Celtis philippinensis, Calophyllum persemile, Castanopsis acuminate,* and *Intsia bijuga.* Some orchid populations abundant, growing on very steep, narrow mount ridges (*Dendrobium macrophyllum, D. amboinensis, Ceratostylis* sp.*, Cadetia* sp.*, Eria javanica, Thelasis* sp.*, and Appendicula* sp.). Begonias grew very well.	*Intsia bijuga, Celtis philippinensis, Calophyllum persemile, Castanopsis acuminate,* and *Intsia bijuga.*
630	*Wendlandia* sp.*, Phytosporum ramiflorum, Heritiera javanica, Intsia bijuga, Oleandra* sp*.* The endemics *Schefflera apiculata* and *Calophyllum parvifolium* found. Rocky habitats, very steep, land slides easily, slope 80-90%. Cliff walls were formed by rock piles, united by plant root systems.	*Wendlandia* sp.*, Phytosporum ramiflorum, Heritiera javanica,* and *Intsia bijuga.*

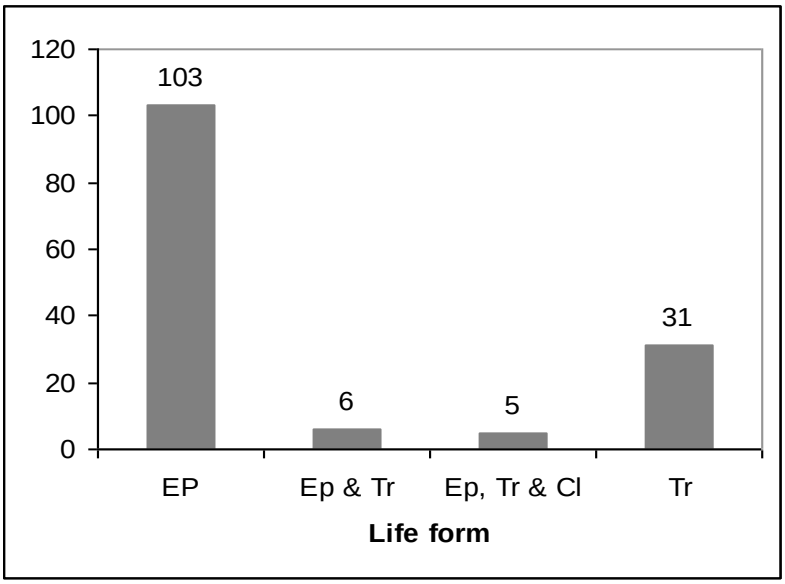

Figure 1. The number of orchid species according to their life forms, found at Mount Nok and Kamtabae River, East Waigeo Island Nature Reserve, the Raja Ampat Islands. Notes: EP (Epiphyte), TR (Terrestrial), and Cl (Climber).

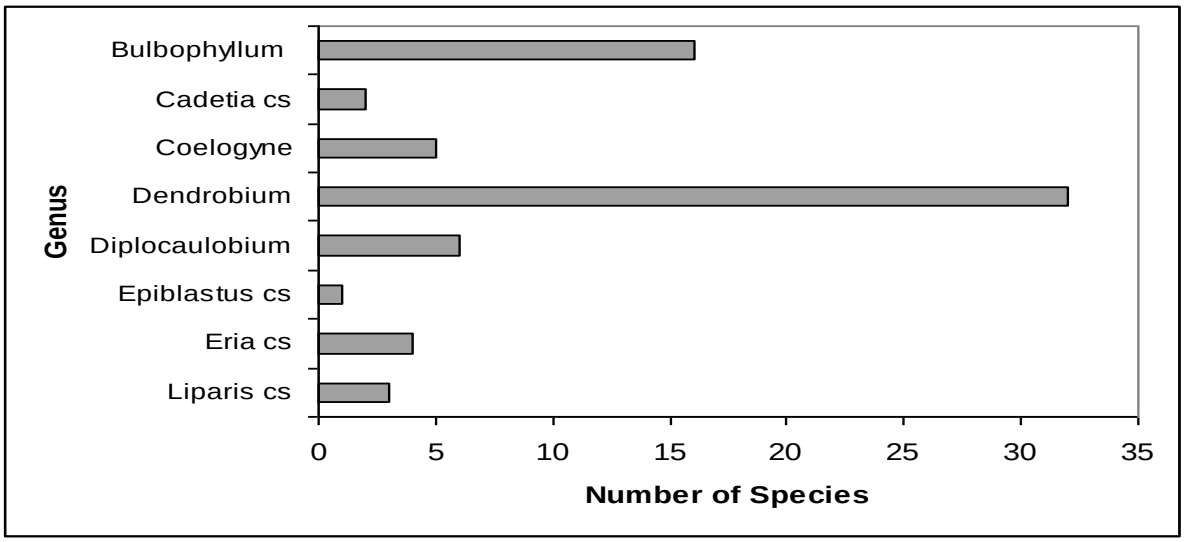

Figure 2. The number of orchid species of each genus found on Mount Nok and Kamtabae River, East Waigeo Island Nature Reserve, the Raja Ampat Islands. Notes: *Liparis* cs (*Liparis, Calanthe, Plocoglottis, Thelasis*), *Eria* cs (*Eria, Flickingeria, Hataeria, Malaxis, Phreatia*), *Cadetia* cs (*Acampe, Agrostophyllum, Appendicula, Ceratostylis, Corymborkis*), *Epiblastus* cs (*Epiblastus, Acriopsis, Brachypeza, Camarotis, Dilochia,*

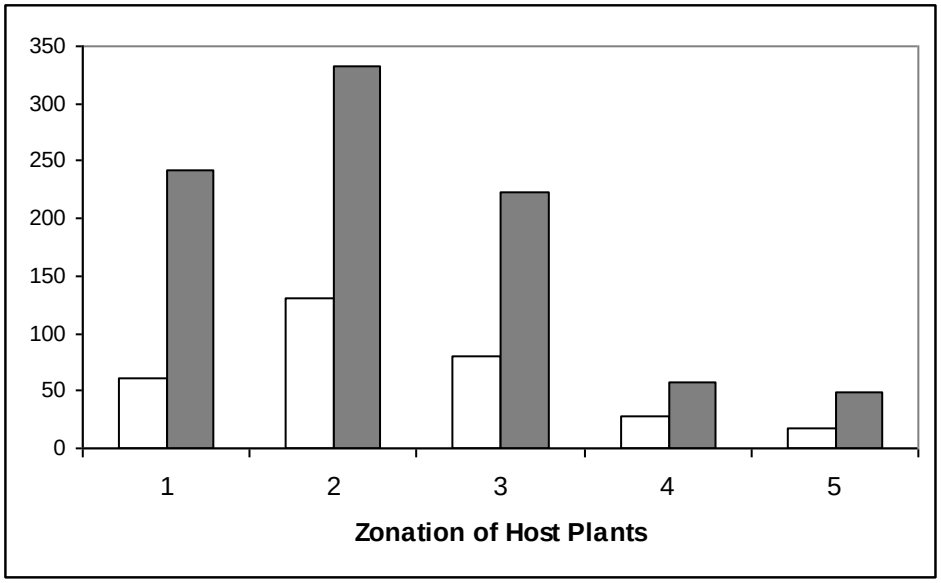

Figure 3. Orchid occurrences (empty bars) and the number of individuals (solid bars) at each zone of the host plants, Mount Nok and Kamtabae River, East Waigeo Island Nature Reserve, the Raja Ampat Islands, West Papua

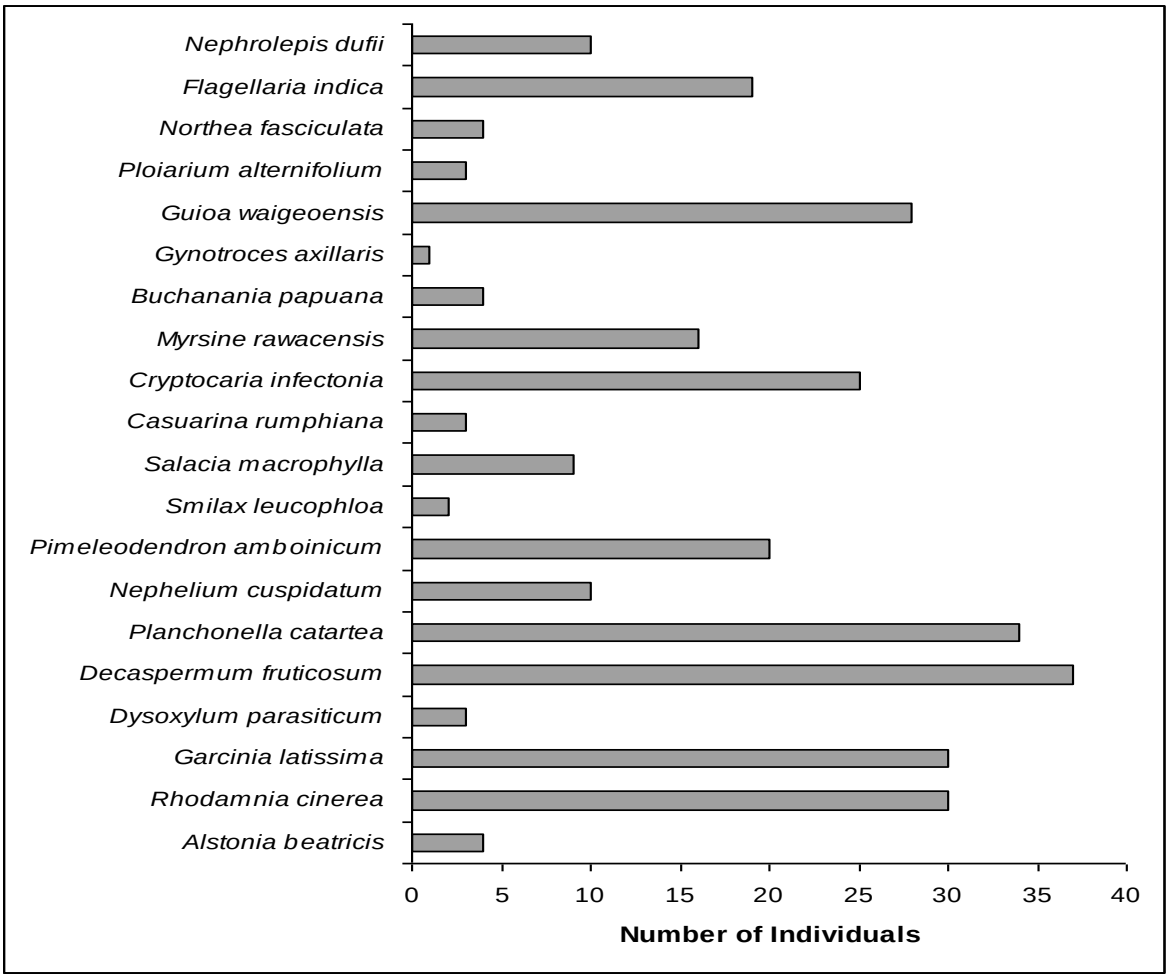

Figure 4. Dominant plant species occurred on hill forests in East Waigeo Nature Reserve (Kamtabae River and the surrounding areas).

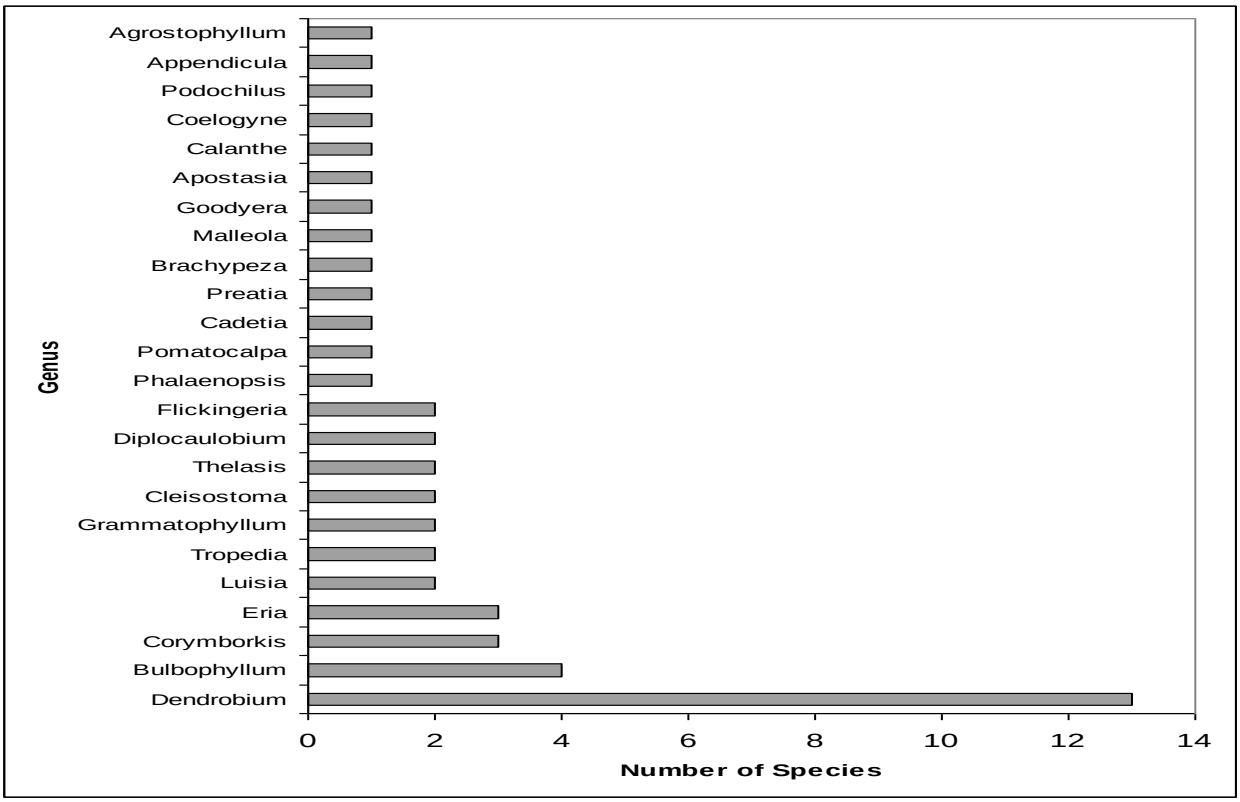

Figure 5. The number of orchid species of each genus found in North Salawati Island Nature Reserve, the Raja Ampat Islands, West Papua

Kirstenbosch (1913 to 2013): celebrating 100 years of conserving South Africa's indigenous plants

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Abstract

The South African National Biodiversity Institute (SANBI) manages a network of nine national botanical gardens spread across six provinces in South Africa. SANBI's flagship conservation garden, and probably the best known, is the world renowned Kirstenbosch National Botanical Garden, situated in Cape Town. Established on 1 July 1913, Kirstenbosch celebrates its 100th anniversary in 2013. This paper looks at how Kirstenbosch has contributed towards conserving and promoting education and awareness of the diversity and importance of South Africa's indigenous plants, as well as how the Garden has influenced and supported surrounding communities and other South African national botanical gardens established during the past 100 years. The paper highlights interventions that have been, and continue to be, made to develop and improve the Garden, its facilities and services that it offers to visitors, over the last 100 years. Lessons learned and efforts made to increase the relevance of South Africa's national botanical gardens to the broader public, as well as opportunities taken to promote partnerships and deliver on SANBI's broad biodiversity mandate created through the promulgation of the National Environmental Management: Biodiversity Act (NEMBA) in 2004, are highlighted. SANBI's current plans, progress and challenges in expanding the network of national botanical gardens within South Africa are also discussed.

Keywords

Africa, botanical garden, conservation, indigenous plants, Kirstenbosch, national botanical garden, SANBI, South Africa

Kirstenbosch's history: an overview

The South African National Biodiversity Institute (SANBI) is a parastatal organisation responsible for managing South Africa's nine national botanical gardens (NBGs). SANBI's flagship garden, the Kirstenbosch National Botanical Garden, was established 100 years ago in 1913 and has been supported by the Botanical Society of South Africa (an NGO serving as the 'Friends' of SANBI's gardens) since 1913.

Kirstenbosch was designed to research, conserve, display and represent South Africa's unique indigenous plants, being located in the Cape Floristic Kingdom, one of only six floral kingdoms in the world, and the only one restricted to one country. The topographic setting of the Garden, set against the eastern slopes of the iconic Table Mountain, made Kirstenbosch a very special place. According to Prof. Robert Harold Compton (1965), Director of Kirstenbosch from 1919 to 1953:

> *The idea of "landscaping" at Kirstenbosch was always rendered futile by the grandeur and diversity of its setting, making any sort of "improvement" seem foolish. No botanic garden in the world has a more magnificent site, with its hills, slopes, streams and forests and its superbly bold mountain background and distant views. The landscape was already there and the main thing was to ensure that it should not be spoilt by the uses to which it would be put."*
>
> *The layout of Kirstenbosch has therefore followed no fixed plan. It has gradually unfolded itself, as it were, in response to experience, to a realisation of what is necessary and what is possible, and to expanding ideas of the scope of its work. Each*

> *piece of construction involved a consideration of what could be done with the labour and funds available, and further, whether it would be possible to carry out the consequent additional maintenance.*

The Garden endured tough times in its earlier years, when the sale of acorns (as pig-fodder) and firewood were used to pay salaries. It set the standard for future national botanical gardens to be established in other parts of the country. The Kirstenbosch Development Campaign, championed by the then CEO, Prof. Brian Huntley, in the 1990s, has resulted in Kirstenbosch Garden reaching financial sustainability in the mid-2000s.

National botanical garden network

Due to the immense diversity of South Africa's indigenous flora, there was an early realisation that a single garden was not sufficient. SANBI was the pioneer of a national botanical garden network representative of different vegetation types. Kirstenbosch served as the 'mother garden', providing standards and support to all future national botanical gardens established around South Africa. More gardens meant accessibility to more people, and the opportunity to focus on the conservation of both local and regional floras. From 1921 till now there has been a gradual expansion of national botanical gardens. Before South Africa's first democratic elections held in 1994, South Africa had four provinces. Post-1994 the number of provinces increased to nine. A deliberate attempt was then made in the mid-2000s to start the expansion of national botanical gardens in those provinces without national botanical gardens, and which provided the opportunity to include new floras and vegetation types not represented in existing gardens.

Indigenous plants

SANBI's NBGs have always had a focus on South Africa's indigenous plants, which generally do not require expensive climate-controlled shade houses. Over the years, Kirstenbosch has been the centre of horticultural research and has promoted awareness of the value and importance of indigenous plants. Kirstenbosch has also participated in local/international flower shows e.g. the Royal Horticultural Society's (RHS) Chelsea Flower Show in the UK. Staff associated with the Garden have also contributed significantly to publishing articles and books, aimed at both amateur and professional readership. The Garden has also pioneered garden-based interpretation for South Africa, with the aim of 'making the Garden come alive'. A valuable initiative has been the development of a dedicated SANBI web site, www.plantzafrica.com, aimed at sharing with the general public information on the cultivation, propagation and uses of South Africa's more than 20,000 indigenous plant taxa.

Natural and cultivated collections

The majority of South Africa's NBGs are classified as conservation gardens, comprising a combination of natural and cultivated/landscaped areas. The cultivated collections are generally representative of local and regional floras. Conservation collections serve important roles in creating awareness of the threats to South Africa's indigenous plants. Plants are generally of wild origin and collected from natural areas. The four pillars of a botanical garden's function, namely display, conservation, education and research, are all practised in SANBI's NBGs. South Africa's NBGs serve important roles in providing connectivity within the surrounding landscape, providing natural corridors and opportunities for wildlife and biodiversity associated with the natural landscapes to migrate and move between the NBGs and their neighbouring properties. South Africa's NBGs, including Kirstenbosch, all include historical collections, some of which are not indigenous. Whilst invasive alien species are removed from natural areas, exotic plants that do not pose an invasive threat are retained and even showcased to visitors.

Demonstration gardens

Kirstenbosch has also pioneered in South African botanical gardens the concept of demonstration gardens, providing relevance to contemporary issues and showcasing uses of plants by local cultures. Some of the demonstration gardens include 'water-wise gardens', 'useful plants gardens', 'weeds South Africa gave the world', and collections of threatened plants. Demonstration gardens provide the opportunity to promote the appreciation and awareness of living collections and the impact of man on the environment. Through the demonstration gardens and natural areas included within their boundaries, SANBI's NBGs serve as 'embassies of biodiversity and culture'.

