CONGRESS CONCLUSIONS

The **scientific programme** addressed 8 themes and consisted of

- 13 plenary addresses
- 27 parallel sessions, of which 12 were organised symposia on special topics
- 136 talks
- 3 panel discussions

Feedback from each session was provided, and these were divided into three main themes:

- Strategies and targets
- Conservation action
- Engaging with society

Strategies and targets

The Congress has provided an opportunity to gauge the success of the International Agenda and the GSPC in providing a framework for action by botanic gardens.The GSPC has provided a clear framework – all targets are being addressed.

No matter how many targets botanic gardens are working on, they are making valuable contributions to the GSPC.

2010 has provided a clear goal and accelerated progress. For example, Target 1 has been particularly successful. However, the long-term sustainability of deliverables must also be considered.

The enhanced dissemination and impact of the GSPC outcomes will depend on a closer collaboration between science, conservation and education practitioners within the botanic garden. As well as the GSPC, botanic gardens need to engage with other key global policies and strategies – such as the UNFCCC, Millennium Development Goals, World Heritage Convention and the Access and Benefit Sharing provisions of the CBD.

We need to develop wider partnerships beyond the BG community.

Botanic gardens need to continue sharing information and resources and develop informal and formal partnerships, promoting their successes and the benefits of working together.

Working for change means and requires long-term sustainable projects and dedication over many years.

Some specific needs that were identified include:

- ABS Code of Conduct model agreements for use by botanic gardens
- Models, templates and tools to support development of institutional responses to the GSPC

Conservation Action

Botanic gardens are adopting both species-based and thematic approaches to conservation.

Conservation initiatives involving a range of institutions around a common taxa can be productive.

Lower plants, cycads, trees and island flora were all addressed this week.

Partnerships, information exchange, outreach to local communities are key to conservation action success.

During this congress there were calls to establish:

- Botanic gardens cycad collections consortium (as part of IUCN SSC).
- A European network of botanic gardens working with cryptogams.
- Oceanic Island Plant Network.

- **Restoration issues include:**
    - Need to address integration of species and ecosystem restoration
    - One-size does not fit all
    - Need to scale-up from the local to landscape level
    - Need to connect science with practice and engage local communities
- **Information needs include:**
    - Databases to provide an ‘institutional memory’
    - Continuous documentation (seed to maturity) – important for climate change research
    - Meta databases – such as PlantSearch - are needed to make information available to the wider community

- **Research is critical for:**
    - *Ex situ* conservation – which takes on its most significance in cases of extreme rarity
    - Reproductive biology and genetics – this may be critical for the effective conservation of rare species
    - Mutualistic plant-animal relationships are complex and need to be better understood
- **Invasive species issues raised:**
    - Botanic gardens have the knowledge, facilities and applied expertise to address invasive species issues
    - Education and outreach are critical components
    - Greater communication and collaboration required between gardens – development of an early warning system

Engaging with society

- BGs are uniquely placed to develop a stronger role across all social demographics.
- There is a need to raise the profile of BGs with other cultural organisations, public bodies and governments.
- Societal impact must be documented.
- Social vision must be embedded throughout the botanic garden.
- The importance of ecosystem services must be communicated in new ways to visitors.
- We need to interpret climate change and conservation science in locally relevant ways.
- Working with local communities is essential for translating international policies into on-the-ground action. This can include job-creation and economic opportunities for local communities.
- Botanic gardens have a significant role to play in supporting and influencing pedagogy and learning within formal education systems.
- Certified courses encourage participation and standardisation of quality.
- To build sustainable gardens it is important to involve all staff and to layer sustainability principles in all practices of botanic gardens.
- Making use of traditional knowledge and local resources is an effective way of demonstrating solutions and bringing unique habitats to life.
- Individuals can have an impact on determining the development of a botanic garden.
- Inter-relationship between science, horticulture and education is critical in developing education programmes.

Recovery and conservation of the Salento agricultural genetic resources (Apulia-Italy).

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Abstract

Agricultural genetic resources represent a good percentage of total terrestrial biodiversity. The Botanic Garden of Salento University has undertaken programmes of investigation and collection of horticultural varieties selected over the last centuries at the local level with the aim of creating a germplasm bank. The agrarian biodiversity analysis has confirmed a strong reduction of Salento cultivars; many once common, are now preserved only in the historical memory of our grandparents. Investigations were made to identify reproductive material (seeds) of varieties considered by farmers as ancient tasty varieties - varieties with undisputed nutritional quality. Those varieties have been multiplied and cultivated in catalogue fields in order to reintroduce them amongst farmers but also for use in local agrotourism. Many these cultivars have not been characterized by taxonomy or molecular analysis, therefore part of the material is being used for more in-depth investigations.

Key words: biodiversity, botanic garden, molecular investigation, niche variety, propagation, seed bank

Introduction

Salento University Botanic Garden is a centre for studying Mediterranean plant species protection and conservation, providing information to the public and the scientific world with the aim above all of conserving *ex situ* threatened species (Marchiori & Dedej, 2000). Its strategic objective is *ex situ* plant diversity conservation, according to the Convention on Biological Diversity article 9 (CBD) (Secretariat of the CBD, 2005).

Particular attention is given to maintenance of Red List species (National and Regional), and understanding their reproductive ability (Accogli & Marchiori, 2006a). For every species, seed and vegetative propagation success is verified. In the botanic garden, artificial environments are reproduced for plant conservation and seed plant cultivation and collection (medicinal, nutritional and endemic plants). Seed conservation is very important for *index seminum* realization. Priority is given by the Botanic Garden to the reintroduction of rare species and plant protection activities.

Education activities are focused on landscape protection, natural, historic, cultural and social interactions, with natural heritage and humanistic sciences (Blasi, 2007).

Ex situ conservation also focuses on conserving local cultivars used as food. Agricultural genetic resources constitute a good percentage of total terrestrial biodiversity, including both old and new cultivars, as well as intra-and inter-specific hybrids, local populations and mutants (Porfiri *et al.*, 2001).

Salento Botanic Garden has undertaken investigation and recovery programs for horticultural varieties selected in the last centuries at the local level with the purpose of creating a germplasm bank. The agrarian biodiversity analysis has confirmed a strong reduction of Salento cultivars. Many once common, are now preserved only in the historical memory of our grandparents. Crop genetic erosion in Salento has been widespread in the past 25 years; changing socio-economic factors and modernization of agro-techniques has resulted in a new generation of farmers and modern cultivars have caused a rapid decline of landraces which are unable to compete in the market place (Accogli & Marchiori, 2006b).

Botanic Gardens of Moscow State University: a Platform for education and innovation

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Abstract

In line with the Target 14 of GSPC, the Botanic Gardens of Moscow State University (MSU) have been tasked with creating an education system to serve the pre-school, basic, specialized, further education and vocational training sectors.

At the present time the Garden is the base on which scientists and students of different faculties can conduct studies and scientific researches. The Garden carries out programmes of professional skills improvement and professional retraining (80-hour skills enhancement course designed for local government staff; professional training programme for gardeners). Building on its existing programmes, in 2009-2010 the Garden significantly expanded its educational activities thanks to the project sponsored by the Association of Moscow Higher Educational Institutions. The purpose of the project was to create a modern teaching environment in the Garden, using up-to-date forms of interpretation (electronic guides, information displays, and multi-functional internet resources) and developing an innovative educational programme for training specialists within the “Secondary School – Higher Education - Labour Market” and “Higher Education – Business – Staff” streams. One of the project outcomes is the creation of new information and education materials, most of which are freely accessible via the internet and are already being used in Garden-based classes for schools and universities. There has also been progress on formal and public education. The Apothecary Garden’s education programme is expanding into new areas with an initiative to pilot a school-garden collaboration scheme. The garden is prioritizing its work with young people, students and schoolchildren, introducing them not only to plant diversity and ethno-botanical traditions of plant use, but also to the latest developments in science and technology - including biotechnology and agricultural techniques - and the search for solutions to modern-day issues.

Keywords

Basic education, botanic garden; education programme; formal education, professional training course; training for gardeners.

The Moscow University Gardens have been tasked with creating an education system to serve the pre-school, basic, specialized, further education and vocational training sectors. Put more precisely, the task is to create an education and innovation platform within the Garden to achieve a wide range of objectives. These include:

- improving the quality of student training in MSU’s Biology Faculty and other higher educational institutions, with a focus on hands-on experience;
- drawing young people into science and providing early occupational guidance for schoolchildren;
- promoting nature and plant studies amongst secondary school pupils and expanding their understanding of biology, geography and associated disciplines;
- promoting environmental education and awareness across society;
- improving the skills of schoolteachers and local government specialists in various fields.

Bantaba – a gathering place at the heart of Eden's Rainforest Biome.

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Abstract

The Bantaba, or gathering place, is the traditional heart of a Gambian village; a place to meet, to rest, to welcome strangers and to discuss the issues of the day. At the heart of the Eden Project's Rainforest Biome we have constructed a Bantaba of our own, to highlight the story of the Ballabu Conservation Project (BCP). With a conservation area incorporating 14 villages, the goal of BCP is to alleviate poverty for local people by making each village self-sustaining through local industries such as ecotourism and agriculture.

An educational charity, Eden provides a stage on which to celebrate our connections with, and dependence on, the natural world and each other. Our exhibits bring to life the stories we are illustrating. Eden's Bantaba symbolises the people at the heart of the Ballabu project, the villagers and their way of life. It's space for storytelling by our team of Pollinators; a visual tool to highlight issues such as water supply (village well), food security (chop farm), traditions (making palm wine); a direct link to Eden initiatives (Gardens for Life) and partnerships (Ballabu); an essential element of Eden's mission to engage, entertain, inspire the imagination and linger in the memory.

Keywords

Storytelling–gathering place–landscape-education strategy-partnerships

Introduction

Imagine you're in a Rainforest. It's lush and green, but also very hot and humid. You're tired, and you seem to have been walking on this path for a long time. Then, as the way slopes upwards to a bend in the road, a clearing opens up under the trees. Two benches sit invitingly in the shade of a large Gmelina. There's a large pitcher of fresh water, covered with a cloth to keep it clean and cool, and a kettle filled with water for you to wash the dust from your hands and feet. You have arrived at a Bantaba – the traditional heart of a Gambian village; a place to gather, to rest, to welcome strangers and to discuss the issues of the day. This particular Bantaba, however, is not in the Gambia, but is instead to be found in the Rainforest Biome of the Eden Project. It has been carefully constructed at the heart of our West Africa exhibit, to give a focal point to the story we are telling about life in the Gambia. As one of a team of horticulturists working in the largest rainforest in captivity, my responsibilities include the West African exhibits, and I would like to use one of these exhibits, our Bantaba, to illustrate a little about the Eden ethos, and how our landscape shapes and informs our educational strategy.