Millennium Seed Bank Partnership

SANBI entered a strategic agreement with the Millennium Seed Bank Partnership, Kew, in 2000, and renewed the partnership from 2010 to 2015. This global *ex situ* seed conservation programme is of immense value to SANBI and Kirstenbosch; it includes staff training/development opportunities, and provides incentives for target collections.

From NBI to SANBI

SANBI has undergone much change in its past history, as changes in the political landscape of the country and global events and trends have impacted on the organisation. The organisation moved from being the National Botanic Gardens (established in 1913) to the National Botanical Institute (resulting from an amalgamation of the National Botanic Gardens and the Botanical Research Institute) in 1990, to the SANBI in 2004, with a vastly expanded mandate (through the promulgation of the National Environmental Management: Biodiversity Act No. 10 of 2004) that included not just plants but the country's biodiversity as a whole. Since 2004 there has been an increased focus on showcasing and providing awareness of animals in SANBI's NBGs, taking advantage of national citizen science projects championed by the University of Cape Town's (UCT) Animal Demography Unit (ADU) to expand our knowledge of animals by using our NBGs, as 'havens of biodiversity' to play an important role in promoting public awareness about biodiversity. Several dedicated 'bioblitzes', recording both animals and plants, have been conducted in SANBI's NBGs in the past few years.

Restoration

In recent years, Kirstenbosch has actively participated in restoration projects in surrounding areas, integrating *ex situ* and *in situ* conservation. Kirstenbosch's involvement with *in situ* restoration activities provides the example and standard for other NBGs within the country. In order to successfully participate in restoration projects, capacity, partnerships and horticultural expertise are essential components required.

Gardens Expansion Strategy

SANBI's vision as from 2010 was to have one national botanical garden represented in every province of South Africa. Currently there are nine gardens located in six provinces, with new NBGs anticipated in both the Eastern Cape and Limpopo provinces by 2015. The establishment of new gardens is listed as a Presidential outcome and deliverable for the Minister of the national Department of Environmental Affairs (DEA), from where the majority of SANBI's funds are provided. Significant national support has been received from DEA over the past few years for the establishment and operation of the planned two new gardens. Establishing new gardens is a time-consuming activity that requires the necessary resources, approvals and strategic partnerships.

Celebrating 100 years in the 'most beautiful garden in Africa'

In 2013 Kirstenbosch celebrated its 100th anniversary. Some of the activities that have taken place as part of the centenary celebrations have been:

- Launch of a new Kirstenbosch book, to be published by Random House Struik (www.randomstruik.co.za)
- Kirstenbosch staff luncheon
- Participation in the RHS Chelsea Flower Show 2013 (33rd gold medal in 38 years)
- International Biodiversity Day (22 May) – free entry, 'bioblitzes'
- A Centenary Gala Dinner on 1 July 2013
- A Kirstenbosch stamp series launched by the SA Post Office
- Silvertree Restoration on slopes of Table Mountain
- New *Welwitschia* Corner Unit in Conservatory, and new *Welwitschia* book launch
- Kirstenbosch Photographic Competition
- Banner on SANBI web site for public to share old photographs
- Schools Biodiversity Art Competition
- Kirstenbosch Biennale – a botanical art exhibition
- A Chelsea Flower Show exhibit at the V&A Waterfront
- A Botanical Society of South Africa Centenary Gala Dinner
- Summer Sunset Concerts, and
- Construction of a new Centenary Tree Canopy Walkway (to be completed in 2014).

Lessons learned from Kirstenbosch

Some of the lessons learned from Kirstenbosch over the years, as highlighted by Prof. Brian Huntley in his book *Kirstenbosch – the most beautiful garden in Africa* (2012) have included the following: (a) try not to engage in commercial horticultural activities – leave it to the private sector, (b) win and cherish friends, (c) align Strategy to Government policy, (d) consistent 'generosity of spirit' through partnerships is essential – don't need to squeeze profit out of every activity, (e) managers to be resilient to controversy – they must be able to 'ride out the storm', (f) a garden can reach financial independence if all income generating potentials are carefully developed and nurtured (Huntley, 2012).

The Garden as a 'biological entity'

Prof. Brian Rycroft, the third Director of Kirstenbosch (1953–1983; after Harold Pearson and Robert Compton) and champion of the expansion of NBGs in South Africa from the late 1950s to early 1980s, stated the following words about botanical gardens, which are as relevant today as they were more than 30 years ago (Rycroft, 1980):

- A botanical garden is plastic, vibrant, dynamic and alive.
- Objectives and aims change from time to time depending on needs, opportunities, and developments in other fields and even on fashion.
- A garden that does not change becomes static, docile, stodgy and moribund.
- It is essential to keep up with modern trends in presentation, display, techniques and interpretation.
- BUT – adequate restraint and dignity must be observed.
- Gardens need continuous injections of new thoughts, objectives and ideals to keep their organisation vibrant and vigorous.

Conclusion

Kirstenbosch is a world-class South African botanical garden located in the south western corner of Africa that has evolved, adapted and responded to changes, challenges and pressures over its 100-year history. Through its visionary leaders, dedicated and professional families, staff members and the support received from its friends, the Botanical Society of South Africa, it continues to play an important and significant role in providing standards for other South African NBGs and promoting the conservation and awareness of South Africa's unique biodiversity. Relevance to society and surrounding communities, horticulture and conservation are essential for the Garden to thrive as it enters its second century of existence.

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Growing and learning – the vital role of horticulture trainees at Gold Coast Regional Botanic Gardens

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Abstract

Gold Coast Regional Botanic Gardens has developed significantly through the contributions of community volunteers and students. In recent years the Gardens have functioned as an outdoor classroom for a wide range of student groups, from schools, technical and further education institutions and government funded schemes such as Skilling Queenslanders for Work. Providing site-based, horticulture training has benefited the Gardens by providing improved capacity for growth and benefitted students by providing a broad diversity of horticultural and landscaping experiences and practical, on-the-job learning. Gold Coast Regional Botanic Gardens is now investigating alternative ways of incorporating vocational training into gardens operations.

Key words

Botanic Garden; Education; Gold Coast Regional Botanic Gardens; Horticulture; on-the-job training; Outdoor classroom; Skilling Queenslanders for Work

Introduction

Australia's Gold Coast is best known for its theme parks, surf beaches and nightlife. But beyond the towering city skyline is a green hinterland, boasting some of the most biodiverse ecosystems in Australia.

Parts of the Gold Coast hinterland are protected in the Gondwana Rainforests of Australia World Heritage Area – home of relict ecosystems where many plants and animals remain relatively unchanged from their ancestors in the fossil record. The World Heritage Area includes the most extensive areas of subtropical rainforest in the world; nearly all of the world's Antarctic beech cool temperate rainforest (NSW Government Environment and Heritage, 2013). The Gold Coast city and its hinterland are also host to a rich diversity of other ecosystems, including wet and dry sclerophyll forest, littoral rainforest, fresh and saltwater wetlands and coastal heath (Gold Coast City Council, 2009).

With this vast amount of biodiversity on show, the Gold Coast needed a botanic garden! Development of Gold Coast Regional Botanic Gardens began around ten years ago, initiated by a community passionate about the region's local plants and horticulture. The Gardens sit on a 31-hectare site, in a meander of the Nerang River.

At the start of development, much of the Gardens was a blank canvas. Development has been guided by a master plan, which identified the Gardens as '*the interface between the science of botany and the community'* (Landplan Landscape Architects, 2002). The role of the community has been critical to development of the Gardens, from the formation of the Friends of Gold Coast Regional Botanic Gardens, who give their time to the Gardens 365 days a year, to the hundreds of Gold Coasters who have joined in community planting days. Over the last ten years, five hectares of new gardens have been planted at the site by volunteers and students, growing the Gardens and injecting community spirit and vitality into the Gold Coast community.

An outdoor classroom

Over the last ten years, the Gardens have been used as an outdoor classroom for a number of horticultural and conservation training programmes. Student groups from nearby training colleges regularly visit the Gardens, using the site to gain practical experience in plant identification, weed management, pruning and plant nutrition. The Gardens provide a greater diversity of training landscapes then students would be able to experience at their local college campus.

Council traineeships have enabled one or two students to be based at the Gardens full time for one year, working alongside the Gardens maintenance team. Being embedded within the maintenance team allows students to be integrated into the working life of the Gardens and to understand operations across the year and the seasons. From a staffing perspective, Council gains members of staff who understand how the Gardens work and rapidly become a very productive part of our workforce.

Skilling Queenslanders for Work

The Skilling Queenslanders for Work (SQW) programme was a Queensland Government Initiative, providing on-the-job training to assist people trying to enter, or re-enter the workforce. At the Gardens, this programme had similar advantages to the aforementioned council traineeships, in that groups of up to 12 students were permanently based at the gardens for five months. Similarly, this gave students the timeframe to gain a very comprehensive understanding of Gardens operations. Many hands make light work and, with good supervision, these large student groups were able to progress development of the Gardens far more than City of Gold Coast alone would otherwise have had the resources to do.

Each group of students focussed on two or three major landscaping and planting projects, with a whole of project approach that enabled students to experience the project from site preparation and installation to follow up maintenance. Projects such as constructing and planting a native rockery gave students skills in selection and growing native, drought tolerant, edible and wildlife attracting plants, as well as experience in soil preparation, rock placement, planting, fertilising and maintenance of new garden beds.

The diversity of garden types and learning opportunities was critical to the success of these projects at Gold Coast Regional Botanic Gardens (Figure 1). As well as working in native gardens, the students were able to work in the extensive display gardens, which showcase subtropical species from around the world. Students also had the opportunity to work in the heritage garden, which is part of the original site homestead, and a rare example of turn-of-the-century gardens in this part of south east Queensland (Heffernan, 2011). The heritage garden contains many old plant varieties rarely found in contemporary gardens, and gave students the opportunity to get hands-on experience of these, as well as experience in heritage garden restoration, remedial pruning and working at a sensitive site.

A key focus of the SQW programme was on providing students with industry-relevant skills (Figure 2). As well as horticultural skills, Gold Coast Regional Botanic Gardens provided opportunities for students to learn other landscaping tasks, including footpath construction, formwork and concreting, building retaining walls and installing irrigation systems. Students were able to use a large range of the machinery, tools and equipment they were likely to have to use in future jobs, including chainsaws, ride-on mowers, brush cutters and rotary hoes. Students' involvement in preparation and assistance at community planting days also gave them experience of working with volunteer groups and school children – essential skills for staff in botanic gardens that are working to raise their profile in the local community.

Consequently, graduates from Gold Coast Regional Botanic Gardens training courses have a very good reputation, with at least 80% of graduates now employed in the horticulture industry. Many of them have been employed by the City of Gold Coast, which highlights the benefit of quality in-house training in providing the host organisation with a skilled labour force.

Conclusions

Across Queensland, the SQW programme was generally limited to one, five-month project per site. Gold Coast Regional Botanic Gardens was able to host four trainee projects in succession, because the botanic garden setting offered such good training outcomes for students.

Our experience is that a regional botanic garden makes a perfect setting for quality horticultural training. Botanic gardens contain a unique diversity of horticultural landscapes, experience of which puts students in an excellent position when entering the workforce. The community benefits from the integration of unemployed people into the workforce, and the improved employment potential of its residents. The botanic garden benefits from a significantly increased and energised workforce – facilitating development, improving maintenance standards and up-skilling and improving the morale of permanent staff.

As government cuts impact on tertiary education and employment schemes, the challenge now is to seek alternative ways of incorporating vocational training into Australian regional botanic gardens. At Gold Coast Regional Botanic Gardens we are currently working successfully with Job Seekers Australia to provide work experience placements for long term unemployed, and are also involved in the student industrial placement programme with one of the local universities. We are now looking for ways to incorporate formal on-site horticultural training into Botanic Gardens' operations.

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Figure 1 Students working in a variety of different garden settings

Figure 2: Learning industry relevant skills, including path construction, concrete formwork, working with community volunteers and operating machinery.

Engaging communities through smart technologies

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Abstract

Engaging communities through smart-phone device-technology and story-trail tours affords botanic gardens and other outdoor educational institutions the ability to reach out to the public in new and innovative ways. Ventura Botanical Gardens, in cooperation with The University of Redlands Spatial Institute and the Esri Corporation are developing a smart phone device Story Trail application for tours with "geo-fencing" technology that senses the proximal location of a user to a tour stop and delivers relevant educational content, including audio, image slideshow, and video. The location-aware and geo-fencing-app capabilities enable a seamless blending of thematic and geographical tour information. Tour information points can be placed beyond the garden walls to integrate into the surrounding urban community, resolving some problems associated with physical signage. The app is easily configurable to add new or to modify existing tours. The technology utilizes a cloud-based approach so that little or no in-house infrastructure is required to implement the technology. A "Commons" is being established to make the technology accessible to other gardens at an affordable cost.

Keywords

App, interpretive, signage, smart phone, trail, technology, tour

Ventura Botanical Gardens Demonstration Trail

The Ventura Botanical Gardens (VBG) were established in 2005 with the goal of building a botanical garden on a 109 acre coastal hillside in Southern California. The site has spectacular views of the City of Ventura, the coastline, the California Channel Islands and local mountains. The VBG opened a trail in October 2011 approximately 1 mile in length rising to about 300 ft. The start of the trail is an easy two-block walk from the downtown pedestrian heart of the City of Ventura. As of January 2014, estimates indicate that there have been about 2000 visitors per week. An ongoing trail user survey produced results for the time period from trail opening to October 2013 which indicated several trends that guided development of the Story Trail app. The survey results (115 respondents) indicated that over 70% of visitors owned smart phone devices and that the great majority of those who did not were over 65 years of age. Visitors were also asked about their opinion of technology. Visitors did not prioritize technology, but follow up personal interviews (24) were conducted in which the Story Trail technology was explained and demonstrated; this reversed the unfavorable opinions. Demonstration of the audio clips associated with the Story Trail tour seemed to elicit the greatest positive responses. Trends indicated by visitors included: a desire for more than botanical information, in particular, information about what is in the field of view at points along the Trail pertaining to history, culture, information, anthropology, and geology; coupled with a desire for few or no future signs (currently there are no signs on the Trail); and greater directional information.

A team of stakeholders was gathered to develop content based on the assets of the Gardens and the survey results of visitors' interests. Following Tilden's (Tilden 1957) vision of interpretation, a thematic interpretation based on the natural and cultural histories of the site was developed. Geographic content was then overlaid on this theme. Professional audio was recorded by a popular local newscaster Stephanie Edwards and is accessible on SoundCloud.com (search for "vbgardens"). The tour introduces visitors to the assets of the Gardens through eighteen Story Trail educational points of interest along 2 km of the Trail. The resulting outdoor Story Trail education tour app is a general tour for all audiences.

The first Story Trail tour is easily expanded into the urban communities immediately surrounding the Ventura Botanical Gardens. For example, remnant sections of stone wall along the Trail survive from the Mission period. The Story Trail information point at the walls provides visitors with cultural history and is a logical opportunity to place a correlated Story Trail point at the San Buenaventura Mission of 1782 in the downtown pedestrian area of Ventura, which is just a few blocks walking distance from the Trail entrance. A second example correlates aspects of the Australian flora represented in the Gardens. A eucalyptus forest on the Ventura Botanical Garden site presents an opportunity to connect with heritage trees in our downtown area, including a massive Morton Bay Fig planted in 1874. These examples of extending a Story Trail outdoor education tour beyond the Gardens into the surrounding community are anticipated to draw and geographically lead visitors into the Gardens. Visitor experiences with Story Trail points outside of the Gardens will be the subject of post-implementation surveys to gauge effectiveness.

The development of the Story Trial technology and content for the first tour was funded by a grant from the California Heritage Fund and contributions from private donors.

How the App Works

Esri introduced its cloud-based ArcGIS environment in 2011 and developed a technology for publishing interactive, web-browser-based story trail tours. Building on Esri's concept, in late 2012 and early 2013, the Ventura Botanical Gardens explored the possibility of delivering story trail tours with other forms of engaging multimedia content via smart phones and GPS tracking.

The app opens with a list of tours. Selecting a tour changes the screen to a map view with a trail and tour stops. Users or visitors engage with the map by tapping on a tour stop or by walking the trail in a GPS or location-aware scenario. In the latter case, a tour stop animates or an audible sound is heard as the visitor enters a predefined radial distance or geo-fence. In either scenario the tour stop displays a pop-up with a title and options for switching to audio, image, or video content.

The app is designed with six screen views:

- About the Gardens view - a short description and link to the public website
- Story Trail Tours List view - a list of tours to select from
- Map view – including a garden map, topographic map, and aerial imagery map hosted on ArcGIS Online
- Audio view – an audio player with content downloaded from SoundCloud.com
- Slideshow view – an image slideshow viewer with content downloaded from Flickr.com
- Video view – a video player with content downloaded from YouTube.com

Advantages over interpretive signage

The ability to extend Story Trail tours outside of the Gardens makes the technology a powerful tool for achieving the interpretive goal of relating to the everyday lives of visitors, one of Tilden's interpretive principles, and to help visitors understand how the Gardens are related to the their lives and communities (Tilden, 1954; Lewis 1980). The full application of the technology in these regards has yet to be realized.

Placing Story Trail information points outside the Garden walls creates opportunities to connect with visitors' sense of exploration. Physical signs face the challenge of arousing curiosity. The location-aware aspect of the Story Trail technology inherently achieves this on some level, in that

visitors on a trail are prompted by sound and vibration when they reach an information point. The points can be moved easily and new points added, so that the curiosity of repeat visitors may be maintained.

Retention of information presented is a common problem with signs, because visitors cannot recall information presented at the beginning of a tour (Hughes and Morrison-Saunders 2002). This presented information includes both educational content and geographical information about path locations, rest rooms, entrances and exits. Story Trail technology can not only improve self-guided trail tours through visitor location-awareness and geo-fencing, but also allow visitors to retrieve information for any tour point during the tour or after the tour in their community. Placement of Story Trail information points in communities may serve to reinforce retention of information. This is another topic to be addressed in post-implementation evaluations.

Effectively communicating messages to visitors is dependent on visitors having choice of format (Veverka, 2005). Ballantyne proposed that having a suite of experiences to choose from is important when appealing to both first-time and regular visitors (Ballantyne *et al.*, 2008). Visual signs cannot satisfy every visitor's curiosity. The ease with which multiple tours can be created using Story Trail technology means that gardens can present visitors with the choice of general or specific information tours and a greater quantity that is reasonable with signage or brochures. For example, the Ventura Botanical Gardens has developed a second tour in response to visitor requests to present detailed content of the geology of the Garden site. As the quantity of our story trail content increases, the utility and presentation afforded by smart phone technology becomes truly apparent.

Botanical gardens can function as tourism anchors (Sharpley, 2007). The potential for Story Trail technology to facilitate local tourism is particularly strong for urban botanical gardens. Extending Story Trail information points into communities adjacent to gardens is an opportunity to partner with and promote local organizations with similar missions or local businesses relevant to the interests of visitors. The Story Trail app includes screens devoted to recognition of sponsors as well as a splash screen that appears after the initial tour list screen. This advertising space is a small revenue opportunity and dovetails with functioning as a tourism anchor for the surrounding community.

Lastly, the technology has some possibilities in facilitating post-implementation evaluation in terms of quantity, access, and patterns both within and outside the Gardens; but the Ventura Botanical Gardens is not actively developing data-gathering aspects of this technology.

Technical Requirements

Using no in-house infrastructure, the app relies on the distributed information architecture of the Internet cloud to deliver its tour trails, stops, and content. A cloud-based architecture makes servicing the app affordable and manageable for any botanic garden.

Cell phone reception is required.

Esri is a corporate leader and innovator in mapping technologies with a commitment to public service and support for non-profits. Esri sponsors a non-profit program called ArcGIS for public gardens. By joining this program, botanic gardens are entitled to purchase feature-rich mapping software with a nominal fee, obtain free training, and establish a free ArcGIS Online subscription account for publishing story trail tours. You can learn more by going to this link:

http://www.publicgardens.org/files/files/Esri_ New 2012 APGA Application Process.pdf.

Join the Commons

As a non-profit organization, the Ventura Botanical Gardens is committed to assisting other gardens and outdoor nature education venues to implement Story Trail app technology in cost-effective ways. The University of Redlands Spatial Institute and Ventura Botanical Gardens have joined to create a Commons Partnership so that other entities may create story trail tours for their visitors and members. The cost for joining is still being worked out but will be significantly less than the cost of initial development and include an annual maintenance charge for code maintenance and enhancements.