The Eden Project

The Eden Project is a Millennium project conceived in 1994 and built in a former Cornish clay pit in the south-west of the United Kingdom. Eden opened to the public in March 2001 and is a not for-profit Charitable Trust. An educational charity, Eden provides a stage on which to celebrate our connections with, and dependence on, the natural world and each other. In a gentle and positive way, Eden invites people

Status of plant conservation in oceanic islands of the Western Indian Ocean

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Abstract

We review plant conservation in the Mascarenes (Réunion, Mauritius, Rodrigues) and the granitic Seychelles islands. Sizes of angiosperm floras are: Seychelles (200 species, c. 70 endemics of which c. 70% are threatened), Mauritius (691 species of which 273 are single island endemics [SIE] and another 150 are Mascarene endemics [ME]), Rodrigues (150 species, 47 SIE, 72 ME), Réunion (550 species, c. 165 SIE, c. 140 ME). The main threats affecting plant diversity are small population sizes and fragmentation, and invasive alien species. While in Mauritius, Rodrigues and Seychelles <5% of intact habitat is left, this proportion is still 30% in Réunion. Consequently habitat restoration is a priority in Mauritius, Rodrigues and Seychelles. All islands have recently greatly advanced some aspects of plant conservation, while gaps are also apparent. Advances include conservation strategies (all), *ex situ* conservation (all), extent of protected areas (Réunion, Seychelles), new NGOs (Réunion, Seychelles) and outreach (Réunion, Seychelles). Weaknesses include lack of government support (Mauritius, Rodrigues), local scientific expertise (Mauritius, Rodrigues, Seychelles). Given the similarity in biogeography and past and current anthropogenic disturbances a regional plant conservation network and strategy needs to be strengthened.

Keywords

Angiosperm flora; conservation status; granitic Seychelles; Mascarenes; Mauritius; oceanic island; Réunion; Rodrigues

Introduction and aims

The importance of islands for the conservation of global plant diversity is disproportionately high relative to the small land surface area they occupy (Kreft *et al*., 2008). However, humans have already heavily affected island ecosystems (Millennium Ecosystem Assessment [MEA], 2005; Whittaker and Fernández-Palacios, 2007; Kingsford *et al*., 2009) and, in the foreseeable future, human pressure on ecosystems will likely increase more markedly on islands than on continents (Brooks *et al*., 2002; MEA 2005; Kier *et al*., 2009). In consequence, island plant conservationists are faced with a huge conservation challenge and though they could learn much from each other, contact among researchers and managers of threatened plants on different archipelagos worldwide has been generally limited (Caujapé-Castells *et al*., 2010). If we are to maximise potential benefits from inter-island exchanges between researcher and managers, an important prerequisite is to conduct an accurate and up to date review of the status of plant conservation on these islands. The aim of this paper is thus to provide a summary of the current taxonomical knowledge of the angiosperm floras of the Mascarenes (Mauritius, Réunion and Rodrigues) and the granitic islands of Seychelles, evaluate their conservation status and finally unravel the major conservation achievements and gaps.

How to get students to conserve plant diversity? The benefits of a new approach to the relationship between scientists and society.

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Abstract

Conserving biodiversity with efficiency needs the participation of citizens. So the fourth mission of the Conservatoire Botanique National du Bassin Parisien is to promote education in the framework of biodiversity conservation programmes. Since 1995, the Conservatoire has been studying the decline of a glacial relict in the Fontainebleau forest, near Paris. We conducted *in situ* experiments to evaluate the benefit of bringing new genotypes in genetically depreciated populations, and we could set up a programme of reintroduction that gives the *A. grandiflora* populations the best chance to face global changes. We wanted to make the public at large participate in this ambitious programme of biodiversity conservation and we choose ninety students aged from eight to ten years, in the framework of an educational programme carried out by a wide community interest, to ensure the success of the project. In order to make their participation in the biodiversity conservation a permanent reflex in the mind of each student, we wanted them to have good memories of this experience: a personal diploma and the presence of the regional and national media allowed us to reach this aim.

Keywords

Participatory sciences, reintroduction sponsorship, primary school students, educational project, reintroduction diploma, glacial relict, hybrid populations, Community Interest.

The network of French Conservatoires Botaniques Nationaux: from research to public awareness.

In the late seventies, the French government entrusted the Conservatoires Botaniques Nationaux with the task of developing an original concept for plant conservation. Thus the network of Conservatoires Botaniques Nationaux was created to guarantee the plant biodiversity, thanks to four missions: (1) to know the situation and evolution of wild flora and natural & semi-natural habitats, using scientific methods; (2) to identify & conserve rare and endangered wild species and natural & semi-natural habitats; (3) to realize evaluations for the State and all local communities; (4) to inform and educate populations to know and protect plant biodiversity.

The Conservatoire Botanique National du Bassin Parisien is a laboratory of the French National Natural History Museum, located in Paris. Accordingly, our fifth mission is an applied research on very limited size populations of protected species, to understand their disappearance, and to set up efficient tools to face this evolution as well as to restore populations with capabilities of adaptation to the global changes.

A glacial relict near Paris: the reasons of its disappearance.

Arenaria grandiflora L. (Large-flowered Sandwort, *Fig. 1*) is a very rare caryophyllaceae in the lowlands of France. More common in the Pyrenean and Alpine regions (*Fig. 2*), it is considered as a glacial relict and is on the verge of extinction in the Fontainebleau forest, in the Parisian region. In this forest, *A. grandiflora* is an emblematic species because this is one of the oldest plant observation reported in the literature, by Tournefort in 1698.

Educatıon ın botanıc gardens for young chıldren

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Abstract

Early childhood is a crucial period for the formation of human personality, intelligence and social behaviour. Considering this fact, young children should be introduced to botanic gardens. In this paper, educational programmes for young children of the Nezahat Gökyiğit Botanic Garden (NGBB) are looked at and the underlying educational principles of these programmes will be presented.

Key words

Botanic Garden Education, Early Childhood, Environmental Education

Introduction

Today's children are getting disconnected from nature day to day (Louv, 2006). They have little chance to explore nature by direct experiences and according to Louv (2006) this loss is underlined in many emotional and physical problems for them. Botanic gardens, that are generally built in crowded urban cities, can make enormous contributions to maintaining this connection between nature and humankind. Nezahat Gökyiğit Botanic Garden (NGBB) is one of these gardens, which opened in İstanbul, one of the most populated cities in the world.

NGBB is a new botanic garden located in Turkey. The garden is unique in the sense that it is the first and only botanic garden built in a motorway junction. The garden hosts over 150,000 visitors per year and, is the first, and only botanic garden running educational facilities in Turkey. It offers a wide variety of educational facilities such as school's and children's programmes, adult education courses including practical horticulture training and botanical illustration, public talks, exhibitions and so on. However, the focus of this article is educational activities and the perspective of the garden for children in early childhood.

Early childhood is the period from conception to the beginning of primary school at about age 6 or 7 (Myers, 2002). According to Myers (2002) the early years have a great importance because of rapid and dramatic changes in mental and physical characteristics. Formation of intelligence, personality and social behaviour are completed largely within this period. Especially, after age 3 children become independent explorers. So, botanic gardens should aim to reach children between 3 to 6 or 7 years old to contribute to the development of positive attitudes towards the environment. But, in which percent should botanic gardens target young children? If botanic gardens would like to reach young children, they should negotiate with families or schools. The survey done by Kneebone (2006) indicates that 58% of the participant gardens target students between 0-5 ages and 74% of them target families. Findings of the survey show young children are the least targeted group between school groups. Also, it is not possible to say whether targeted family groups are ones with young children or not. Why are preschool aged children the least targeted group among others? It can be considered that it is difficult to reach this age group or the misunderstanding that science is not for young children. However, it should be considered that preschool aged children have a more flexible schedule than children in the obligatory schooling period. Also, scientific process skills begin to be obtained in the early years (Lind, 1996). So, botanic gardens need to reach young children and work on proper programmes that support scientific skills, and environmentally friendly attitudes toward them.

We have introduced some of them…. Do we take the responsibility to eradicate them?

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Abstract

Invasive species have been spread from private gardens, parks and in many other ways, among them from botanic gardens. Several of these involuntary introductions of alien species into the nature have now become a severe threat to biodiversity. One of the new duties for botanic gardens is to inform our visitors about alien species, cooperate with the authorities in how to deal with the problematic invasive plant species, and take an active role in eradication programmes. The botanic gardens have been guilty in introductions of problematic alien plant species into nature and must feel their responsibility. Some examples of how the Botanic Garden in Oslo, Norway, has started to deal with the problem are given.

Keywords

Invasive alien species, demonstration area, eradication, responsibility

In Norway the Norwegian Biodiversity Information Centre is responsible for our Red List Database and Alien Species Database. They collect and coordinate facts from all researchers and produce the Norwegian Red List and the Norwegian Black List. The first Norwegian Red List came out in 1999, the second in 2006 and now in 2010 a third revised version will be published. The first Norwegian Black List came out in 2007 and we will get the next revised version in 2011.

But lists and databases don't reach out to the public. It is here we – the botanic gardens – have an excellent opportunity. We are reaching the public, we provide guided tours and educational programmes and we have the knowledge of rare threatened indigenous plants, as well as introduced problematic species. And - as we must admit that we are responsible of several introductions of plant species that have escaped into the nature - we must take this opportunity of spreading knowledge about the topic "problematic alien species are a considerable threat to indigenous species" seriously as well as compensating our own faults.

The little *Noccaea caerulescens* is a central European crucifer. It came to Norway with seed mixtures sent to the Botanic Garden in Oslo in the early 19th century. It was first found growing wild outside the Botanic Garden in 1874 and spread slowly until 1900. Since then it has become naturalised in most of our long and narrow country. This is a tiny harmless plant that wilts down after flowering, and it does not compete with the indigenous flora. Not many escapes from botanic gardens are so exactly documented as this, and we must admit that we don't know how many species have escaped from our gardens. Ongoing studies divide introduced plant species into different categories, from very harmful and strongly competitive, to harmless and - so far - nothing to bother about.

The Botanic Garden has excellent opportunities to be community-oriented through:

1. Information to our visitors about both threatened, indigenous plants as well as problematic, alien species.
2. Include threatened wild plant species and alien species into our educational programmes.
3. Cooperation with the authorities (locally, regionally and nationally), in species identifications, education, training of staff and eradication plans.
4. Active participation in combating alien species.
5. Conducting experiment with eradication of alien species not problematic in other parts of the world.

Informing pest prevention efforts through Sentinel Plant Monitoring

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Abstract

Botanic gardens with international collections provide a unique opportunity to help detect potential invasive threats to forest health. Nursery stock is well-recognized as a major pathway for the introduction of invasive insects and pathogens to native ecosystems. Plant health regulators need help knowing what pests attack host plants abroad so they can develop ways to encourage clean nursery stock production. The New Zealand expatriate plant pilot demonstrated that systematic observation of native plants in botanical gardens overseas is effective. Ten new pests were detected in just 14 overseas site visits. European Union entomologists have initiated collaborative research with Chinese and Russian counterparts to monitor plantings of European trees. A more holistic approach to monitoring and data sharing could greatly strengthen our ability to predict pest problems before they arrive in new lands.

Keywords

Pathogens, pests, sentinel gardens

Introduction

Chestnut blight, Eurasian poplar leaf rust, white pine blister rust and sudden oak death are just a few examples of forest diseases that were introduced into the United States via the nursery stock pathway. For many agricultural products, the pests abroad are fairly well-known, and phytosanitary measures can be developed to prevent their spread in fruits and vegetables moving in trade. However, most forest pests were unknown to science before they established in a new land and started causing big problems to the natural environment. Furthermore, the volume of international trade in plants has grown so quickly that inspectors in ports of entry simply cannot inspect them all. In the United States, only 2% of each shipment of incoming nursery stock shipments is inspected. New countries entering the global trade also increase the diversity of pests that can occur on nursery stock. The scientific community recognizes that international communication and collaboration offer the best hopes for preventing new pest incursions.