Conclusions

The Story Trail tours app implemented at the Ventura Botanical Gardens has great potential to realize geographic and thematic integration with the surrounding urban community. The flexibility in application and ease with which the Story Trail technology can be implemented is key to its widespread adoption by botanical gardens. Public access to the Ventura Botanical Gardens Story Trail app is expected by summer 2014, available through Apple Store™ and Android Play Store™. For information on joining the Commons to build a Story Trail app for your gardens, please contact University of Redlands Spatial Institute or Ventura Botanical Gardens Administrative Director.

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The Ghost of Courtney Puckey: the use of theatre and history to enhance visitor experience at Wollongong Botanic Garden

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Abstract

This paper explores the use of theatre at Wollongong Botanic Garden as an education technique, with particular reference to the latest project 'The Ghost of Courtney Puckey'. The paper helps to explain the philosophy and methodology behind the performance at the conference.

Keywords

Theatre, heritage, botanic gardens, interactive, experience, humor, character

The education team at Wollongong Botanic Garden has used theatre as a powerful tool to teach and to entertain visitors to the Garden for many years. Characters such as *Captain Compost, The Tree Musketeers, The Talking Tree* and many other creations from the team can be seen roaming the Botanic Garden, interacting with young visitors. Now the general community and older students are getting a taste of this wonderful visitor experience in one of the Garden annexes, through the *Ghost of Courtney Puckey* tours. The main component of the *Puckey* tour is the appearance of Mr. Puckey himself. The ghost of this remarkable man interacts with the visitors sharing his views on the history, culture and ecology of this coastal Garden annex.

What are the successful ingredients of theatre/education in botanic gardens? Why do shows like *Captain Compost* or the *Talking Tree* appear to be so successful in engaging our young visitors and their families? The evidence supports the notion that theatre works well as a teaching method in botanic gardens. The customer surveys that we have run over many years consistently indicate a very high satisfaction rate from children and their parents and teachers. Our follow-up questionnaires also show that participants remember the lesson and issues explored in the plays for many months and years after they experience the shows.

The ingredients are…

Humor and Exaggerated characters: Larger-than-life theatrical characters, such as the *Giant Water Bugs* and the *Animals in Pajamas*, with their bright and exaggerated costumes, use fun and laughter to help the audience absorb and remember the issues of the play.

Audience Participation: Participants are invited on stage to dress up and to sing. Recent audiences joined the animal characters in '*It's a Long Way to hop so Stop, Drop and Roll'* during *Bush Fire Madness* shows. There is a constant dialogue between actors and audience in this type of show.

Demonstrations: An in-built demonstration to focus on the issues explored in the action of the play. In *The Tree Musketeers* volunteer conservation people from the audience build a scaled-down rain forest. Pollution Police Trainees clean up the creek in *Clean Up your Act*. In *No more Dodos* volunteers explore the contents of a secret parcel to work out the fate of a host of endangered plants and animals. In *Captain Compost* the children help the Captain to build a compost heap that is balanced, healthy and rodent free.

So how have we applied these important features in *The Ghost of Courtney Puckey*? First of all Courtney Puckey was a larger-than-life character himself. He was an obsessive, eccentric chemist/optician from England who dabbled in salt making. He settled in Wollongong in 1887, and later purchased an area of land close to the city that has since become an annex of Wollongong

Botanic Garden. Puckey with his long grey beard, strong Cornish accent and dressed immaculately in a bowler hat and waistcoat, is a wonderful character for theatre.

There is also plenty of opportunity for audience participation in *The Ghost of Courtney Puckey Tour*. To begin with Puckey invites the audience to ask the questions like 'Can you tell us something of your family?' Members of the audience are also invited to take part in a reenactment of the Council meeting of 1957 to decide the fate of his grand home 'Seafield'.

There is also a planned demonstration component for the Puckey tour. This will be used with school students; they will build a model of the evaporative tea tree salt towers used by Puckey to extract salt from the sea. Puckey also demonstrates the use of folk medicine and its similarities to Australian Aboriginal bush medicine.

The use of local history is an additional ingredient in this project**:** the life of Courtney Puckey is like a time–line for the Estate. By meeting Puckey in the flesh, visitors are gaining a first-hand experience of the environmental issues related to the Estate at the close of the 19th century and into the early 20th century. Elderly local participants in the tours also share their own experiences of the Estate in the past. This provides invaluable insight into the life of Courtney Puckey for the actor/creator of the project. One elderly lady remembers as a child being chased away from the Estate by Puckey. Another gentleman remembers how messy Puckey's chemist shop in Crown Street was.

The Puckey project was launched in March 2012 to celebrate Senior Citizens Week, and is booked in for Seniors Week 2014. We have conducted a dozen tours of the Estate since that time, including a twilight tour, and we have presented the tour off-site to a number of community groups, including the Wollongong Historical Society, the Heritage and Conservation Society, the Society of the First Fleeters and The University of the Third Age. The project has been presented at a number of BGCI conferences in Australia and overseas. A tour through the Estate was also used to help launch the New South Wales Eco Arts Conference in May 2013. In 2014 we aim to target high school students. This will include visits to the schools and tours of the Estate. We will also include family tours and presentations during school holiday periods.

Can heritage-based theatre succeed at other botanic gardens? The possibilities are endless: for example the Royal Botanic Garden Melbourne could develop a tour around one of the original directors, Baron Von Muller. This amazing Austrian botanist was known as 'Baron Von Blue Gum' because of his obsession with the Tasmanian Blue Gum. If your botanic garden doesn't have a famous individual, use a stock character to represent the period, for example a 19th century gardener. Various old-time horticultural practices could be demonstrated as part of a tour. The aim is to lead a modern audience down memory lane, to entice them into the experience, and to show the relevance to the present. We recently used two important female historical figures from different decades in the twentieth century at Wollongong Botanic Garden to celebrate international Women's Day: Edna Walling, prominent in the 1930s and 1940s, and Ester Dean in the 1970s. These two wonderful characters made significant contributions to the development of gardening in Australia and they made wonderful tour guides for the day. It is also important to provide opportunities for audience participation, perhaps a re-enactment or a demonstration to reinforce the presentation. On the International Women's Day, Ester demonstrated her famous 'no-dig' gardening technique.

In summary I can only encourage you to embrace the past through theatre in your botanic gardens. I can guarantee that you won't be disappointed and, more importantly, your audience will be completely involved in the experience. Participants in *The Ghost of Courtney Puckey* tours revel in the experience, continuing to ask 'Mr. Puckey' questions and provide him with useful treasures of information about his Estate, even after the actor's identity has been revealed.

The role of botanic gardens in health and well being

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Abstract
This paper is based on a literature review carried out on the therapeutic qualities on human health of green spaces within the urban environment. The themes are: 1. The benefits of accessible green space with regards to general health and well being, stress management, recovery from illness, quality of life and longevity. 2. The cost benefits to the community in the provision of green spaces and the need for collaboration between urban planners, green space providers, health administrators. 3. The importance of these landscapes in the developmental stages of children.

Within the context of this paper the term “green spaces” covers an extensive range of situations and opportunities from which people can achieve both short and long term health benefits through the accessing of nature. It includes natural settings, public park systems, public and private gardens among others. This paper focuses on the derived health benefits that people living in a highly urbanised setting can gain through having access to publicly owned/controlled “green spaces”.

The paper briefly discusses the three main theories linking health with the natural environment; the biophilia theory (Wilson, 1984), attention restorative theory (Kaplan, 1995), and the Psycho – physiological Stress Recovery Theory (Ulrich, 1983). Summaries of the three theories can be found in Marshall *et.al.* 2010 (pp. 2/3).

Keywords

Botanic Gardens, green Infrastructure, health, wellbeing

Report

The City of Dubbo is located at the geographical centre of New South Wales state and borders four major bioregions: the Brigalow South, the South West Slopes, the Cobar Penneplain and the Hunter section of the Sydney basin. In recognition of our unique opportunity to display species from these four neighbouring bioregions, as well as providing a new recreational and educational facility for the residents and visitors to the City, Dubbo City Council commenced the development of a master plan for a botanic garden in 1997. In April of the following year Council adopted the Elizabeth Park Master Plan that set the stage for the development of the Dubbo Regional Botanic Garden at the 10 hectare site in East Dubbo.

Development commenced in 1999 with the planting of an avenue of *Populus yunnanensis* as part of the 150th anniversary of Dubbo being proclaimed a village. The first of the major garden elements Shoyoen, the Japanese garden, was formally opened in 2002. This garden was a gift by Dubbo’s sister city Minokamo to the people of Dubbo. The attention to detail and the authenticity in maintaining this garden is reinforced through an annual visit by gardeners from Minokamo and results in Shoyoen being recognised as one of the best examples of a “strolling and refreshing garden” in Australia.

In keeping with the original intent of the master plan to display and promote the endemic vegetation found within the Dubbo area the next garden to be developed and opened to the public was the Biodiversity Garden in June 2006. This garden replicates the major vegetation communities of the Dubbo region that include: Grassy Box Woodlands, Ironbark and Redgum forests, rocky creeklines and wetlands.

The Sensory Garden followed in 2011 and provides the public a garden that stimulates the five senses through the landscaping and the choice of plants displayed. The newest garden, the Oasis

Valley opened in April 2013, again returns to the objective of providing a collection of plants that are found within one of the four bioregions. Within the Oasis Valley there is a collection of "dry rainforest" species which reflect the dry rainforest community of the northern Hunter Valley region.

Figure 1. Dubbo Regional botanic garden master plan and gardens

Although Elizabeth Park is being established with the intent to create a botanic garden and provide opportunities for scientific research and education, botanic gardens can play another significant role within their communities. This role is one of a "health provider" which it can achieve through the provision of spaces within the confines of the botanic garden for promoting physical activity that can help reduce the incidence of a range of diseases and medical conditions within our communities. Studies have shown that the simple activity of walking can:

- improve general health, reduce the risk of coronary heart disease by 14% and reduce the risk of cardiovascular disease by 25% (Willis and Crabtree 2011).

- Reduce the incidence of Type 2 diabetes, some cancers and osteoporosis and improve mental health and mood (Coutts, 2010).

To help illustrate the extent of the problem and the opportunities that it provides, botanic gardens and other recreational providers should consider the following statistics:

- 61% of the Australian population is overweight or obese. 25% of children aged between 5–17 years are overweight or obese (NSW Dept. of Health, 2008). However girls and boys living near accessible green space were, on average, 5.1kg and 5.9kg lighter than those living in a more urbanised setting (Bird, 2011). Another study (Ellaway, Macintyre & Bonnefoy, 2005), also found that increasing levels of accessible green space led to increasing levels of physical activity that resulted in a lower incidence of obesity (Table 1)

- In Australia, 1,086,860 people are registered as having diabetes, with 937,480 people having Type 2 diabetes (NDSS, 2013); this costs the economy $10.3 billion annually. Type 2 diabetes is recognised as Australia's fastest-growing chronic disease, with over 200 cases registered per day. However up to 60% of Type 2 diabetes cases are reportedly preventable through increased physical activity and improved diet.

- In Australia over 3 million people suffer from depression-related illnesses, that costs the economy $3.3 billion annually in lost productivity (Beyond Blue 2005).

There is also an increasing amount of evidence for the benefits of green spaces to children suffering from Attention–Deficit /Hyperactivity Disorder (ADD/ADHD) and their potential for utilising nature-based restorative therapy as a non-medicating and inexpensive treatment for children

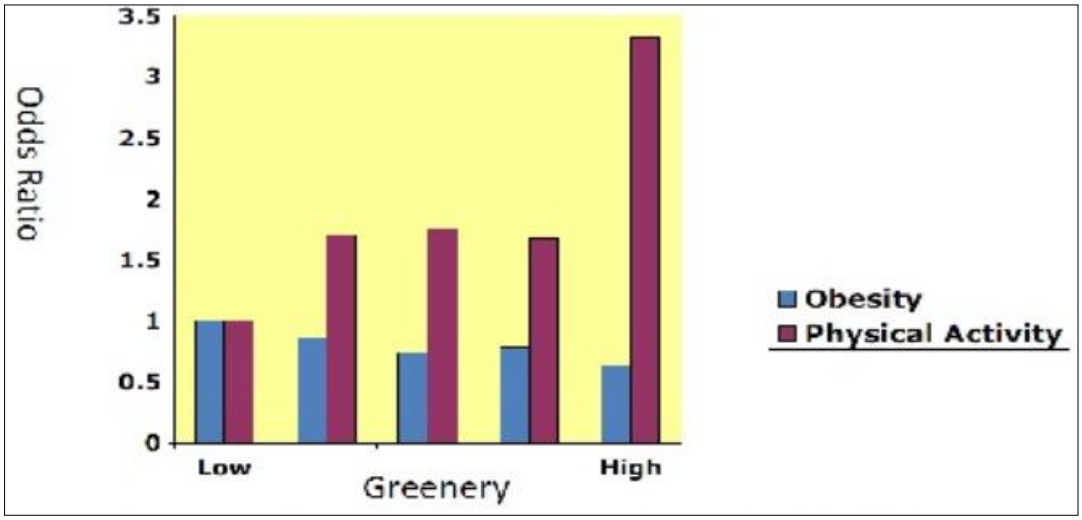

Figure 2. Relationship between the level of greenery, physical activity and obesity. (Ellaway, Macintyre and Bonnefoy 2005)

suffering from ADD/ADHD (attention deficit disorder). Results from studies carried out (Faber Taylor, Kuo & Sullivan 2001 (p.73), and Kuo & Faber Taylor 2004 (p.1584)) found that children suffering from ADD or ADHD who undertook nature-based activities exhibited reduced ADD symptoms by up to 30% compared to urban outdoor activities (p.65), and also a three fold reduction in symptoms where the same nature-based activity was carried out indoors (Bird 2007 (p78)).
The positive relationship between the improved behaviour of children with ADHD undertaking nature-based activities, compared to indoor activities or activities within an outdoor built environment, is shown in Figure 3.

When you consider that most botanic gardens are well designed and laid out with a system of paths, trails etc, and are well embellished with plants and developed landscapes, then there is an opportunity for botanic gardens to develop collaborative partnerships with formal health providers and urban planners to deliver positive health outcomes to the community, while still meeting the fundamental criteria of a botanic garden. While these benefits may not translate directly into an additional income stream for the botanic garden itself, these benefits and cost savings may express themselves throughout the community in terms of a general improvement in health and cost savings in a tax funded health system.

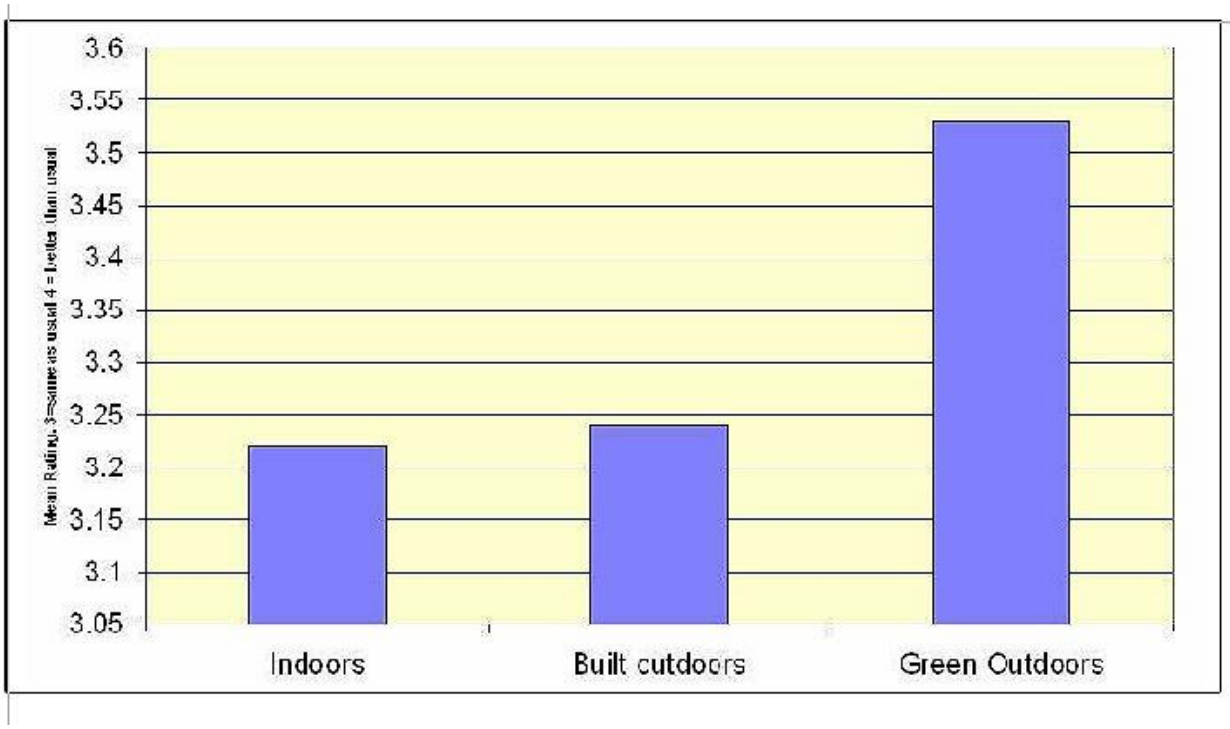

Figure 3. Relationship between ADHD symptoms and playing indoors, in the built environment or in green space (Bird, 2011)

Figure 4. Proposed path network for the Dubbo Regional Botanic Garden

Upon completion the Dubbo Regional Botanic Garden will have over 8 km of trails to provide pedestrian access throughout the Garden, as shown in Figure 4, with 2.5 km already constructed.

While these paths provide the opportunity for physical activity within the garden, they also connect to a much broader park concept for the City of Dubbo – the City Wide Park, seen in Figure 5 below.

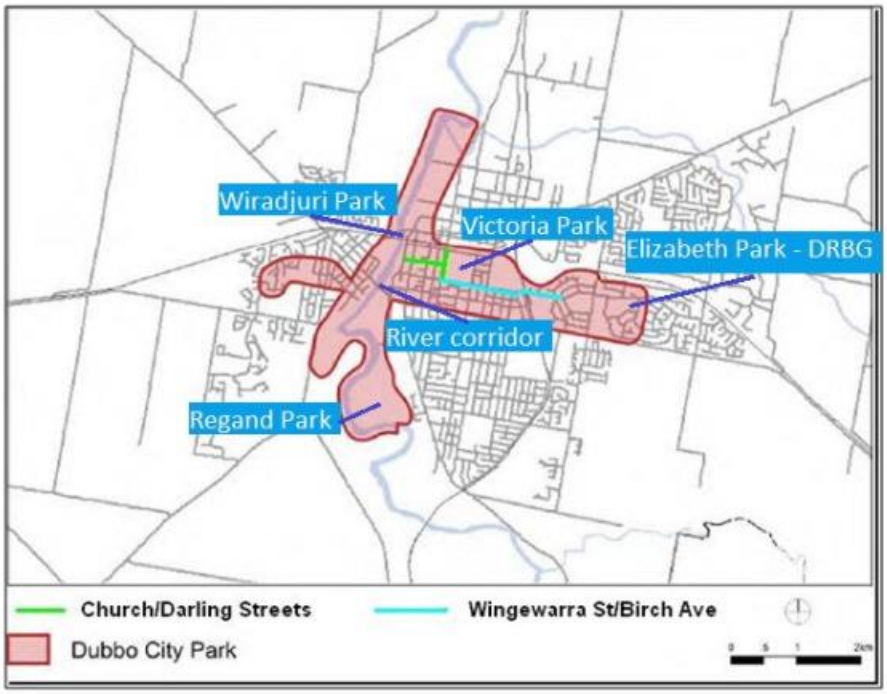

Figure 5. Future extent of Dubbo's City Wide Park

The City Wide Park already contains a large area of recreational land that includes parks, sporting facilities and reserves. As a result of good long-term planning by Dubbo City Council, much of this green space is concentrated along the river corridor. However the further you move away from this corridor the public open space becomes increasingly fragmented within the urban fabric of the city. To help re-establish the connectivity of the public open space, the City Wide Park plans to utilise this "green spine" and re-connect it to other major parks through a network of "park streets", pedestrian and cycle ways. These parks include the Dubbo Regional Botanic Garden, Victoria Park (the oldest park in Dubbo dating back to 1876 and home to a wonderful collection of Victorian-era plants), Regand Park and Wiradjuri Park. While neither Regand Park nor Wiradjuri Park are yet developed, they will both make a significant enhancement to the recreational facilities of Dubbo.