In response to this threat, we are beginning to develop a Sentinel Plant Network. Initial steps involve enhancing the Botanic Gardens Conservation International (BGCI) databases to include more gardens in PlantSearch, and information in GardenSearch on the plant health expertise present in each garden. Training modules are being developed to help garden staff learn to monitor their collections for insect and disease attacks, and know who to call when a new pest is discovered. A unified system of data sharing needs to be developed to ensure that new host/pest associations are recognized and used to help make trade in horticultural plants safer.

Methods

BGCI received funding from the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service to increase the scope and content of their two existing global botanic garden databases in order to support key components of the Sentinel Plant Network.

Role models in botanic garden education networks

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Abstract

Networking opportunities are the key to effective and efficient capacity building and support for botanic garden educators. Developing a solid infrastructure for any network - with aims, objectives and clear development processes is equally critical for effective network support and sustainability. The two networks discussed here, the Botanic Garden Education Network (BGEN) in the UK and the network of Argentinean botanic gardens (RAJB), provide case studies on how networks function and the impact networking can have on delivery of programmes.

Key Words

Capacity building; communication methods; network; resource exchange; staff support;

Case Study 1 - The Botanic Gardens Education Network (BGEN)

BGEN was started informally in 1994 by a small group of educators who wanted to share their working experiences and programme ideas. Initially targeted at botanic gardens education staff, and staffed by educators from a number of botanic gardens who volunteered their support, the network offered one annual training course and produced a regular newsletter for members. In 2002, the committee held a number of strategic development workshops and decided that it should operate on a more business-like footing and started the application process to become a registered charity and a company limited by guarantee, both of which were granted in 2003. The registered office for BGEN Ltd is currently hosted by the Royal Botanic Gardens, Kew. A strategy for fundraising was also put in place, ensuring sufficient money for BGEN to employ a part-time coordinator. This post-holder administrates the day to day activities of the network and maintains an excellent, timely e-network service for all members.

With a new constitution and enlarged committee, BGEN redefined its mission statement: *'Supporting inspirational learning about plants and their importance'* and refined its objectives as:

BGEN will work with its members to:

- Foster a greater awareness of the importance of plants and plant diversity among people of all ages and cultures
- Encourage a responsible attitude towards the natural environment, conservation and sustainability
- Provide a bridge between visitors and the varied skills and expertise of the staff and volunteers of all member organisations
- Interpret the living plant collections and other resources on-site (and where appropriate, off-site)
- Promote awareness of and support for the aims and objectives of the Convention on Biological Diversity (CBD), Global Strategy for Plant Conservation (GSPC), Millennium Development Goals and other relevant legislation

The status of plant conservation on the Macaronesian archipelagos

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Abstract

We assess the threats to the endemic plant diversity on the Macaronesian oceanic insular hotspot, consisting of five Atlantic archipelagos where heterogeneous bio-geographical, historical and political characteristics have determined contrasting conservation priorities. A recent review identified invasive alien plants and vertebrates, small population sizes and fragmentation, and demographic and economic growth as the main overall drivers of plant diversity loss in this area. Cogent with deficiencies detected on basic reproductive biology knowledge, taxonomy, and implementation of scientifically streamlined *in situ* conservation strategies (including management of invasives), priority actions to be undertaken by the botanic gardens in this region should include (i) to foster multi-disciplinary research collaboration aimed at filling those knowledge gaps, (ii) to monitor the possible effects of environmental shifts on plant diversity, and (iii) to increase interaction between policy makers and researchers through applying the resulting information. *Ex situ* conservation is a major priority for all the endemic floras; consequently, the already existing herbaria, seed banks and DNA banks should receive better institutional support. An international network of island plant conservationists would be a major milestone to share knowledge and expertise with other insular areas of the world facing similar challenges, and to better address urgent conservation needs.

Introduction

Macaronesia is an oceanic insular biodiversity hotspot in the Atlantic Ocean with a total land area of ca. 15,000 kilometres, and consisting of five archipelagos: from North to South, Azores, Madeira, Selvagens, Canaries, and Cape Verde. This region encompasses many minor islands and islets, and a total of 28 main islands, ranging from only one in both Madeira and the Selvagens to ten in Cape Verde. Politically, these archipelagos belong to three countries: the Azores, Madeira and Selvagens are Portuguese overseas territories, the Canaries are Spanish, and Cape Verde is an independent republic. Therefore, the laws, scientific priorities and practical policies to investigate and preserve biodiversity in different archipelagos vary considerably.

The Macaronesian archipelagos are situated between mainland Africa and Europe, which are also the main sources of the major colonizing stocks that gave rise to their current and variably lush floristic makeups. According to the reconstructions in published molecular phylogenies till last May (first author's personal database), about 35% of the current Canarian endemic plant species have Mediterranean ancestors, roughly 25% bear a closer relationship with North West African extant groups, 22% are

The role of native species nurseries in mitigating threats from invasive species: case studies from UK Overseas Territories

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Abstract

Many invasive species have been introduced via the horticulture trade during years of plant exploration and movement of plants around the world. Pests and diseases often piggy-back on these movements and find new hosts and prosper. Kew's UK Overseas Territories Programme is developing strategies with Territory partners to address these threats. The development of native species nurseries that supply plants for conservation actions that mitigate invasive species threats are yielding positive results. Three case studies are presented:

- St Helena: The St Helena Government is expanding the capacity of its nursery to provide plants of native species for direct replacement of invasive plants as they are removed in an ambitious restoration programme.
- Cayman Islands: The native species nursery at Queen Elizabeth II Botanic Park is growing the 'Cayman Collection', thirty native species for sale in an attempt to reduce the number of exotic species used in landscaping, many of which are invasive or showing invasiveness potential.
- Turks & Caicos Islands: Turks & Caicos National Trust has established a pine nursery to grow an *ex situ*, pest-free collection of the national tree, *Pinus caribaea* var *bahamensis*. The wild populations of this endemic variety are being decimated by an invasive scale insect and may become locally extirpated.

Keywords

Cayman Islands; conservation; restoration; St Helena; Turks and Caicos Islands;

Introduction

The UK Overseas Territories (UKOTs) comprise 16 former colonies that retain their direct British links and are part of the United Kingdom and they are British citizens. Including many remote oceanic islands, the UK Overseas Territories contain unique species and habitats and by far the most important UK biodiversity is located in the Territories. Kew's UK Overseas Programme is helping UKOTs implement the Global Strategy for Plant Conservation (GSPC). This paper illustrates some of the approaches to tackling invasive species and helping achieve Target 10 (GSPC, 2002).

Like most biodiverse regions of the world, UKOT biodiversity is being threatened by habitat loss and fragmentation, invasive alien species, development and the increasing threat of global climate change (Millennium Ecosystem Assessment, 2005). However, if serious inroads are not made into tacking habitat loss, and in particular invasives, in some Territories there will be no biodiversity left to be impacted by climate change which will become a social issue and not a biodiversity one.

Native species nurseries and invasives

Kew is supporting developments in key botanical infrastructure in the UKOTs. These include the establishment of native species nurseries working with local Botanic Gardens, National Trusts and Government Departments. This paper illustrates three contrasting invasive species challenges where the development of native species nurseries has been a key element in tackling the invasive threat. These are drawn from current projects in St Helena in the South Atlantic, and the Cayman Islands, and the Turks and Caicos Islands in the Caribbean.

The remote island of St Helena has suffered from the negative impacts of invasive species for centuries ever since the Portuguese discovered St Helena in 1502 and left goats there as a source of fresh meat for passing sailors. Over-grazing by goats, now largely removed, has left much of the lowlands as eroded Crown Wastes. The Peaks were hugely modified towards the end of the 19th century by the commercial planting of *Phormium tenax* (New Zealand flax) to provide an economy based on the fibre extracted from the flax and used for a range of products including UK mail bags until the market collapsed with the invention of lighter, waterproof plastic derivatives in the 1960s. This has left St Helena's unique flora on the edge of extinction; six of the approximately 50 endemic plant species are already thought to be extinct, many species are down to single individuals and others have a very restricted distribution (Ashmole & Ashmole, 2000; Cronk, 2000).

The first challenge was to get the native and endemic flora into secure *ex situ* conservation and the Endemics Nursery at the Agriculture and Natural Resources Department's headquarters at Scotland was established to do just that (Figure 1). The current project funded by the UK's Overseas Territories Environment Programme (OTEP) is helping increase the capacity of this nursery through providing both staff and training opportunities, both at Kew and in St Helena, as well upgrading nursery facilities (UKOTCF, 2008). Virtually all the key endemic plants from both the dry lands and from the moist cloud forest of the Peaks are now in cultivation and being propagated in large numbers for re-introduction.

Lessons are being learnt from earlier restoration attempts which failed. For example when removal of flax from the Peaks was first undertaken the time between removal and plantings with native species was too long, allowing the establishment of even worse invasive species. *Austroeupatorium inulaefolium* (whiteweed) is an insidious invasive composite shrub, native to Central and South America and Caribbean islands that produces huge numbers of seed and a long-lived seed bank and is a much bigger problem than flax.

A major seed-collecting programme is underway (Figure 2). Seed is being collected on St Helena and excess seed stored locally using a low-tech sealed drum containing silica gel developed by Kew's Millennium Seed Bank Project. This provides a simple and reliable way to dry seeds which can then be stored in sealed foil packs in a fridge until they are needed for sowing in the nursery or for direct sowing in the field. Seeds are also being collected from St Helena species in the living collections at Kew for repatriation. This is particularly important for those species that produce little or no seed on the island. For example, *Mellissia begoniifolia* (St Helena boxwood) which is being hand pollinated and 13,000 seeds have been collected this season to be sent to St Helena. This is critical as the boxwood is extinct in the wild and the few *ex situ* individuals on St Helena were not producing seed.

The current approach to restoration is to carefully clear invasive plants from specific areas only when there are sufficient supplies of a suitable range of native/endemic species available in large enough numbers to plant out and get established to out-compete invasives. Early indications are that this approach is working and the on-going challenge is to produce enough plants in the nursery over a sustained period to establish functional native habitats (Figure 3). The nursery management plan is now producing thousands of plants, many of which have never been in cultivation before. Resources, including sustained long-term funding remain challenges for the continuation of this work.

The challenges in the Cayman Islands (CI) contrast starkly with those in St Helena. The Cayman economy, based on the finance industry, has been vibrant and there is a lot of development. Landscaping is an important component of new developments and a norm is to use plants imported from Florida. There are no restrictions on species and there are minimal quarantine regulations. Consequently several serious invasives have been introduced which threaten native habitats.

Working with the CI Department of Environment (DoE) and the Queen Elizabeth II Botanic Park (QEIIBP) in a Darwin Initiative funded project, the impact of invasives and dealing with these threats was a central component (Darwin Initiative 2005). A typical example is the coastal shrub, *Scaevola taccada*, native to the Indo-Pacific and introduced as a landscaping plant and used widely for hedging. *Scaevola taccada* has escaped cultivation and is converting the diverse, native coastal dune vegetation into a monoculture of this fast-growing invasive. Many native species are in decline, including the native *S. plumieri*, which is on the verge of local extirpation. The identification of native species that can be used as native alternatives to non-native invasive species is an important role for botanic gardens. For example the native silver buttonwood (*Conocarpus erectus* var *sereceus*) makes a good substitute hedge in new housing developments and has none of the problems associated with using *Scaevola taccada*.