Both Regand and Wiradjuri Parks have been designed with a high level of consultation with the community; they have very different goals and objectives. Regand Park is a 62 ha park located on the Macquarie River. Figure 6 below shows parkland features that have been designed largely around passive (walking trails) and active recreational pursuits (running, sport, bike riding, horse riding, swimming etc) to provide opportunities for the residents of Dubbo to increase their level of physical activity. There is also a strong focus on the rehabilitation and restoration of the riverine vegetation. This too provides the opportunity to encourage people to "get physical" through community planting days that develop community ownership of the Park.

In contrast, Wiradjuri Park is a much smaller park of 3.5 ha. Through a community consultation process, this park has been designed as an Aboriginal cultural park and a place for quiet contemplation. It is a place where the Aboriginal community can both celebrate their culture, a space to sit quietly and reflect, and a place to acknowledge significant dates on the Aboriginal calendar.

Figure 6. Master plan for Regand Park showing the extent of recreational facilities on offer.

Figure 7 Wiradjuri Park – contemplative space

An important feature of the City Wide Park is the increased connectivity of the public open space through “park streets”. These are streets which retain their functionality as a vehicular carriageway but are significantly embellished with park-like qualities that include plants, footpaths, cycleways, street furniture etc. The purpose of these park streets is to allow people to move between different parcels of parkland through an aesthetically pleasing setting rather than the traditional urban setting seen in figure 8.

Figure 8. The development of Brisbane Street into a 'park street'. Before and after Phase 1 of the central planting of *Angophora floribunda* in the median, completed June 2013

Through the development of the City Wide Park in conjunction with the Dubbo Regional Botanic Garden, the City will possess over 30 km of connected footpaths and cycleways with still more to be developed.

The Dubbo Regional Botanic Garden provides a range of other opportunities and spaces that can help:

- Encourage the community to participate in exercise and social interaction. These programs cover a wide range of opportunities that include:
- Educational programs that link into the National Curriculum that involve children moving, exploring and interpreting their environment,
- Community planting days to help with the ongoing development of the Garden, and
- One on One learning opportunities.
- Children gardening programmes that, according to Wake 2006, can provide the following benefits:

  - Inspire learning about plants
  - Provide ownership and belonging to a child-centered space
  - Multidisciplinary learning in arts, sciences, social skills etc.
  - Foster the appreciation of gardens and the outdoors
  - Create positive memories that may lead to a sense of earth stewardship that they can then take into adulthood.

- Improve social inclusiveness and recovery from injury through occupation therapy spaces. These programs can also be are tailored to meet the needs of:

  - Elderly or less mobile persons, and
  - Disabled persons.

Figure 9. Opportunities for helping to increase physical activity through the Dubbo Regional Botanic Garden

These gardening programmes have proven to be successful for a number of reasons, including the design and construction of the potting bench that enables access to both electric and standard wheelchairs for both adults and children, as well as the choice of plant material used. The cultivation of succulents has proven to be extremely successful, because of to their large fleshy leaves and their ability to withstand damage but still take root.

Summary

While the role of botanic gardens will always be based on their scientific and education utility, there is also an opportunity for them to collaborate with town planners, councils and health providers to help promote a healthier lifestyle. In recognising that the influence of the botanic garden does not necessarily stop at the front gate but can be effective throughout the urban environment, not only can the botanic garden benefit through increased patronage and community assistance in future development, but the entire community can also achieve a higher level of fitness and mental well being that can reduce the incidence of a number of diseases and conditions that are becoming more common within our society.

> *An experience of nature can help strengthen the activities of the right hemisphere of the brain, and restore harmony to the functions of a brain as a whole. Furnas 1979.*
>
> *"This is a technical explanation of the process that occurs when people "clear their head" by going for a walk in a natural setting". Maller et. al 2005*

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A new botanical garden-led undergraduate course combining botany and high level conservation management thinking

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Keywords

Botanical garden, Botany, Capacity-building, Course, Employer-employee, Management thinking, Nature conservation, Plant families, Undergraduate

Abstract

We describe a newly-developed BSc course that aims to produce a new type of conservation expert. One of the main goals of the course is for students to obtain knowledge of plants and vegetation and their adaptations and needs. Another is to teach students at a high management level how to deal with major conservation issues, such as the ecological footprint, fragmentation and sustainable exploitations of forests. Course material is provided in the form of lectures and hands-on work sessions presented and led by experts in a certain field.

In this course the principles of botany are discussed in detail. Describing and identifying plants is practised, both in the practical rooms as well as in the botanical garden. The characteristics of 47 plant families, tropical as well as temperate, are highlighted and considered in the light of conservation issues. For this the botanical garden plays a crucial role, allowing students to recognise the true scale of biodiversity in a challenging yet engaging way. This will give students the essential skills to be used in discussions with decision makers on conservation issues.

At the end of the course companies as well as representatives from institutions and governmental bodies will be present at an employer-employee day. During this day students will become aware of what employers may expect from potential employees. Good plant knowledge often seems a crucial condition, alongside a high level of critical thinking.

Initial feedback confirmed that this course, with the aid of the botanical garden, has truly started a new way of capacity building in the field of plant conservation.

Conservation and the botanist effect

> Over the last few decades, *resources for descriptive taxonomy and biodiversity inventories have substantially declined, and they are also globally unequally distributed. This could result in an overall decline in the quality of biodiversity data as well as geographic biases, reducing the utility and reliability of inventories.*
>
> *We* suggest that *greater investment in the training of botanists and in the provisioning of good facilities would substantially increase recording efficiency and data reliability, thereby improving conservation planning and implementation on the ground.*
>
> Ahrends *et al*. (2011)

Introduction

In order to build capacity in the field of plant conservation at management level, it is vitally important that today's biology students are made aware of the sheer beauty and astonishing variety and complexity of endangered ecosystems. Getting to appreciate an ecosystem's vegetation, and especially its individual plants, is a good starting point. Plants do not move and can therefore be easily collected and studied. A good place to study plants is in a botanical garden, where biodiversity is on display in a relatively small area. Moreover, the use of a botanical garden

for undergraduate and postgraduate courses may also serve as one of the validations for its existence.

Plants are the building blocks of every ecosystem. Plants are also very visible to decision makers and politicians visiting vulnerable ecosystems. These decision makers may be more easily convinced to take action on preservation issues, if their conservationist counterparts can demonstrate in-depth knowledge of the plants and the vegetation surrounding them.

Currently, courses on conservation at management or research level do not include any substantial botany training, be it pure plant knowledge or how plants interact with the environment. In this course the concepts of biodiversity and species decline will be correlated to an understanding of nature conservation, sustainability and human activities. This will be illustrated with examples from the plant kingdom, drawing on the expertise and plant diversity of the botanical garden. In addition, companies, as well as foundations and governmental organisations, will present themselves at an 'employer-employee day' and will explain what is expected from potential employees. Comprehensive plant knowledge is often one of the crucial skills required.

Feedback confirmed that this course has truly started a new way of capacity building in the field of plant conservation. A follow-up MSc-level course is under development as the next stage in a new series of courses to generate plant conservationists.

Intended learning outcomes

At the end of this course students should:

- have gained a detailed understanding of plant diversity.
- be familiar with techniques to identify species.
- be able to correlate plant diversity to the overall condition of an ecosystem.
- be able to describe and interpret morphological trait patterns and relate them to taxonomy (species, genus and family level) and functional and ecological adaptation.
- be confident in using a herbarium.
- appreciate the importance of botanical knowledge in the field of conservation and sustainability research.
- be familiar with different scientific views and conservation models to quantify the loss of species and ecosystems, and be able to propose measures to counteract this.
- be able to explain habitat loss, overexploitation, fragmentation, climate change, their influence on wetlands, the influence of microbes, and the introduction of non-native species, and combine these issues with practical nature conservation policies at local, regional and global scales.
- be able to compare and contrast conservation of species and ecosystems with issues concerning sustainable use of natural resources and climate.

Outline of the course

Content (Table 1):

- 2.5 days a week for 10 weeks
- Every week:

  - 1.5 day botany, partly in the botanical garden.
  - 1 day conservation issues, supervised by an expert in a particular field.
- In all:
  - 4 x 0.5 and 7 x 1 day of botany (= 9 days)
  - 6 days of conservation issues
  - Throughout the course: a research project (groups of 5) on a conservation subject created and supervised by an expert who also serves as an e-mail coach, starting with a job application and resulting in a paper and a poster presented at a mini-symposium on the last day at WWF Netherlands Head Office
  - Week 7: an employer-employee day
  - Exam on the penultimate day of the course.

Examples of research projects:

- Wood certification and tropical forests
- Fragmentation and nature conservation
- Reintroduction of the otter in the netherlands
- The ecological footprint
- Carbon dioxide sinks in tropical forests
- Other functions besides carbon dioxide in redd (united nations, 2008)
- Bromeliaceae, their taxonomy and conservation
- Genetic diversity and nature conservation
- Red lists and nature conservation: plants
- Eco-cities, sustainable cities
- Sustainability, religion and culture
- Sustainability and the landscape: regulating
- Botanical gardens and *ex-situ* conservation: tropical or temperate.

Conservation Issue Days

- REDD
- Living Planet Report (WWF, 2012) and ecological footprint
- Sustainable (tropical) forest management
- Corridors and fragmentation

- The role of herbaria and taxonomy in conservation projects
- The role of microbes in the conservation of ecosystems
- Every Conservation Issue Day starts with two lectures, followed by a workshop, each resulting in a short essay or a presentation or a fact sheet made by the students (in groups of 5) based on given literature

Botany (1), 4 x 0.5 day

- Lecture: introduction to 'botanical language'
- Workshop: making a complete description of a living plant
- Lecture: introduction to nomenclature, botanical keys and floras
- Workshop: identifying living plants using the Dutch Flora
- Lecture: introduction to collecting and taxonomy of Bromeliaceae by a world expert
- Workshop: answering taxonomical questions about this group using herbarium material
- Lecture: The Foundation Trésor
- Workshop: tour of the Utrecht Botanical Garden greenhouses
- All workshops in a laboratory (binoculars available).

Botany (2), 7 x 1 day

- Lectures (2): introduction to pollination syndromes
- Workshop: a practical exercise in a laboratory: studying flowers in relation to the pollinator
- Lectures (2): introduction to dispersal mechanisms
- Workshop: a practical exercise in a laboratory: studying fruits in relation to the dispersal mechanisms
- 5 days: Lectures (2): introduction to 46 plant families
- Workshop: a practical exercise in a laboratory: studying family features and making diagnostic descriptions, 10 families each day
- Workshop: aided by a map (Fig 1) and blue labels with only a family name (standard labels are green) in the garden (Fig. 2) a 'plant hunting' session in the botanical garden focussing on the diversity within each family
- All material supplied by the Botanical Garden.

Assessment

- Marks for the application letter, poster session and research project paper (30%)
- Marks for essays, presentations and factsheets of the workshops (10%)

- Exam marks, exam consisting of half botany, half conservation issues, including making a description and a flower diagram of a living plant (50%)

- Attendance and marks for practical sessions (10%).

Typical outline of a plant family lecture

- An example of a well-known species within the family.

- A detailed botanical drawing and an explanation of the flower features.

- Flower diagrams showing the diversity within the family.

- A distribution map.

- An overview table including almost all, mostly morphological, characteristics of the family (details of which are formative and not assessed); for instance, numbers of genera and species, habit, position of leaves/stipulae, inflorescence, flower formula, gender, fruit etc.

- Pictures of flowers and fruits and their characteristics.

- An overview table including ecological features (details of which are part of the assessment); for instance, pollination, dispersal, uses, habitat and CITES information.

- Pictures of examples of the use of species within the family.

- Pictures of endangered and CITES species.

- Pictures of 'species with a story' (*e.g.* invasive, poisonous, historical, spectacular, symbiotic or generally unusual plants)

- Pictures showing several species within the family that are part of the botanical garden collection.

- Pictures from a personal photograph collection, for tropical plants mostly taken during field trips in the Trésor Nature Reserve in French Guyana (a nature conservation project of Utrecht University), together with stories with personal experiences, highlighting fascinating aspects of the family.

- An overview slide detailing the diversity and variability observed within the family.

For a list of the families studied see Table 2.

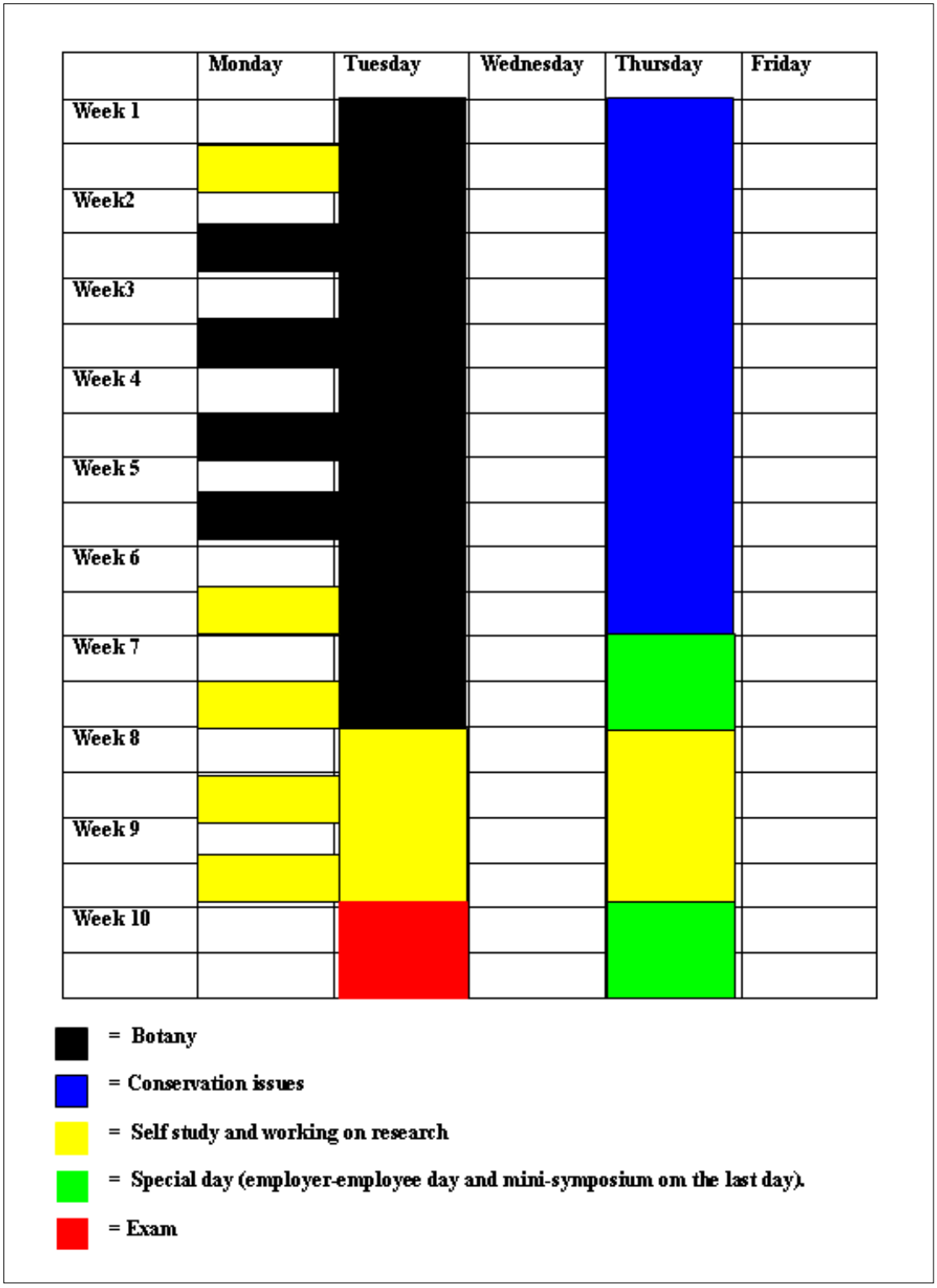

Table 1 Outline of the course schedule

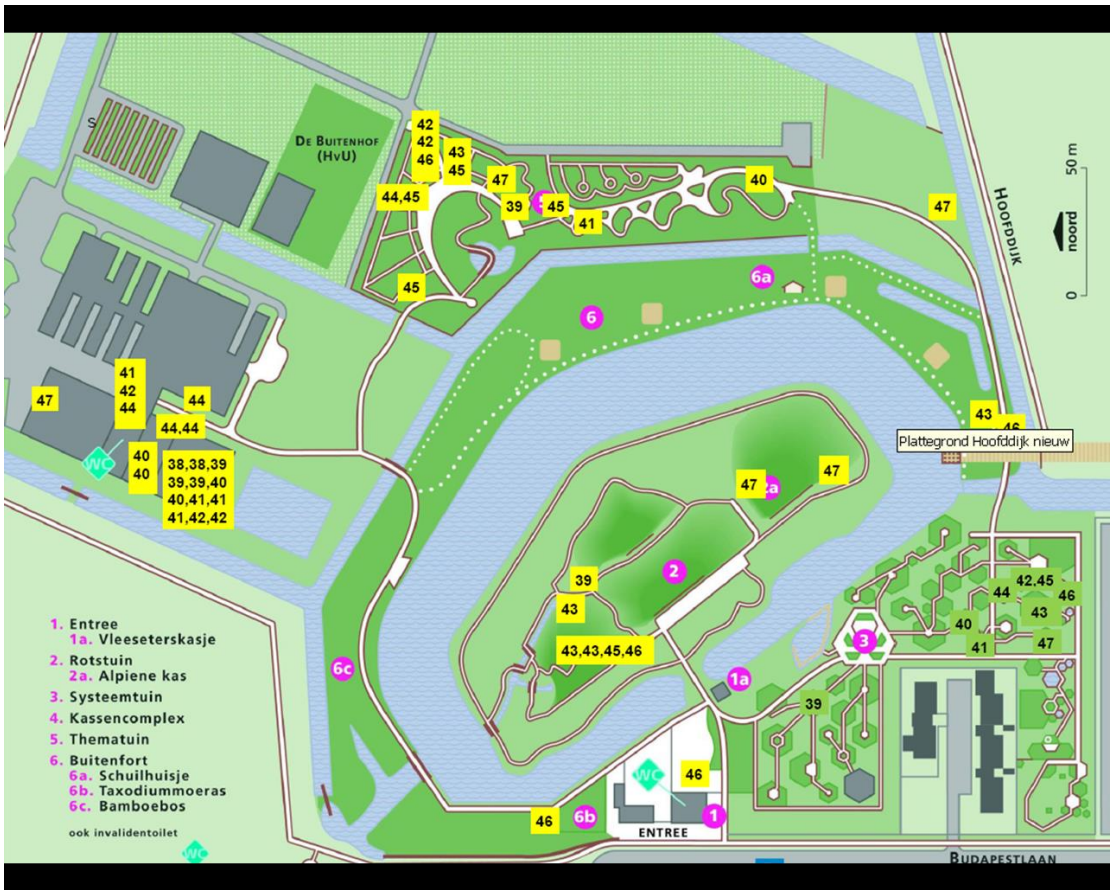

Figure 1 Map of the garden with family number positions

Figure 2 Blue labels in the Garden

Families:				
Day 1	Day 2	Day 3	Day 4	Day 5
Cyatheaceae	Lauraceae	Poaceae	Melastomataceae	Lecythidaceae
Polypodiaceae	Annonaceae	Cyperaceae	Myrtaceae	Primulaceae
Cycadaceae	Magnoliaceae	Bromeliaceae	Rutaceae	Apocynaceae
Zamiaceae	Piperaceae	Ranunculaceae	Sapindaceae	Rubiaceae
Cupressaceae	Araceae	Crassulaceae	Dipterocarpaceae	Lamiaceae
Pinaceae	Asparagaceae	Euphorbiaceae	Malvaceae	Plantaginaceae
	Iridaceae	Passifloraceae	Brassicaceae	Solanaceae
	Orchidaceae	Fabaceae	Caryophyllaceae	Boraginaceae
	Arecaceae	Rosaceae	Cactaceae	Apiaceae
	Costaceae	Moraceae	Ericaceae	Asteraceae
		Betulaceae		

Table 2 List of families **studied**

Literature for the family days and References

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Rescue and conservation of a rediscovered endemic fern: *Anogramma ascensionis* on Ascension Island

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Abstract

The Ascension Island endemic fern, *Anogramma ascensionis*, was listed as extinct on the 2003 IUCN Red List, having been last seen 1958. A 2009 survey rediscovered four plants on a remote cliff on the Island's highest peak, Green Mountain. Spores collected from two of these plants were cultured *in vitro* at the Royal Botanic Gardens, Kew, where a living collection of thousands of gametophytes and hundreds of sporophytes has been developed. Initial results from liquid nitrogen storage indicate that this may be a viable long-term storage option for both spores and gametophytes.

Prior to the large-scale invasion of the Island by alien species in the 19th and 20th centuries, which dramatically transformed Ascension's vegetation, it is likely that *A.ascensionis* flourished in sheltered, humid and shaded parts of the mountain. These habitats have been very heavily invaded, especially by non-native maidenhair ferns, *Adiantum* spp., providing an indication of why *A.ascensionis* came so close to extinction. We have developed a multidisciplinary approach to species recovery, involving *in vitro* culture, up-grading the Green Mountain nursery and providing horticulture training, the clearing of invasive species and controlled translocation, as the road map for re-establishing functional populations of this critically endangered island fern.

Keywords

GSPC; *ex situ* conservation; horticulture; Red List; threatened plant; UK Overseas Territories;

Introduction

Ascension Island lies in the middle of the South Atlantic Ocean, 1,500km from the coast of Africa, just over 2,000km from South America and 7,500km from the UK. Ascension is a UK Overseas Territory, one of 16 former colonies that remain part of the UK. Kew has an active programme providing botanical support to help the territories implement the Global Strategy for Plant Conservation (GSPC) (Clubbe *et al*, 2010).

Ascension is a small (97km^2), young (1Myr old) volcanic land mass with a hot, dry climate, except for the moister upper slopes of Green Mountain which rises to an elevation peak of 859m. Green Mountain is Ascension's only National Park, established in 2005 (Ascension Island Government, 2014a) and the habitat for its most important plant diversity (Figure 1). Being a young volcanic island with poorly formed soils and a relatively short time for plant colonisation, Ascension supports a relatively modest vascular flora. A comprehensive island-wide census in 2009 recorded 249 wild species, 95% of which are considered non-native, but of the native flora more than half are endemic to Ascension (Lambdon & Darlow, unpublished data). The biggest current threat to Ascension's native flora is non-native invasive species. Results from the 2009 census suggested that non-native species occupy approx 99% of the vegetated area of Ascension.

One of the most important plants on Green Mountain is the endemic Ascension Island parsley fern, *Anogramma ascensionis* (Pteridaceae) which we know from the type specimen in the Kew herbarium; it was collected by Kew's former Director Sir Joseph Hooker in 1843 (UKOTs Online Herbarium, 2014) (Figure 2). The only confirmed 20th century record for *A. ascensionis* is by Eric Duffey in 1958, although with no associated voucher specimen (Duffey, 1964). The Ascension Government Conservation Department conducts an annual census lead by Ascension's Conservation Officer, Stedson Stroud, and despite concerted efforts no *A. ascensionis* had been

found at the site documented by Duffey nor in any other likely habitat locations. As a result of these directed, unsuccessful searches over several years, *A. ascensionis* was assessed as Extinct for the 2003 IUCN Red List (Gray, 2003). The annual plant censuses continued and in 2009 four small plants of *A. ascensionis* were found on a remote cliff side on Green Mountain, and a race against time was started to save this fragile species. Plants were monitored and watered in the field to ensure survival and to induce sporulation (Figure 3). Sterile collecting materials were sent to Ascension from Kew and when the spores were ripe the fronds were collected into sterile petri dishes and with the support of the Island's Administrator and the Royal Air Force we were able to get the spores from the field into micro-propagation in the laboratory at Kew within 24 hours (Gill, 2010).

At Kew the team in the Conservation Biotechnology Unit successfully established these spores in micro-propagation and have taken the fern experimentally through its whole life-cycle, through to mature sporophytes weaned out onto growing media in pots in the Tropical Nursery and collected viable spores from the mature sporophytes. Under these optimal conditions the sporophytes are substantially larger that any seen in the wild on Ascension but interestingly of a size similar to Hooker's original collections, giving the impression that the re-discovered plants are growing in sub-optimal conditions (Figure 4). We now have hundreds of viable plants in *ex situ* conservation at Kew. The Ascension conservation team have been to Kew for training in micro-propagation techniques as well as in the conventional propagation of ferns. Kew horticulturists have been to Ascension to help upgrade the Green Mountain nursery. Capacity building is a very important aspect of Kew's approach to partnerships and a key contribution to target 15 of the GSPC (CBD, 2011)

Recently gametophytes and spores have been stored and successfully recovered from liquid nitrogen and grown on agar right through to the sporophyte stage, providing a viable long-term *ex situ* storage solution for this threatened fern. The whole protocol has been documented, shared with the Ascension team and published as a contribution to GSPC Target 3 (Baker *et al*, 2014).

Targeted surveys in 2009-2012 discovered three further populations around Green Mountain, giving us encouragement that *Anogramma* is more widespread but cryptic and hanging on in the more inaccessible areas of Green Mountain. More worrying is that two species of highly invasive maidenhair ferns (*Adiantum raddianum* and *A. capillus-veneris*) are rapidly spreading on Green Mountain and occupying *Anogramma's* favoured niches, the wetter south and west as noted by Hooker. As a result of this re-discovery and its securing in *ex situ* conservation, *A. ascensionis* was re-evaluated and down-listed from Extinct to Critically Endangered for the 2010 IUCN Red List, but its existence in the wild is still fragile (Lambdon *et al*, 2010). Work is well advanced to upgrade the facilities at the Green Mountain nursery to provide better growing conditions for Ascension's endemic plants including *A. ascensionis* (Figure 5). The first batches of flask-grown plants have been repatriating from Kew to Ascension and are growing well in the Green Mountain nursery. The challenge now is to develop a successful protocol for weaning the plants from flasks into a local growing medium and maintaining them in the Nursery until they are at a suitable stage for re-introduction. This process has started and the advantage of having lots of material now available is that a range of approaches can be tried in an experimental way in Ascension in order to optimise the protocol.

The challenge for re-introduction is to tackle the invasive species that dominate *Anogramma's* habitat and in particular the two species of non-native, invasive maidenhair fern (*Adiantum raddianum* and *A. capillus-veneris*) which aggressively out-compete *A. ascensionis* for its favoured niches (Baker *et al*, 2014) (Figure 6). Some experimental hand weeding of potential re-introduction sites has been undertaken as part of the preparations for re-introduction.

An added complication to re-introduction has emerged whilst studying the life cycle of *A. ascensionis* at Kew. Unusually for ferns, the sporophyte seems to be an annual with green spores which have limited viability. The evidence points towards the sporophyte being the short-lived part of the life cycle with the gametophyte being the persisting generation, living for several years

cryptically in the volcanic substrate (Baker *et al*, 2014). In the light of this, more success may be gained by re-introducing the gametophyte rather than the sporophyte, an approach which we are currently investigating.

A Species Action Plan was completed for *A. ascensionis* in 2009 as part of a more comprehensive conservation plan developed for Ascension's native flora (Lambdon *et al*, 2009). In light of these new discoveries and a better understanding of the biology of *A. ascensionis*, this Species Action Plan is being revising as part of the development of a more comprehensive Biodiversity Action Plan for Ascension currently being funded by the UK Government's Darwin Initiative Programme (Ascension Island Government, 2014b).

The Ascension Islanders have really taken *A. ascensionis* to their hearts and it has attracted lots of publicity and community engagement locally. There are regular articles in Ascension's weekly newspaper, *The Islander*, and a special issue of stamps to celebrate the re-discovery of this thought extinct endemic fern was issued in 2011. Constitutionally, Ascension is a dependency of St Helena and as such used the flag of St Helena. However, in 2013 Ascension got its own flag for the first time which was first raised on Ascension Day, 11 May 2013. Significantly *A. ascensionis* is represented on this flag. Is this the first time an endemic fern has made it onto a national flag? An interpretation board recently erected on Elliot's Path, a circular walking path in Green Mountain National Park, tells the story of the re-discovery of *A. ascensionis* and highlights the conservation work underway on Ascension; this is a contribution to Target 14 of the GSPC (CBD, 2011).

In summary this conservation success story highlights how botanic gardens – using their unique skills set comprising science, horticulture, education and awareness raising – can be brought together in a multi-disciplinary way to save species and deliver successful conservation.

Acknowledgements

This project has been a real team effort. Many people have been closely involved and contributed to its success and I'd like to fully acknowledge their contributions. At Kew: Viswambharan Sarasan, Katie Baker, Ed Jones, Margaret Ramsay, Marcella Corcoran, Martin Hamilton and Sara Barrios. In Ascension: Stedson Stroud, Phil Lambdon, Olivia Renshaw, Joleen Sim and Matti Niissalo and everyone else who got involved with this exciting story.

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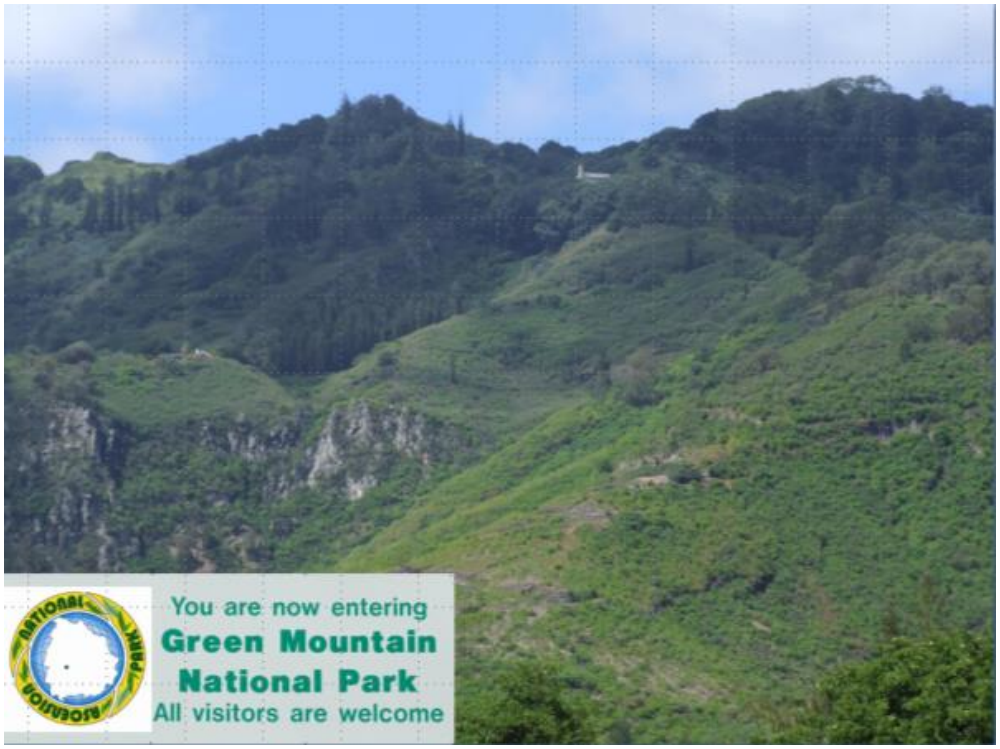

Figure 1: Green Mountain National Park (photo: Colin Clubbe)

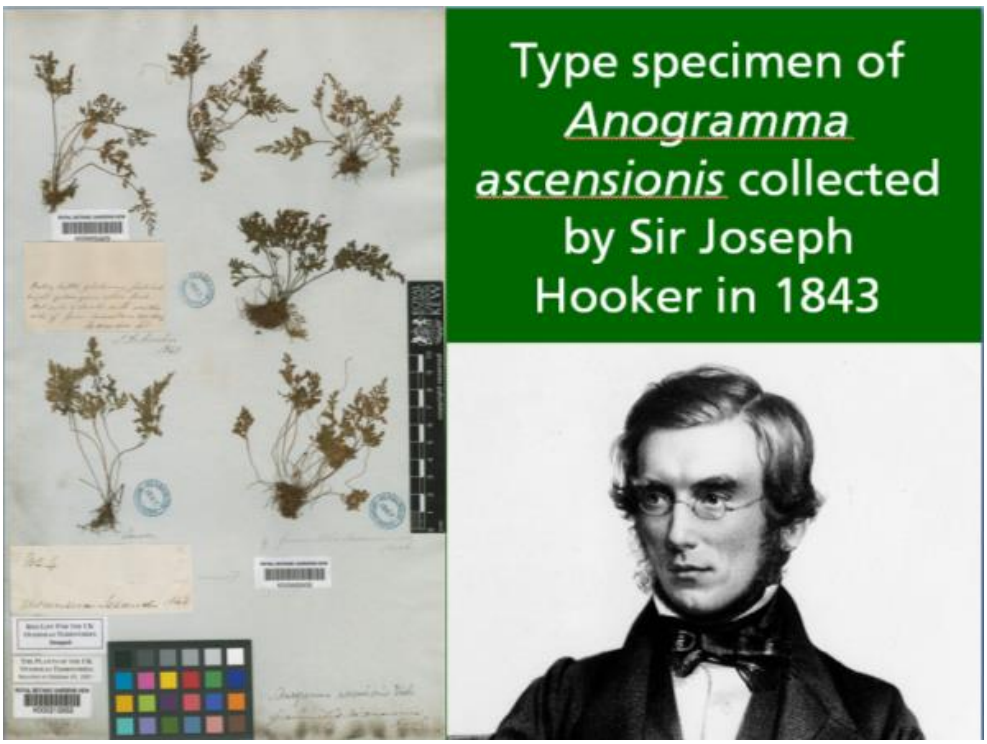

Figure 2: Type specimen of *Anogramma ascensionis* collected by Joseph Hooker in 1843 and an image of Joseph Hooker from the Kew archives. Image copyright: Trustees of the Royal Botanic Gardens Kew.

Figure 3: *Anogramma ascensionis* on Green Mountain.

Clockwise from left: Young *Anogramma ascensionis* sprorophyte (photo: Colin Clubbe); Stedson Stroud examining *A. ascensionis* (photo: Colin Clubbe); Olivia Renshaw watering *A. ascensionis* (photo: Phil Lambdon).

Figure 4: *Ex situ* cultivation of *Anogramma ascensionis* at Kew.

Clockwise from left: Cultures of *A. ascensionis* gametophytes in the Conservation Biotechnology Unit at Kew (photo: Andrew McRobb); Mature sporophyte of *A. ascensionis* in the Tropical Nursery at Kew (photo: Andrew McRobb); Hooker's type specimen with cultures of *A. ascensionis* at different stages (photo: Colin Clubbe); Transferring *A. ascensionis* gametophyte cultures from plates to flasks (photo: Andrew McRobb).

Figure 5: The Green Mountain Nursery in Ascension (photo Colin Clubbe).

Figure 6: Invasive *Adiantum* spp. rapidly colonise the volcanic substrate on Green Mountain, out-competing *Anogramma ascensionis* (photo Colin Clubbe)

Germination of *Veronica parnkalliana* seeds in response to seasonal and fire cues

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Key Words
Burial, fire, seed germination, *Veronica parnkalliana*

Abstract

Veronica parnkalliana (Scrophulariaceae) is an endangered herb endemic to South Australia, with only six herbarium specimens recorded since its first collection in 1909. A targeted search of a fire scar in the Flinders Ranges during the spring of 2008 found prolific regeneration of the plant after a prescribed burn during the previous autumn. This post-fire discovery prompted an investigation into the seed germination requirements for this species. *In vitro* laboratory studies showed that germination was stimulated by gibberellic acid (GA_3), heat or smoked water. A seed burial experiment suggested that an annual cycle of dormancy was present, as germination of seeds that were exhumed after spring and summer was stimulated by a combination of heat and smoked water, but this did not occur after autumn or winter. Seeds buried at different depths before a fire were later monitored for seedling emergence *in situ*, and germination of exhumed seeds was also assessed. The depth of seed burial was a critical factor affecting germination. Results indicated that *V. parnkalliana* is a fire-ephemeral species with morphophysiological dormancy. These findings will provide valuable direction for future conservation planning for this species.

Introduction

Veronica parnkalliana was first recorded from the Eyre Peninsula in South Australia in 1909. It is a perennial herb with erect to ascending branchlets reaching a height of up to 40 cm. Leaves are opposite with serrated, tooth-like margins and during spring plants produce attractive white flowers with purple striations in the center of the petals. There are no further records of the plant until it was collected in the southern Flinders Ranges from 1984 to 1986. A more recent record was made after a targeted search of a fire scar in the Mount Remarkable Conservation Park during spring of 2008. A total of 12,000 viable seeds were collected during the following summer and are currently in long-term storage (at -20 °C) in the seed bank at the South Australian Seed Conservation Centre. *Veronica parnkalliana* is endemic to South Australia and is listed as Endangered under the National Parks and Wildlife Act, 1972. Assessment under IUCN (2001) criteria also leads to a rating of Endangered (EN B1&2ac(ii)(iii)(iv)).

To safeguard this species from extinction, it is important to understand its seed biology, and develop effective germination techniques to facilitate potential future translocations. The post-fire sighting of this endangered plant indicated that *V. parnkalliana* may belong to the group of plants known as fire-ephemerals. These plants are generally short-lived and mostly germinate after fire, producing seeds that persist in the soil seed bank between fire events (Baker *et al.* 2005). Seeds remain dormant in the soil and germination is stimulated by components of fire rather than by soil moisture or seasonal changes. Triggers for germination in fire-ephemerals often include heat and smoke, acting separately or concurrently.

The seed biology of *V. parnkalliana* was investigated using a combination of *in vitro* germination experiments and *in situ* seed burial. Seeds were exhumed and tested for germination at the end of each season to determine whether burial time affected seed dormancy. We were able to test the natural response to wildfire by burying seeds prior to a prescribed burn in the autumn of 2010. Seedling emergence was monitored at two sites and seeds were also exhumed for laboratory germination experiments. This provided a unique opportunity, as very few studies have combined burial and bushfire in this way. The aims of this study were to develop an effective protocol for

germinating seeds of *V. parnkalliana* and to determine how germination is affected by burial and fire.

Methods

Seeds were collected from Mount Remarkable in December 2008 and maintained in storage at 15 °C and 15% relative humidity until use.

In vitro *germination experiments*

Germination experiments were set up in replicates of four. Each replicate contained 25 seeds plated onto agar plates (1% (w/v)) and placed in a thermogradient plate with temperatures ranging from 5 ˚C to 40 ˚C. Germination was scored when the radicle had grown to at least half the length of the seed coat. GA_3 (250 mg/L) was added as a supplement to the agar plates.

In situ *burial*

V. parnkalliana seeds were buried on 21 December 2009 at four sites in the Mount Remarkable Conservation Park. Seeds were enclosed in wire mesh in packets of 100 and four were buried at each site, within the region where the natural population was found in 2008. A packet of seeds was exhumed from each site at approximately 3-monthly intervals, timed to coincide with the end of each season. After retrieval, seeds were tested for viability using a vital stain (tetrazolium chloride), and for germination using the following treatments: control (no treatment), GA_3 (250 mg/L), smoked water (soaked for 24 h in 10% (v/v)), dry heat (15 min at 90 °C) and a combination of smoked water and dry heat. Seeds were incubated at 10 °C 12 h dark, 22 C °12 h light. Burial control seeds were not buried and were tested at the start of the experiment.

Prescribed burn burial experiment

To examine the effects of wildfire on seedling regeneration, two sites were selected in the area to be burnt, and a control site was selected in an adjacent unburnt area. At each site, 100 *V. parnkalliana* seeds were sown (in 20 x 20 cm quadrats) in each of three treatment plots; soil surface, buried at 1 cm, or buried at 2.5 cm. These plots were individually covered with wire cages to protect against disturbance. The prescribed burn took place on 24 April, 2010. Early seedling emergence was monitored monthly, with the highest number of seedlings being recorded approximately 4 months after the fire.

Prior to the prescribed burn 100 seeds were encased in wire-mesh bags and buried at the same depths as in the previous experiment (0, 1, 2.5 cm). Two bags were buried at each depth at burn each site. Seeds buried in the unburnt control site were buried at 1 cm depth. The seeds were exhumed on the morning after the burn and were subsequently tested for germination *in vitro.* Four replicates of 25 seeds were tested on agar plates (1% (w/v)) and four replicate positive controls of 25 seeds each were placed on agar (1% (w/v)) supplemented with GA3 (250 mg/L). Plates were incubated as above.