The most recent development is the establishment of a native tree nursery at QEIIBP to grow native species for landscaping as a response to the current usage of non-native and in some cases invasive species. This has been accompanied by a high profile advertising campaign to encourage the use of native species for landscaping (Figure 4) and the development of the 'Cayman Collection' – 30 native species specifically chosen to meet the current landscaping needs. Attractive plant labels have been produced with growing instructions and environmental information (Figure 5). The Cayman Collection has been a great success and it is a challenge keeping up with demand. QEIIBP are negotiating with the Government for extra land to expand production and also exploring links with private enterprise to diversify production.

The plant labels, specifically designed for this project have been a great success, appealing to a community interested in gardening and landscaping and we are developing similar 'local native collections' in other projects, for example, in the Falkland Islands. QEIIBP received some large orders including one to landscape the new airport expansion on Grand Cayman. However, the economic downturn has significantly affected the Cayman Islands and the airport expansion has been postponed. A lot of businesses including the landscape trade have cut back significantly and the long-term impacts are not yet known, but sales are very slow at the Nursery.

In the Turks and Caicos Islands (TCI) the challenge is a very specific invasive pest issue. The national tree of TCI is the endemic *Pinus caribaea* var. *bahamensis* (Caicos pine) and is suffering attack from an invasive scale insect first observed in 2005. This has been identified as *Toumeyella parvicornis* (Pine tortoise scale) which is a well known species in North America on the Pinaceae family, but this is a new host record and the first record for the Caribbean region. The course of the infestation has been rapid and five years on most of the TCI pineyards are populated with dead and dying pine trees (Figure 6).

TCI's pineyards have been mapped and fieldwork is documenting the extent of the scale's spread (Figure 7). A pine recovery plan has been formulated and the first phase of its implementation has been funded by the TCI Government. This included establishing an *ex situ* collection of Caicos pine to secure the species in cultivation and to build up stocks for potential reintroduction and restoration. To house the *ex situ* collection a new pine nursery has been built and a comprehensive Caicos pine collection programme started. Seed are collected where possible, but cone production has been severely curtailed by the disease. In addition seedlings have been rescued (Figure 8). Those that show signs of infection are treated with a soap wash to remove the scale. There is now a healthy *ex situ* collection in a functioning pine nursery and plans are underway for some experimental re-introductions on Government land allocated to the project for trials. The next year will be critical and funding has been secured for the next phase (UKOTCF, 2010).

Conclusions

These three contrasting case studies illustrate the range of invasive threats to unique biodiversity of the UK Overseas Territories. The invasive species threat continues and is getting worse, so a key requirement is for better bio-security to prevent new establishments as well as containing existing ones. Native species nurseries are proving vital in the fight against invasives, but there is a need for sustained funding and greater capacity to really ensure success. There is a need to up-scale production of native species in order to embark on large scale habitat restoration and species recovery. There is a great opportunity to establish small commercial nurseries on islands to work with the local Botanic Garden, National Trust, or Government Department which can stimulate the local economy, whilst making a positive contribution to conservation – a win-win situation. The funding model is a challenge, but we have the techniques and know-how to tackle invasive species and pull the pendulum back in favour of native communities.

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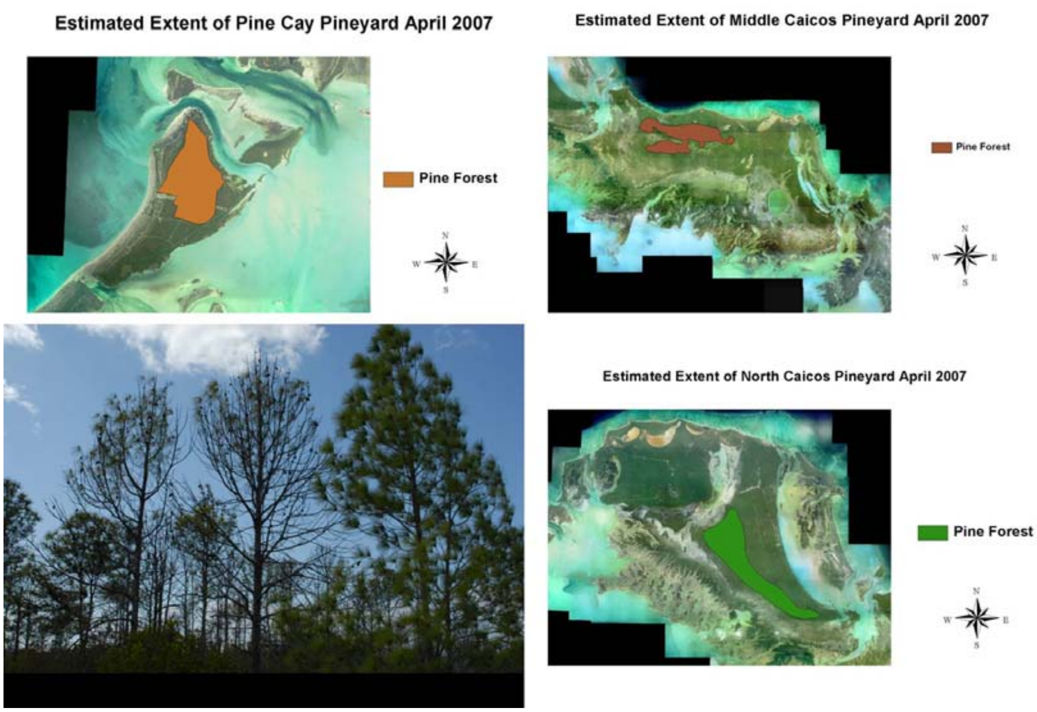

Figure 8: Collecting *Pinus caribaea* var. *bahamensis* seeds and seedlings for the pine nursery in TCI

Developing horticulture protocols for threatened plants from the UK Overseas Territories

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Keywords

Conservation, St. Helena, Ascension Island, Falkland Islands, Turks and Caicos Islands, Montserrat, Global Strategy for Plant Conservation (GSPC),

Abstract

Kew's UK Overseas Territories (UKOTs) Programme has an active training and seed collection programme with local partners in most of the UK's sixteen Overseas Territories. Seeds are being banked at the Millennium Seed Bank for long term storage and conservation of these endemic and threatened species, contributing to Target 8 of the GSPC. The strong capacity building element to this programme contributes to Targets 15 and 16 of the GSPC.