Results and Discussion

In vitro *germination experiments*

Initial *in vitro* germination tests showed that seeds had a high level of dormancy, with no germination recorded over a wide temperature range (5 - 40 ˚C). However, high levels of germination (80 to 90%) were observed after treatment with GA_3. Germination in the presence of GA_3 was assessed at temperatures between 5 ˚C and 40 ˚C using a thermogradient plate. Optimal temperatures for germination were between 10 °C and 18 °C. Germination declined at temperatures over 20 °C and no germination was recorded at 30 °C or above.

Seed embryos were linear and underdeveloped (Figure 1), which indicates that embryos need to grow within the seed before germination can occur. Seeds within this class often respond to the application of GA_3 and have been shown to have seasonal cyclic dormancy that may be affected

by periods of cold, or warm followed by cold stratification (Ooi *et al.* 2007). Several reports have suggested that seed burial may also affect dormancy and germination (Baker *et al.* 2005; Ooi, 2010).

Germination after in situ burial

This experiment showed that seed retained viability during the burial period, although a slight decline was observed throughout the year (Figure 2). Mean germination levels for GA_3-treated seeds were above 75% for all burial times, also confirming maintenance of seed viability throughout burial. Germination of control seeds was negligible throughout the burial experiment, indicating a high level of dormancy. Seeds responded positively to both the heat and smoked water treatments, and a synergistic effect was observed when both these treatments were combined, yielding increased germination.

Fire components stimulated germination after burial during summer. However, there was no response from seeds buried throughout autumn and winter. In the following, spring seeds germinated in response to heat and smoke treatment. Such seasonal responses have been reported for seeds with cyclic dormancy, where seeds are responsive to certain environmental cues and cycle through seasonal periods of dormancy (Baskin & Baskin, 2004).

In situ burial of seeds prior to prescribed burning.

The germination of seeds that were buried prior to the prescribed burn and exhumed the following morning is shown in Figure 3. The highest level of seed germination was recorded at a burial depth of 1 cm. Seeds recovered from the surface were mostly charred and nonviable, and seeds that were buried at 2.5 cm remained dormant.

These results supported those from the seedling emergence counts at site 1, where 51 seedlings were observed from a depth of 1 cm, while only a single seedling was observed at each of the 0 and 2.5 cm placements after 4 months. Thus it appears that burial depth had a major influence on seed germination, although this pattern was not observed at site 2 where only a few (5) seedlings were counted from the surface-sown seeds. These results suggest that several factors could have an important role in stimulating germination. Factors that may have varied between the two sites could be fire temperature, the density of smoke, or the level of nitrates in the soil post-fire. No seedlings emerged at the unburnt control site.

Conclusions

Germination may be induced following stratification at high or low temperatures, and/or after a period of after-ripening to alleviate dormancy. The present results showed that germination of *V. parnkalliana* did not occur after burial alone and that treatment with GA_3, smoke or heat was necessary for germination to be initiated. The observed cyclic dormancy pattern changed through the warm and cool seasons. Seeds responded to fire cues in December and March, at a time when bushfires are likely to occur in the natural habitat. Factors influencing the emergence of *V. parnkalliana* can be deduced using the data obtained from both the field and the laboratory. We propose that fire during the warmer months delivers the fire cue to the seeds at a time when dormancy is at its lowest. Germination would then occur when moisture conditions were maintained by sufficient rainfall and temperatures were conducive to germination. These conditions would occur naturally during winter, resulting in plants growing and flowering during spring with seeds ripening during early summer.

Broadening the understanding of the seed biology of our threatened plant species increases our ability to monitor biodiversity and restore habitats. Identifying *V. parnkalliana* as a fire ephemeral species greatly increases the chances of locating this plant in its vegetative stage. These results provide new insight into how the interplay of environmental conditions affects the life cycle of this endangered and endemic species.

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Figure 1. A) Flowers, buds and leaves B) seeds and C) longitudinal cut showing the underdeveloped embryo.

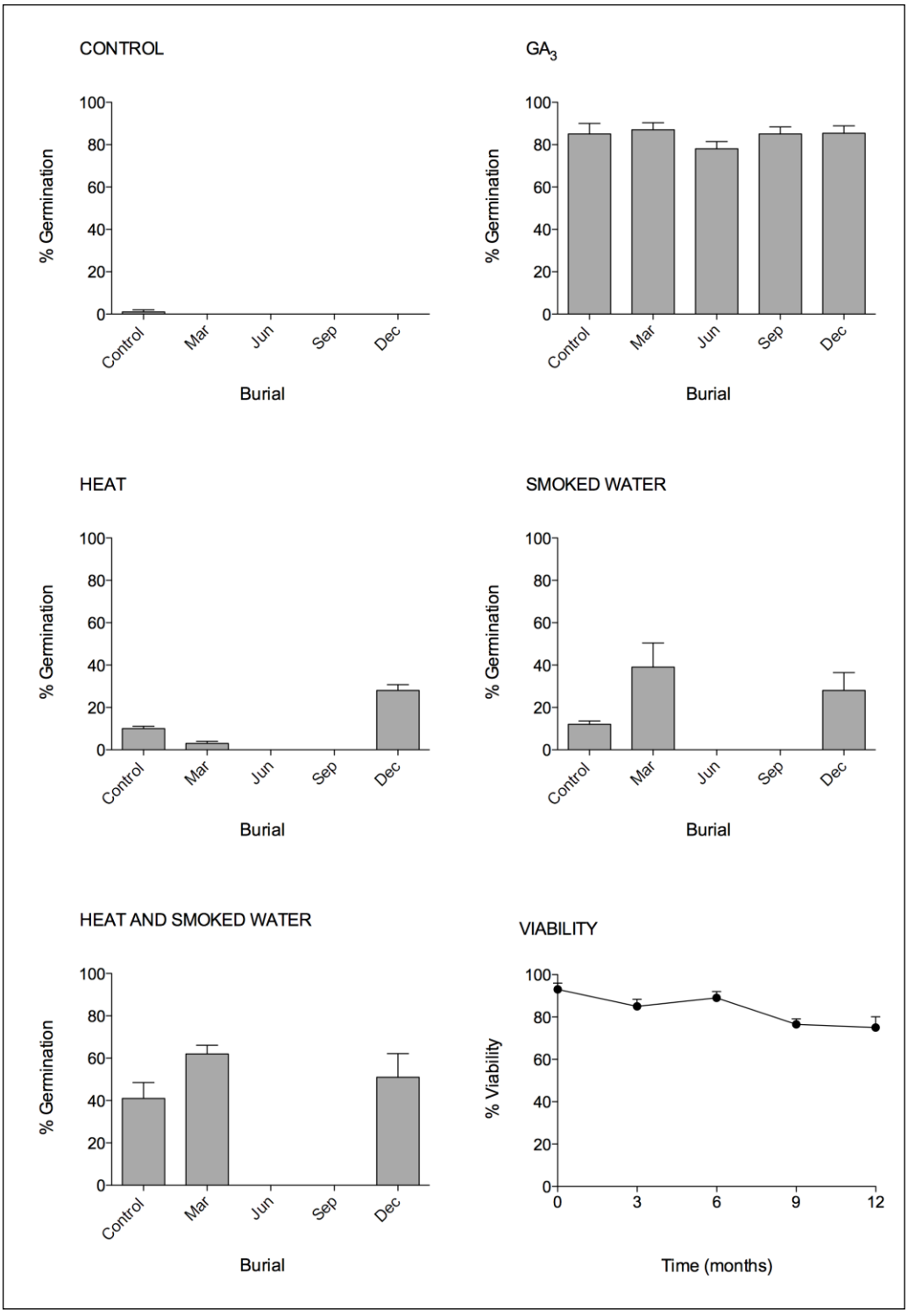

Figure 2. Germination data from the *in situ* burial experiment. Seeds were buried in December 2009 and exhumed at the end of each season in 2010, then tested for germination. Seed treatments are shown on top of each graph and the month that seeds were exhumed after burial is shown on the x axis. Burial control seeds were not buried. Viability was determined using a tetrazolium chloride stain. Bars represent standard error.

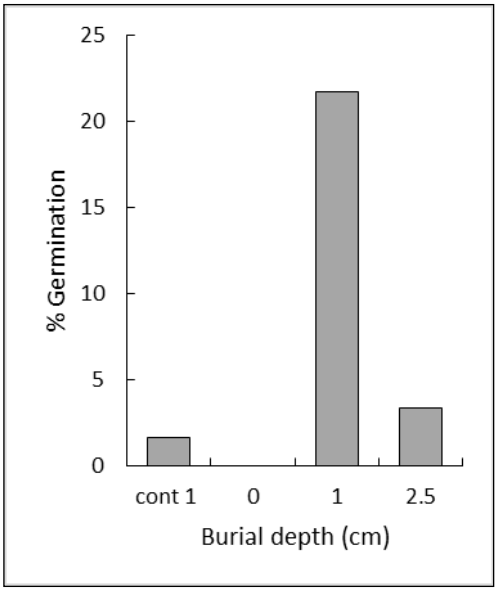

Figure 3. Germination of buried seeds exhumed after a prescribed burn. Seeds were buried at different depths prior to the prescribed burn. The control site (cont 1) was unburnt and seeds were buried at 1 cm depth. The % germination shown is the number of seeds that germinated with no treatment relative to the number of seeds that germinated in the positive control (supplemented with GA_3)

A rock to a hard place: gardening in a difficult environment.

Lex Nieboer

Wilson Botanic Park Berwick, Victoria , Australia

Abstract

Wilson Botanic Park Berwick is a unique site hiding two seams of fossil plants, researched and documented as very significant finds, that identify the transition from Rainforest to Eucalypt forest. An exciting aspect is reintroducing plants growing here over 22 million years ago which will form the basis of collections of the future. The story reads like a good saga: extraordinary plant fossils, a quarried landscape, "interesting" soils, selecting suitable plants, water use, drying environment, weed control, as well as demands of residents in the south east growth corridor. This coming-of-age story is a relevant tale of a young botanic garden with an ancient history.

The site

Wilson Botanic Park Berwick, Victoria, Australia is located 40 km south east of Melbourne city centre. The entrance is on the Princes Highway, Australia's Highway One. As a local government facility, it is owned and managed by the City of Casey and is approximately 12km North West of the Royal Botanic Gardens, Cranbourne, a State Government facility., Wilson Botanic Park, covering 40 hectares, is located at the entrance to Berwick Village, Princes Hwy and surrounded by suburban development. The official opening to the public was on 26th July 1992 by Australia's Governor General, Bill Hayden.

The site is a former basalt (bluestone) quarry that was quarried for 117 Years. The first rock quarried was used for the Gippsland Railway to eastern Victoria and then used in the construction of local roads. The whole site was owned by the Wilson family and its descendants from the 1850s until 1976.

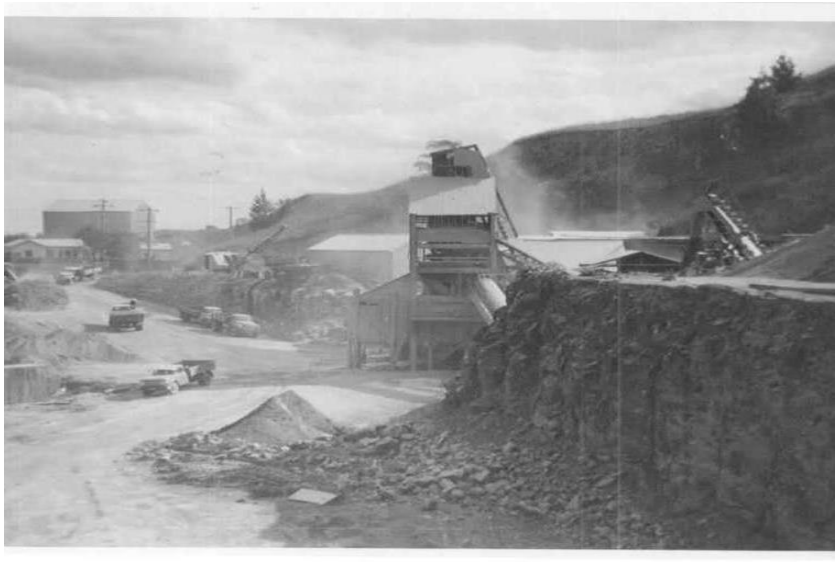

Figure 1 Berwick Quarry in the 1960s

The highest point in the Park is 143m above sea level, giving distant views: 3% of the state of Victoria, from the You-Yang Ranges in the west to the Strzelecki Ranges in the east. Quarrying left sheer rock faces, areas of steep slopes and some unstable ground with occasional rock falls and lands slips.

Figure 2 Anniversary Lake, Wilson Botanic Park, in 2012

There are three lakes on the site, the largest being Anniversary Lake which has an average depth of 5.5m., is spring fed and suitable for irrigation. The lakes support a variety of wildlife, including birds, fish, tortoises, frogs, and insects. Basalt Lake, 2m deep was quarried, but Waterlily Lake was developed during Stage 1 of the development of the site as a Park.

The site was mainly quarry overburdened with some uncompacted stockpiles, which presented difficulties such as landslips, erosion and drainage problems. There are many areas with underlying rock.

The site generally has very heavy yellow clay soil with many hidden rocks, making it hard to dig holes for planting. These soils dry out in summer and are wet and sticky in winter. Jackhammers, air-knives, picks, mattocks, crowbars and shovels are needed for digging holes. Water crystals, gypsum, fertilisers and mulch are necessary when planting.

Water is pumped from Anniversary Lake for irrigation. The lakes are spring-fed and supplemented by surface drainage into the lakes, yet at the height of the drought in recent times the water levels of the lakes have been down by approximately 1.5m. This year (2013) they are full, although in recent times aquifers have not been recharging the lakes as quickly as in the past. Presumably this is because storm water from the surrounding housing developments is piped to the sea rather than penetrating the farmland which previously surrounded the site.

Garden planning and management

Berwick township is historically known for its mix of exotic and native plants, and this theme continues into Wilson Botanic Park Berwick. In the same municipality, the Royal Botanic Gardens Cranbourne has its Australian Plant Garden, so we do not duplicate what is developing with native plants showcased there.

The first master plan in 1986 was drawn up by Scott & Furphy Landscape Consultants, followed in 1999 by one produced by Taylor and Cullity. In 2003 plans by the City of Casey Landscape Architect have been succeeded by the 2013 Plan from the City of Casey Landscape Design and Parks Departments.

In 2003 suggestions were made for over 50 different plant collections, yet in 2013 the number was reduced to a more manageable seven collections. These will include: a fossil plant collection, an arboretum with *Eucalyptus, Quercus and Cedrusa* and a “Casey Collection” of plants most suitable for the local or home gardener.

The original master plan included a selection of many plants which were considered suitable. Time has shown that many plants proved to be unsuitable in the conditions: *Camellia, Rhododendron, Magnolia* and *Picea*. But many plants have proven to be more successful than expected: *Quercus, Cedrus, Pinus, Betula. and Carpinus.* The site is large enough for experimental planting and plant trials.

The significant fossil plant discoveries on this site are a major focus of the future collection planning for Wilson Botanic Park. The original investigation of plant fossils at the site was carried out by Henry Deane in 1902. 1993 saw the study and subsequent publication of further evaluation of the Berwick fossil flora (Pole *et al*, 1993).

Wollemia, Agathis, Araucaria, Eucalyptus, Nothofagus and Gymnostoma are some of the genera

Figure 3 Rock specimen showing fossilised leaves of *Eucalyptus* and *Nothofagus*. Dated c. 22 million years BCE. Uncovered on-site in 1902.

found in the fossil remains on site. Macrofossils, leaves and fruit, and pollens have all been found.

The macrofossil specimens of *Nothofagus* and *Eucalyptus* indicate a climate change from a rainforest to a drier climate. The *Nothofagus* specimens found are more reminiscent of the tropical species from New Caledonia than the existing species found in Victoria.

Growth has been aided by the use of water crystals at planting to retain moisture in the soil. Mulching is widely used around the trees. Rocks dug out of the ground are used to create stability and wells around the base of trees, especially on slopes.

Vandalism was a huge problem in the initial stages of development. Some of the vandalised trees, such as *Quercus*, were transplanted to other sites and have grown into impressive specimens. A vandalised *Doryanthes* doubled in size and even flowered before the adjacent, non-vandalised specimen.

Sources of plants include other botanic gardens, commercial and specialist nurseries donations from private gardens and nurseries such as the Australian Plant Society, garden clubs and the Victorian Rose Society.

Summary

The site has witnessed the change from disused quarry to a beautiful garden/ park, with over 100,000 visitors a year, that provides fresh air and relaxation, and appreciation from its visitors –

local, metropolitan, regional, interstate and from overseas. Most exciting is the reintroduction of trees on-site which have been missing for millions of years: a real success story!

Figure 4 *Wollemia nobilis* growing beautifully where fossil specimens of it had been discovered

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Advances in living collections management

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Abstract

The living collections at Missouri Botanical Garden serve many purposes, including research, conservation, education, and display. With increasing threats to plants and plant habitats worldwide, conservation has become the most important aspect of the living collections. However, outdated curatorial practices, including the plant records database system, were inadequate and impeded progress towards the science and practice of plant conservation. MBG recognized the urgent and critical need to redesign and redevelop its plant records database and supporting curatorial practices. Now, these modern approaches are helping MBG achieve the highest standards of record-keeping and curation, and are making the comprehensive information on its living collections accessible to visitors, staff, and scientists.

Keywords

Collections, conservation, curate, database, plant records, GIS, technology

Missouri Botanical Garden's (MBG) living collections serve as the basis for meeting key horticultural, educational, research, and conservation goals and are of critical importance to multiple constituencies, including staff, Garden visitors (onsite and on-line), and scientists and conservationists working at local and international levels. In order to ensure top-quality collections care and maintenance, meet programmatic goals, and serve important audiences, living collections must be adequately tracked, documented, labeled, interpreted, and curated. Comprehensive information about the collections must be easily accessible to multiple audiences in multiple formats.

Unfortunately, many of the curatorial practices used at Missouri Botanical Garden had become antiquated, and the information about MBG's living collections was spread out among several fragile, outdated, and incompatible database systems that had been developed over a 20-year period. These systems each served a narrow purpose and were not coupled or integrated. They were prone to poor access speeds and data capture failure when accessed by multiple users simultaneously. Data could not be easily transferred to internet-compatible formats. Due to the time and cross-referencing necessary to enter data, or to transfer data from one database to another, information was entered incorrectly, lost, or skipped over entirely. Work was duplicated and valuable time, effort, and accuracy was lost. When data needed to be accessed by staff, visitors, or scientists, it was not easily found or sometimes even available at all. The inadequacy of the various database systems directly affected the care of collections and the fulfillment of programme goals and audience needs. It was a barrier preventing progress toward MBG's strategic goals in key areas.

Recognizing the urgent and critical need to redesign and redevelop the living collections management system, MBG embarked on a process to create a modern, comprehensive collections management system. Firstly, the database infrastructure was upgraded to meet current technological standards, basic plant records fields were fine-tuned, data from the GIS was integrated, and taxonomy and related data from MBG's renowned Tropicos® plant database (the world's leading repository of scholarly botanical information) was integrated. This new living collections management system was built in SQL Server, a global standard relational database system with strong integration to ESRI software, and provides a stable and robust platform for daily operations and programmatic growth. This modern database technology has also allowed the development of many features that improve living collections curation.

First and foremost, the new database features seamless integration between plant records data and GIS data. In most plant records systems, these systems are separate, essentially resulting in duplicate information in two database systems that is difficult to maintain and keep synchronized. In the new Living Collections management System (LCMS), plant records data can be updated on the same user screens as GIS data, and while the plant records data and GIS data are held in separate SQL databases, the synchonization between the two systems is seamless and invisible to the user. This enables increased efficiency and accuracy, and also the ability to visualize the locations of specific taxa on interactive maps and edit inventories in the field (See figure 1).

As the LCMS was further developed, fields and functionality were added to support various projects and workflows. For example, MBG developed and produced custom field books for MBG staff, with fields to record information on location, habitat, soil type, etc. that will enable horticulturists to more successfully grow the plant *ex-situ*. A concerted effort was made to match the fields in the LCMS to the fields in the field books exactly. In addition, the fields match MBG's Tropicos plant database as well as several fields in the Center for Plant Conservation (CPC) database. This allows for more accurate and efficient record-keeping, as well as enabling data linkages between databases used by staff in different divisions (See figure 2).

Other features in MBG's LCMS include:

- The addition of fields for data associated with permits and agreements. These documents are scanned, data pertaining to the document is entered, and each document is linked to the appropriate accession records. This allows for easy document storage and retrieval, especially as it relates to CBD (See figure 3).

- Labels and accession tags can be requested in the LCMS by horticultural staff and printed directly to engravers and embossers.

- All stages of propagation are tracked and related data can be queried and valuable reports can be generated.

- Data from a RAWS weather station on garden grounds is routinely uploaded to LCMS, along with temperature readings from several sensors located in various areas of the garden. This data is used in various analyses and reports, alongside plant records data, and to provide meaningful information for our horticulture, education, and research programmes.

- Tools within LCMS allow the printing of QR code labels directly to a mobile printer via an iPad or other mobile device for use on accession tags. A scan of the code directs the user to the planting edit screen.

- A data dashboard provides collections information at a glance that allows horticulture staff to understand and plan future additions to the collections.

- A user interface designed specifically for mobile devices with commonly used tools provides easy access to add data such as assessments and measurements, images, and phenology (See figure 4).

- A visitor-friendly user interface allows easy access to cultural information for over 7400 plants in the LCMS. The site is extremely popular, and allows the public to access gardening information, plant locations in the Garden, photos, and more.

In conclusion, well-documented living collections are one of the greatest assets of public gardens (Hird and Dosmann, 2010). While some curatorial practices remain the same as they were 150 years ago, modern technology can allow more data to be stored, increase accessibility, and streamline curatorial processes, ultimately increasing the value of living collections. High quality

standards are vital in order for living collections to be used for research and conservation, and MBG has already experienced a higher demand for using the living collections for scientific research and conservation projects. This, in turn, has resulted in exciting and relevant stories to share with the public, which increases their understanding and appreciation for plants.

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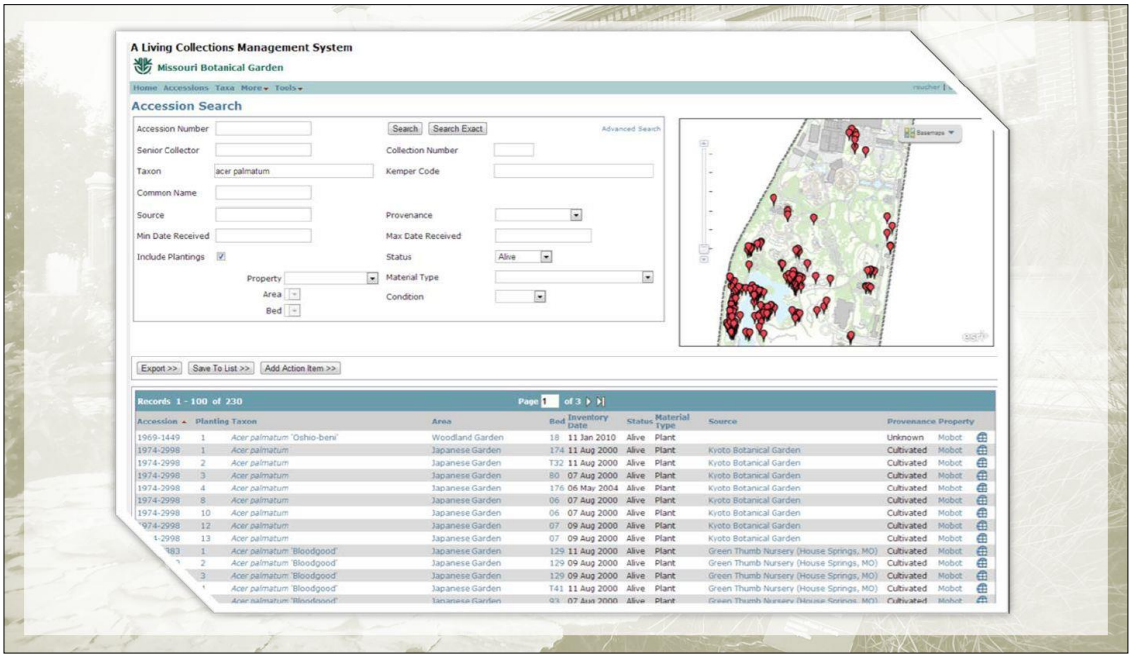

Figure:1 Screen shot from MBG's Living Collection Management System

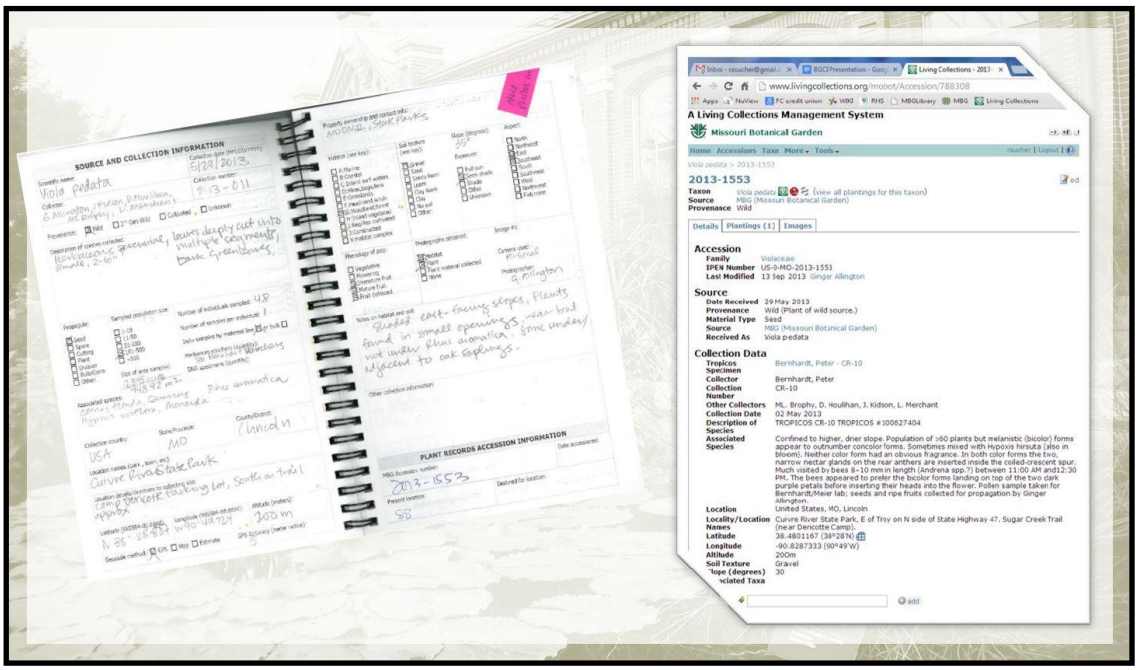

Figure 2 Field books produced in house that match database fields exactly

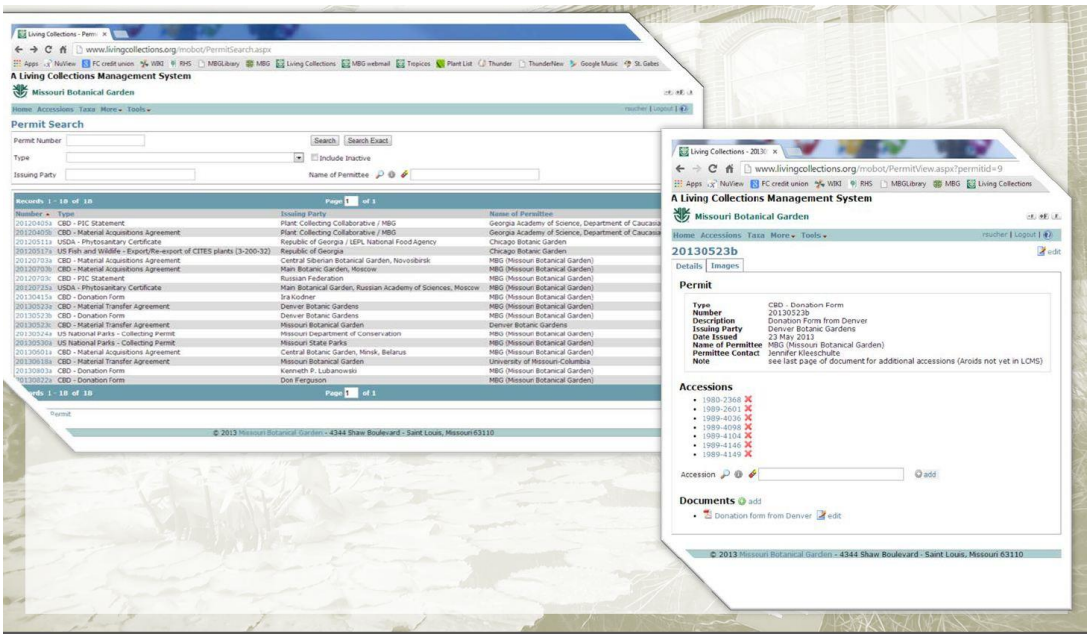

Figure 3 Permits and agreement s can be linked to multiple access records

Figure 4 Database screens designed for mobile devices, for tasks commonly performed in the garden

Saving the National Tree of the Turks and Caicos Islands: *Pinus caribaea* var. *bahamensis*

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Keywords

Conservation, Restoration, Horticulture, Pine tortoise scale, *ex situ*.

Abstract

The Caicos Pine Recovery Project (CPRP) is working to save the National Tree of the Turks and Caicos Islands (TCI) *Pinus caribaea var. bahamensis* and to maintain the ecological integrity of TCI's unique pine ecosystem. Caicos pine is an endemic variety of the more widely dispersed *Pinus caribaea*. In TCI, the taxon is threatened with extinction, due to a severe infestation of the non-native invasive pine tortoise scale, *Toumeyella parvicornis*. To date the infestation has killed around 90% of the mature pine trees and is affecting nearly all of the remaining trees. This has led to the near destruction of the threatened pine's habitat in TCI.

The Project is working to control the invasive insect, propagate healthy pine seedlings for *ex-situ* conservation, undertake habitat restoration using nursery-grown plants, enhance local capacity, collect important baseline and monitoring data, collect seed for long-term storage and provide basic infrastructure to support the Project. Royal Botanic Gardens, Kew is working in partnership with TCI's Department of Environment and Maritime Affairs (DEMA) and Department of Agriculture in cooperation with the Turks and Caicos National Trust and the Environmental Health Department, along with several other international organisations and individuals, to save the species from being extirpated from TCI.

Introduction

TCI is one of the UK Overseas Territories (UKOTs) in the Caribbean. Their National Tree has almost been lost to an invasive pest species. The Caicos Pine Recovery Project (CPRP) includes horticultural skills for *ex-situ* recovery and restoration of this damaged habitat; showing the importance of these skills to conservation and restoration work. The Royal Botanic Gardens, Kew's UK Overseas Territories Programme has been working with the National Trust and the Government of TCI to save the Caicos Pine, Pinus *caribaea var. bahamensis*, and restore its habitat. The UKOTs comprise 16 former colonies that have elected to retain their direct British links and as such form part of the Nation State of the United Kingdom, thus being British citizens. They include many remote oceanic islands, and contain unique species and habitats – and by far are the most important for UK biodiversity.

The Turks and Caicos Islands are situated just at the southern tip of the Bahamas archipelago. The Turks Islands are separated from the Caicos Islands by Turks Island Passage, which is more than 2,200 m or 7,200 ft deep. The pine trees occur on three of the Caicos Islands: Pine Cay, Middle Caicos and North Caicos.

The Caicos pine is the dominant canopy species of the "pineyard" (as it is locally known) ecosystem (Fig 1), an open pine savannah, which is adapted to periodical burning caused by lightning strikes during the wet season. This habitat is home to many important plant species. This tree is an endemic variety of the more widely dispersed *Pinus caribaea*. This variety of pine is a keystone species of the ecosystem and only occurs on four islands in the Bahamas and three islands in TCI. The loss of this species has the potential to change entire ecosystem processes. Its

disappearance from the Islands could degrade the ecosystem's hydrology and vegetation structure.

The discovery of a non-native invasive scale insect on the pines by Kew's Martin Hamilton in 2005 (Hamilton, 2007) led to a confirmation of the scale species as pine tortoise scale, *Toumeyella parvicornis,* by Chris Malumphy at the UK Food and Environment Research Agency (FERA) (Malumphy *et al.,* 2012) .

This pine tortoise scale (Fig 2) is a well known pest species in North America on the pine family, *Pinaceae.* It is believed that the scale insect arrived on Christmas trees imported from North America. This is one example of an extreme emergency; because of the lack of bio-security at the borders. In TCI, the pine is threatened with extinction, due to the pine tortoise scale (Manco, 2010). To date the insect has killed circa 90% of the mature pine trees and is affecting nearly all of the remaining trees. A secondary effect of the scale feeding on the pine trees is sooty mould; which develops when frass (sugary secretion) drops onto understory plants. This greatly reduces the photosynthetic capacity of the ecosystem's plants.

Information on this non-native scale insect's natural range and life cycle raised alarm bells and generated the urgent need to take action to conserve the Caicos pine. Native to the northern pine forests of the USA, the scale is kept in check by dormancy during the severe winters there. Its occurrence in TCI represented the first record for the Caribbean and for this host species. TCI's consistently tropical climate allows the scale to survive and multiply year round, resulting in the ecosystem devastation seen today. The pine tortoise scale secretes a wax coating for defence; this coating causes them to resemble reptilian or fish scales, hence their common name.

Saving the Pinus caribaea var. bahamensis

The Caicos Pine Recovery Project was established in 2008 to address this emergency – bringing together the TCI National Trust and DEMA on the island with Kew and FERA, working together to save the National Tree of the TCI and maintain the ecological integrity of TCI's unique pine ecosystem (Hamilton *et al*., 2010a).

The key knowledge gap was an understanding of the current extent and status of the pineyards. The extent of the remaining pineyards in TCI: Pine Cay, Bottle Creek & Ready Money on North Caicos, and Conch Bar in Middle Caicos, have all been mapped onto a GIS which has been incorporated into the TCI Government's national GIS (Hamilton *et al*., 2010b). Also mapped are the pine forests in the Bahamas, with help from the Bahamas National Trust (Sanchez, 2012). In the Bahamas conditions are more suitable for the pine as annual rainfall is higher than in TCI. Healthier trees seem to have a greater resistance to pests. The trees are also taller, more robust and healthier in the Bahamas.

As well as mapping the extant pine forests, we developed an *ex situ* programme by establishing *ex situ* collections of Caicos pine in order to secure the taxon and to build up stocks for potential reintroduction and restoration. To house the collection the team (Kew and TCI partners) built a temporary nursery in which the pines could be grown and protected from the scale insect. The first plants into the nursery were collections from two populations; 97 seedlings, in 2008.

Seedling rescues continued to fill the nursery, choosing plants which were in danger of dying in the wild from scale or even fire (Fig 3). Those plants that show signs of infection are treated with a soap wash to remove the scale. Each individual plant had a small amount of DNA taken for a population genetics study. At the same time, a priority task was to build capacity with in-territory partners for developing good *ex-situ* collections of the species. A comprehensive Caicos pine seed collection programme was also started at this stage. Seed has been collected where possible, although cone production has been severely curtailed by the disease. Currently in-territory there is

a healthy *ex situ* collection grown from wild collected seed with documentation for each individual plant.

At RBG Kew there are seedlings from two populations of the pine tree. The seed and resulting seedlings have enabled further research on this species in the controlled conditions of the Quarantine House. Some of the research carried out at Kew has consisted of germination trials; as a result a clear and precise protocol has been developed for seed germination. Together with partners in TCI, a very specific method has been developed for sowing and germinating the seed to avoid damping-off fungus killing the seedlings (Fig 4).

DNA material was taken from 90 individuals in the TCI *ex situ* collection and from 459 mature individuals in the wild across the Bahamas and TCI pine populations, for research on conservation genetics using plastid and nuclear microsatellite markers. This genetic research in the Jodrell Laboratory at Kew has been carried out by Michele Sanchez who worked on this taxon for her PhD (Sanchez, 2012) (Fig 5). Results from nuclear DNA have shown genetic differences between the populations found in TCI and those found on the four other islands of the Bahamas, with some unique alleles which were only present in one or the other. However, populations from both countries were genetically similar at plastid DNA, indicating recent genetic differentiation through isolation by distance (Sanchez, *et al*. 2014).

Work is also being carried out on the plant chemistry and mychorrizal associations of the species. Initial findings indicate that there may be a chemical difference in trees that have far less scale infestation, which we hope may imply some pest resistance in some of the wild trees.

The situation continues to worsen for the pine tree (Fig 6). Although the numbers of scale insects are decreasing; this is simply a direct result of the numbers of trees dying. There are hints of natural resistance with the odd few trees here and there (in particular on one island) which remain almost scale insect-free. So far experimental re-introductions on Pine Cay have found that the scale insect is likely to colonise them early; this is after some monitoring on 75 trees which were planted out from the nursery in May 2012.

Summary

At the Millennium Seed Bank (MSB) at RBG Kew there are collections from two of the three islands in TCI. The adjusted seed quantity is over 2,400 for the last season's collection, after discounting empty and infested seeds. BNMPC-2011 (i.e. Pine Cay collections) yielded 6653 seeds. The X-ray of a sub-sample gave 104 good seeds, 14 infested and 163 empty. So the 'adjusted' seed quantity is 2462. BNMMC-2011(i.e. Middle Caicos) yielded 61 seeds. The X-ray of a sub-sample gave four good seeds, and 16 empty. So the 'adjusted' seed quantity is 12.

Approximately 100 saplings are currently growing securely at RBG Kew. These are from seed collected on two islands in TCI. Some will be destined for Kew's newly restored Temperate House in 2018 when it re-opens after a full restoration. Each pine grown from seed has had DNA sampling material collected for further research and storage in Kew's DNA bank at the Jodrell Laboratory.

In May 2012 on Pine Cay the first outline plan for some experimental re-introduction plots occurred. These plots were planted up with 25 trees of mixed ages in each plot. Careful selection was made of the area on Pine Cay in order to create a restoration-monitoring model for the pine and the scale insect (Earle-Mundil, 2010; Green, 2011).

Conclusion

This is a very long-term project; its key aims are yet to be completed. Trials are being carried out at the MSB to ensure that the pine seed can be stored safely for the long term. Germinating seed to

produce robust saplings in TCI must continue. In May 2012 on Middle Caicos a trial burn was conducted. More prescribed burns are required to maintain the pine forest ecosystem, as these forests are fire-dependant. Funds for the Project still need to be raised. Plot monitoring data will need to be collected regularly. Last but not least, the need is to make every person in the Territory aware of their National Tree's plight and the issues surrounding bio-security.

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Figure 1. TCI Pineyard ecosystem

Figure 2. Pine Tortoise Scale on pine trees

Figure 3: Caicos Pine Recovery Project Nursery

Figure 4. Germination protocol steps for pine seed

Figure 5. Field and laboratory work by Dr. Michele Sanchez

Figure 6. Middle Caicos Island pineyard mortality

From strategy to action – the first steps in the ESCAPE project

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Abstract

The Finnish *ex-situ* conservation strategy for plants includes five targets: to (i) secure the extant collections; (ii) increase the number of conserved taxa; (iii) develop *ex-situ* conservation for northern species; (iv) incorporate *ex-situ* conservation into reintroduction programmes, and (v) increase the use of collections in education and public outreach. To achieve these targets a five-year EU Life+ funded project was launched in autumn 2012. Here we present the first steps of the project: establishing a national seed bank, ensuring the storage of micro-propagated tissues in a cryogenic unit, preparing assisted migration trials based on *ex-situ* material, and initializing *ex-situ* conservation of bryophytes.

Keywords

Assisted migration, botanic garden, conservation strategy, cryogenic storage, endangered taxa, *ex-situ* conservation, micro-propagation, seed bank

Introduction

Biodiversity loss has been recognized as a threat to human well-being (Cardinale et al. 2012) and several strategies and targets for limiting the losses have been agreed upon. However, the targets have not all been successfully fulfilled. In Europe, the conservation status of more than half of the habitats and species listed in the annexes of the EU Habitats directive is classified as unfavourable, and the EU Biodiversity Action Plan target of halting biodiversity loss by 2010 was never achieved. The Global Strategy for Plant Conservation (GSPC), including several outcome-oriented global targets for 2020, was approved in Nagoya in the Conference of the Parties (COP) to the Convention on Biological Diversity (see UNEP/CBD/COP/10/19). Target number 8 includes a commitment for the *ex-situ* conservation of threatened species: '75 per cent of threatened plant species in accessible ex-situ collections, preferably in the country of origin, and 20 per cent of them included in recovery and restoration programmes'.

A national *ex-situ* conservation strategy and action plan for Finnish plants (Hyvärinen et al. 2011) was produced in the EU project VACCIA (Vulnerability assessment of ecosystem services for climate change: impacts and adaptation) in November 2011. Subsequently, many elements in it were incorporated in the national strategy and action plan for conservation and sustainable use of biodiversity in Finland 2013–2020 (Heikkinen 2013) when it was renewed in order to take into account the accumulating evidence of rapid changes in climate and to extend the period to 2020.

The Finnish national *ex-situ* conservation strategy and action plan sets two general scheduled goals for *ex-situ* conservation: 'By 2016 40 % of threatened plant species (VU-CR) and by 2020 75% of them should be found in Finnish *ex-situ* collections. In practice this means the collection of 180 taxa on top of those already found in botanic gardens. Those taxa in *ex-situ* conservation will represent known accessions of native Finnish origin and they will be stored separately from any potential sources of cross-breeding (e.g. close relatives). Moreover, in order to conserve the genetic diversity of a species a sufficient number of its populations must be collected. Once a solid and sufficiently large collection is established, the material should preferably be used for re-introductions *in-situ* or for assisted migration (AM) programmes.'

The five main objectives of the strategy are to (i) secure the extant collections; (ii) increase the number of conserved taxa; (iii) develop *ex-situ* conservation for northern species; (iv) incorporate

ex-situ conservation into reintroduction programmes, and (v) increase the use of collections in education and public outreach. These objectives will be achieved by twelve concrete actions that are linked to relevant stakeholders who are responsible for implementing them.

Moreover, the strategy recommends several areas for future research: (i) Evaluation of the conservation status of cryptogamic taxa and assessment of feasible *ex-situ* methods for them, (ii) development of scientific criteria for the selection of plant taxa to be conserved *ex-situ*, (iii) development of scientific criteria for the selection of plant taxa to be considered for assisted migration, (iv) analysis of biological criteria together with socio-economic constraints and (v) development of potential new solutions for economically viable *ex-situ* conservation.

In order to turn this national ex situ strategy into action, a new Life+ Biodiversity funded initiative called ESCAPE (*Ex-Situ* Conservation of Finnish Native Plant Species) was launched in September 2012. The project is coordinated by the Finnish Museum of Natural History (University of Helsinki), which houses two botanic gardens (Kaisaniemi and Kumpula BGs). Other parties in the project are the Botanical Gardens of the University of Oulu, the Finnish Environment Institute, and the Natural Heritage Services of Metsähallitus.

The first objective of the project is to reach the *ex-situ* conservation level, indicated in the ex situ conservation strategy by the year 2016 (40% target), and to increase the number of endangered vascular plant taxa in *ex-situ* conservation to 118 (60% target) by the end of the project. The participating institutions will continue this work after the project and the level of 75% will be achieved by the end of the decade.

The second objective is to develop methods and new combinations of conservation means that can help increase the population size and the genetic diversity of threatened plant species in Finland. This entails encouraging a more extensive use of *ex-situ* methods in combination with *in-situ* conservation. Bryophytes that have largely been ignored in *ex-situ* conservation thus far are included in the development of new innovative methods of *ex-situ* conservation. Another methodological development scheme is micro-propagation and cryopreservation of plants, which will increase the possibility to achieve the above targets.

The third objective is to test the possibilities for using *ex-situ* conserved plant material in reintroduction and assisted migration programmes (AM, i.e. translocation to new sites that become favourable under climate change). In this project, both methods will be tested with three carefully selected species. This is particularly important for the future possibilities to achieve the second obligation of GSPC Target 8 (20% of endangered species in restoration programmes).

Methods

Seeds for long-term storage are collected and stored according to the protocols published by the European Native Seed Conservation network (ENSCONET 2009a & 2009b) with minor modifications. As there are several endangered taxa that either do not set seed at all, or often fail to produce living ones, some taxa are propagated vegetatively, either with traditional methods such as cuttings or in pure culture in the laboratory. This requires a thorough screening of suitable methods and often prior testing with closely related species.

Ex-situ propagation and storage methods have also been tested in practice on selected bryophytes, including some of the species that have previously been tested in the Micro-propagation Unit of Kew Gardens (e.g. Rowtree, 2006) and on some rich mire species such as *Meesia longiseta*, which is considered endangered in Finland because of habitat deterioration and climate change.

The actual micro-propagation and cryopreservation tests in ESCAPE take place in the BG of the University of Oulu, while the Helsinki BG is responsible for the conservation of seeds and scientific

advice in case of bryophytes. *Ex-situ* conservation in living collections takes place in both Gardens. A six-scale vitality index has been adopted to assess the condition of living collections.

Assisted migration (AM) and reintroduction are both tested using three different species. In order to assess the feasibility and the probability of success of AM, a set of AM criteria was formulated.

Results and discussion

The seed bank located in Kumpula BG, Helsinki, was started in summer 2013. During the first collecting period, seeds of 27 endangered taxa from 39 populations were collected and the seeds stored in the seed bank. Initial germination tests for most of them have been carried out. Also micro-propagation methods for three species have been developed and one species' seeds have been stored cryogenically.

The living collections of threatened native species in Oulu and Helsinki (Kumpula) BGs have already markedly increased. At the moment, the former harbours 24 threatened native taxa in 29 accessions, whereas the latter contains 16 taxa in 19 accession.

Reintroduction and assisted migration experiments have been designed and a set of criteria for AM has been published on the Project webpage (www.luomus.fi/escape). The Project has also published a priority list of focal taxa to be included in the *ex-situ* conservation scheme, seed collection instructions and a compilation of *ex-situ* conservation methods (the latter two in Finnish) on the website. AM and re-introduction experiments in natural sites will start in 2014.

Some AM experiments involving collaboration between Finnish, Norwegian and Estonian gardens with the threatened species *Primula nutans* ssp. *finmarchica* var. *jokelae* (Siberian primrose) are already taking place. These are managed by a multidisciplinary research project called CO-ADAPT (Constraints and Opportunities of Assisted Migration of Plants in Climate Change Adaptation – biological, legal and ethical analyses) funded by the Academy of Finland in 2013-2017 and based at the Finnish Museum of Natural History. ESCAPE collaborates with CO-ADAPT on the multitude of scientific, legal and ethical aspects and problems connected to AM. The objectives of the proposed research are to (i) develop biological theory for selecting plant species, populations, and sites suitable for AM; (ii) analyse current national, EU, and international regulations in relation to AM and offer recommendations; and (iii) set an ethically and conceptually viable framework for AM. The Project includes a number of researchers from the fields of biology, law and practical philosophy.

Given the initial success in the launch and establishment of ESCAPE, the first part of the GSPC Target 8 can hopefully be reached during the post-Project era by 2020. It is obvious that the first steps of ESCAPE have already significantly improved the *ex-situ* conservation status of native threatened plant taxa in Finland, as the situation a couple of years ago was far from satisfactory (see Miranto et al. 2012). Nevertheless, instead of concentrating on the percentage of threatened species in *ex-situ* conservation, it is very important to analyse how the most vulnerable and endangered taxa are to be conserved and what combination of methods should be used to obtain the best results. This requires careful consideration of the genetic representation in *ex-situ* accessions and also needs analyses of the risks of causing maladaptive microevolution in *ex-situ* conserved populations. These are challenges also for the future *ex-situ* conservation research projects.

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Smart plant use in water management and shown in a new display water garden in Delft Botanic Garden

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Abstract

Modern water management has preferably been carried out in the system of 'Building with Nature'. In 1980, Ronald E. Waterman started to initiate this new approach and principle in civil engineering to create coastal extensions and/or artificial islands by using materials and forces present in nature. These natural forces, as well as marine organisms and sand/silt/clay particles in beaches, dune areas and near shore, include the action of tides, waves, swells, estuarine, bay and sea currents, river outflows, gravity, wind and precipitation, solar radiation and interaction with vegetation. Two case studies, one with plants such as mangrove, of coastal defences in Vietnam and the use of *Vetiver zizanoides* (vetiver grass), are discussed. Next, the case studies and current construction of new coastal defences in the Netherlands and the concept of 'Building with Nature' in a new display water garden adjacent to the Delft Botanic Garden.

Key words

Water management, building with nature, mangroves, vetiver grass, coastal defence, Vietnam, the Netherlands, display water garden

Introduction

Traditional water management, especially in coastal defence, has nearly always been carried out with man-made constructions such as sea walls, concrete blocks deposits, or artificial dams. These methods need to be reviewed. Modern water management uses the forces and materials of nature, and creates long-lasting, very cost-effective coastal defence systems. These methods could also be applied in solving water management problems and in land stabilization of coastal hinterland. For example, mangroves in Vietnam have replaced concrete sea walls as coastal defences; they provide a natural belt of tidal mangrove forest in front of the current coastline in order to break the waves and to diminish the tidal wave impact and tidal forces. They form a very simple clay or soft soil dike that can protect against the highest water levels, such as experienced in typhoon conditions.

The other example is the use of tropical and subtropical *Vetiver zizanoides* to reduce the impact of waves in front of a dike or, when planted on a dike, to diminish the run-up or wave overtopping. Furthermore, not only do the sod or pieces of grass clumps reduce the force of the water, but also their root systems contribute to dike stabilization, because of their long taproot system and horizontal adventitious roots which sprout at several layers from the taproots; this creates a matrix of fixating root-structure in a dike.

A similar root system to *Vetiver zizanoides* is formed by *Ammophila arenaria* (European marram grass) in Dutch dunes and beaches, capturing sand forced by wind and forming primary dunes on the highest beach parts. These primary dunes evolve in the same way, further capturing and building sand deposits, until the dunes grow to mature sizes up to 70 metres in height and thus creating a perfect long-lasting coastal defence.

The Vietnam and mangrove case

Vietnam has lost nearly all its natural mangrove forests along the coast. Only remnant pockets of inland mangrove species can still be seen today on the shoreline, which will be destroyed by its

unsuitable natural conditions in a very few years. During the Vietnam War (1962-1971) nearly 40% of the mangrove forests in southern Vietnam were destroyed (Hong & San, 1993). In Camau province, for instance, it was estimated that there were 200 000 ha of highly diverse mangrove forest, but after the war approximately 100 000 ha had been destroyed.

In the 1980s and early 1990s the mangrove forest was again heavily destroyed, due to the overexploitation of timber for construction and charcoal and the conversion of forest land into Silvo-Aquaculture-Fisheries Farming Systems (SAFS) (Christensen, Tarp, & Hjortsø, 2008). By the end of the 1980s the highly diverse mangrove forests of Ca Mau had been turned into 51 000 ha of monoculture forest, consisting mainly of planted *Rhizophora apiculata*.

By the mid-1990s forest-felling bans were imposed and the forest enterprises were now to replant and protect forest rather than utilise it; by 1999 the felling ban ceased. The mangrove forests remain in the middle of everywhere, like elsewhere in the world, described in publications such as 'The Botany of Mangroves' (Tomlinson, 1986), 'The Biology of Mangroves' (Peter J.Hogarth, 1999) and the specific book about mangroves in Vietnam by Phan Nguyen Hong (Hong & San, 1993) published by IUCN in 1993.

Figure 1. Coastal area in Vietnam with revetment on clay soil and remnant pocket of mangrove

But, due to the collaboration between in Delft Universiity Bptanic Garden and its Vietnamese partners, interest in mangroves had grown since 2004. Mangroves could be the solution to uncontrolled problems of coastal defence for nearly the whore shoreline of Vietnam and a replacement for ugly and non-effective sea walls, sea ramparts and concrete revetments.

In order to grow mangroves, an inventory was made between 2004 and 2009 on the bathymetry and historic sediment distribution of the major affected rivers of Vietnam: the Mekong and Saigon in the south and the Red River in the north and coastal shifts in the past. Next to this, a new approach was developed by the Botanic Garden in cooperation with the Department of Coastal Engineering, both of Delft University of Technology and shared with its Vietnamese partners, the Water Resources University in Hanoi and the Southern Institute of Water Resources in Ho Chi Min City. The new approach had its origin in the discovery of mica deposits on the remnant pockets of beaches. Mica is a mineral that floats on water and is known to have an origin in acid rock formations. Because all the above-mentioned Vietnamese rivers originate or pass through acid mountains or rock areas in the hinterland, we can be assured that deposits of mica, at the highest tide level in a predominant clay rich suspension on the coast of the South China Sea, are a perfect

indicator of the influence of river systems and so provide for future possible outbuilding or reclaiming of land formations into the sea.

In coastal systems, the sea can bring materials with the tide and waves in the upper current and can take the same materials also with the tide and waves in the undercurrent. Building up land or reclaiming historic depositions by the sea involves obstructing the undercurrent with a bar of rods. The width of the bar is correlated to the grain size of deposition. So first we capture sand or larger particles until the shore is shallow enough with a very gentle slope of maximum 3 degrees angle. Then we put in out sticks to stop the deposition of materials and to regulate equilibrium of sand or grain between sedimentation and erosion. The same process will repeat until a stepwise structure of deposited material has built up into the sea. As soon as the sea is shallow enough with grain or sand, as a second step of building with nature, the space of the bar will be reduced to capture the smallest materials such as silt and clay. This also will grow in clay or silt deposition on top of the grain or sand layer and regulated in the same manner until the clay or silt layer is about 30 centimetres thick.

Figure 2: Third-succession remnant mangrove forest in front of a sea rampart

The young clay or silt layer of 30 centimetres will be planted with pioneer mangroves *Rhizophora apiculata* (red mangrove) and/or *Sonneratia caseolaris (*crab apple mangrove). Because of continuous sedimentation the young plants roots in an oxygen rich clay or silt, but this soon becomes deficient in oxygen. When the oxygen level in the soil is almost zero, the plants start to produce stilt pneumatophores. Pneumatophores are essential for respiration and help to break up waves and diminish wave impact. Other species such as Avicennia *alba* (grey mangrove) with partial stilt growing pneumatophores are also suitable additions in the pioneer mangrove vegetation. *Avicennia alba* can also form pencil-like pneumatophores and is perfectly suitable for the second succession of the young mangrove forest. After three years of development, the second succession of mangrove vegetation can be introduced and these can eventually take over from the pioneer mangroves. Pioneer mangroves need, and can only grow in, dynamic tidal systems.

As the primary mangrove forest matures, tidal impact reduces over time and provides perfect conditions for the second succession of mangrove vegetation. Mangroves of the second succession of vegetation, with only pencil-like pneumatophores, capture silt and clay very efficiently. Thus species like *Sonneratia alba* (mangrove apple) and *Avicennia marina* var.

intermedia (guave mangrove) contribute very much to building on soil sedimentation until the effect of the tide varies ten centimetres or less and other stepwise successions follow after.

The third succession begins with the introduction of *Avicennia officinalis* (white mangrove) and *Ceriops tagal* (Indian mangrove), both with very short and dense pencil-like pneumatophores, and also *Nypa fruticans* (mangrove palm), *Sonneratia griffithii* and *Rhizophora mucronata*. The fourth and final low saline and inland environmental mangrove forest consists of shrub and small tree species such as *Bruguiera cylindrica*, *Xylocarpus granatum*, *Lumnitzera racemosa*, *Ceriops decandra*, *Camptostemon schulzii* and *Aegialitis annulata* and in addition *Phoenix paludosa* (mangrove date palm), *Xylocarpus mekongensis* and *Exoecaria agallocha*. The final succession of mangrove forest is dependent on low tide effects, because otherwise the mangrove forest would die and be overgrown with obligate land and fresh water plant species.

Following the stepwise succession of reclaiming land from the sea with mangroves, we create a very sustainable natural coastal defence for nearly the whole shoreline of Vietnam, resulting in an annual saving of 7.8 billion Euros for the maintenance of sea ramparts, concrete revetments and sea walls on very unstable clay soils. With a single investment of 1.1 billion Euros by the Vietnamese Government to execute this 'building with nature', coastal defences have reclaimed historic land areas and contribute to wildlife restoration, with at least an 800 year long-lasting permanent coastal defence at nil cost. As mentioned earlier, a single clay or soft soil dike at a height of typhoon level, as the Dutch have had along their former Zuiderzee (Southern Sea) for 800 years, will be the smartest solution for any coastal defence in the tropics on clay rich estuaries and shores.

Vetiver zizanoides, *Ammophila arenaria* and the new Water Garden

As mentioned in the introduction, *Vetiver zizanoides* and *Ammophila arenaria* are extremely suitable in water management projects. The first example is in the tropics and subtropics and the latter in dune building in the Netherlands. *Vetiver zizanoides* forms a matrix root system and can be seen as very cheap bench defence systems in rivers and canals.

Ammophila arenaria helps together with a native pioneer *Elythrigia juncea* subsp. *boreoatlantica* (sand couch), to fix sand in a 'building with nature' project to create a double coastline and a new inner sea. A big dam is built perpendicular to the current along the shore, shaping a hollow and moves the current more outward into the North Sea. A sand-sucking motor piles up huge masses of sedimentation at the tip of the dam and sand will be spread and taken by the predominant current along the shore. This is deposited in a narrow beach-line and beach ridge parallel to the old beach ridge line and it encloses a partial inner sea. Both plant species capture sand on the beach and create primary dunes and eventually mature full-sized dunes form.

The predominant western wind will diminish the height and transport the sand upon the second, inland dune ridge. As a result, the second and present coastal defence dunes will become higher and adapt in a cheap and 'building with nature' way to protect the Netherlands from future sea-level rises.

This and other 'building with nature' water management projects involve the use of gabions, open structured reinforcement blocks, soft slope beaches, also *Phragmitis australis* (common reed) as a barrier to dune growth, and *Populus nigra* (black poplar) gallery forest along rivers and larger brooklets or creating floating artificial islands with plants to form floating gardens. This will be explained and demonstrated in the new Water Garden next to the existing Delft Botanic Garden.

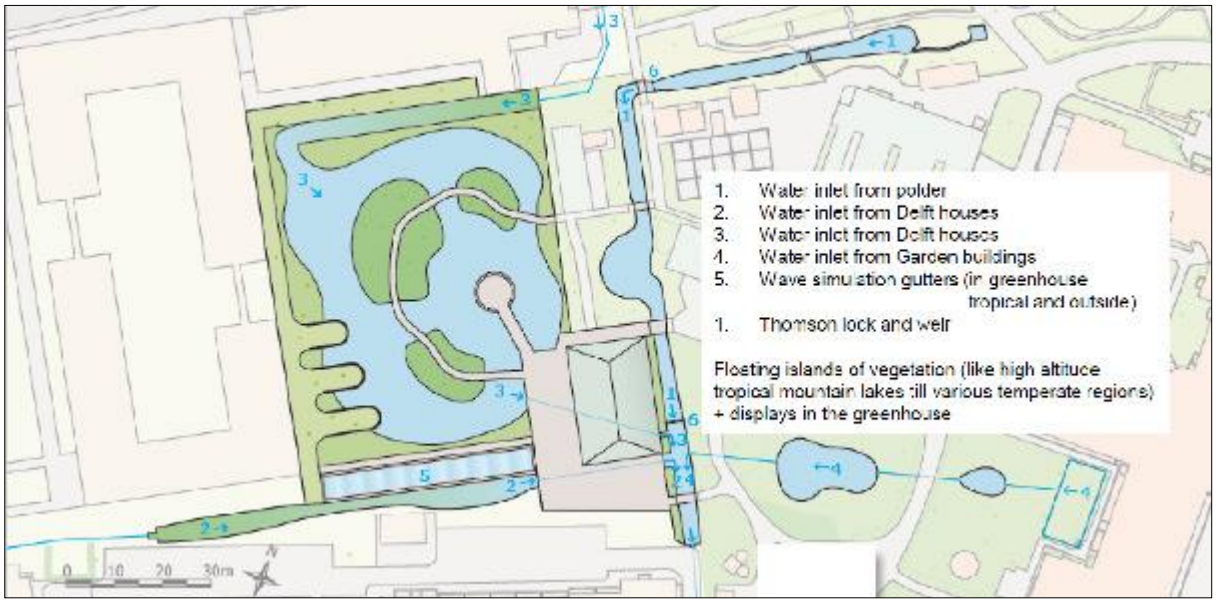

Figure 3: Layout of the Delft Water Garden

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