Many of the threatened species being collected have never been in cultivation so as part of documenting how to turn these seeds back into plants, horticulture protocols for each of the threatened species are being developed. Some of the collected seed comes to Kew to undergo germination trials and growing experiments in order to document the most effective way of growing these plants to a stage where they can be re-introduced back in native habitats. The protocol is written up, together with a short quick nursery guide for sharing with local partners. These protocols also contribute to Target 3 of the GSPC.

Introduction

The Royal Botanic Gardens, Kew's UK Overseas Territories Programme, has been developing horticultural protocols for threatened plant species for the past 5 years. This directly contributes to Target 3 of the Global Strategy for Plant Conservation (GSPC, 2002).

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 and they are British citizens. Including many remote oceanic islands, the UKOTs contain unique species and habitats. UKOTs biodiversity is included in the UK's signatory of Environmental Agreements, including the Convention on Biodiversity (CBD) and the GSPC, once these agreements have been ratified locally.

Developing horticulture protocols

Individual Territories are quite different; however the GSPC has provided a really useful framework for conservation action and helping UKOTs to implement the GSPC has become the Programme's overarching goal. (UKOTs, 2010). The Programme's overall approach to developing and implementing conservation projects is very practical. All of the projects involve documenting biodiversity to understand what plants are found there; determining the origin of these plants; calculating their distribution, and assessing the main threats, which enables Targets 1 and 2 of the GSPC to be delivered.

With a comprehensive desk study complete, field based activities begin. This usually includes baseline survey and mapping with our in-country partners which give the opportunity to provide hands on training. The focus is on both habitat and species level information. This enables a better picture to develop of the vegetation and the individual species. All of the field data are captured using handheld computers that geo-reference these data allowing the mapping of species distributions and the undertaking of modelling work as demonstrated in Figure 1 for *Rondeletia buxifolia* (Clubbe *et al*, 2009; Jones, 2008).

Once the necessary baseline information has been obtained, species of the highest conservation priority are targeted. These may be single island endemic species such as *Rondeletia buxifolia* or restricted range species which occur on only a few islands such as *Charianthus purpureus* both from the Caribbean island of Montserrat. The target species may be threatened with extinction globally or extirpation locally as is the case with the national tree of the Turks and Caicos Islands, *Pinus caribaea* var*. bahamensis*. Some species may be at risk due to exploitation such as the Christmas palm, *Pseudophoenix sargentii,* which has been over collected for landscaping in Florida and the Bahamas archipelago. Finally, species may fall into any of the above categories as well as being of some horticultural merit such as the St. Helena endemic, *Trochetiopsis ebenus*.

In situ conservation is supported by a range of *ex situ* conservation activities and the UKOTs team have embarked on a comprehensive seed collection and conservation programme in the Territories which is a natural extension to the Millennium Seed Bank's successful banking of most of the UK's mainland native flora. The field activities are focused on capacity building and securing high quality collections of seeds with associated herbarium vouchers (Figure 2).

In Territories support is given to key developments in botanical infrastructure. This includes the establishment of native species nurseries. These nurseries are encouraging the use of native species in landscaping as a response to the current usage of non-native and, in some cases, invasive species. For example the Falklands Islands native plant nursery, a joint venture between Falklands Conservation and Stanley Growers, is producing native plants for the local market. There are many horticultural introductions including *Berberis microphylla* that have escaped cultivation, become seriously invasive, and are now causing major problems at both a species and habitat level. These nurseries are also establishing *ex situ* collections to be used for reintroduction and restoration such as the native plant nursery on Ascension Island. The Ascension Nursery is growing endemic species for restoration work following invasive species clearance. Endemic fern species, such as *Pteris adscensionis* and *Marattia purpurascens,* which where once abundant on Green Mountain, are being grown in large numbers for reintroduction.

At Kew there are many different nursery facilities providing the ability to grow plants in a range of different growing conditions (Figure 3). Some, like the UKOTs Nursery are small glass houses that enable close control of conditions specifically for UKOTs collections. Other facilities, like the Tropical Nursery, house many different collections across the 21 climatic zones. The staff who work in these facilities have a vast range of knowledge and experience. These facilities and personnel allow the opportunity to develop back to basics horticultural protocols for a range of species.

UKOTs seed collections banked at Kew's Millennium Seed Bank are used to develop horticultural protocols for threatened species. The protocols focus on producing the best methods for germination of seed and cultivation of the species with low-tech methods.

At Kew, the resulting plants will be used in public display areas, for research, and education. Currently there are over 150 UKOT species being grown in the nurseries at Kew. Over 70 of these have been a result of seed collections for the MSBP. Many species are currently being grown for full protocols as our contribution to GSPC Target 3. For example: *Acacia anegadensis* (Hamilton *et al* 2007)*, Rondeletia buxifolia* (Corcoran *et al* 2009) and *Cordia rupicola* (Wenger *et al* 2010)

The process used in developing the protocols involves a team of horticultural staff in the nurseries at Kew. Firstly the germination trial is carried out, then the cultivation trial and finally the writing up of results after one year. UKOTs Programme and nursery staff meet to discuss the protocol design. This is an opportunity to identify members of staff with specific expertise with the species or a closely related species.

The design includes choosing the growing medium that will be used – normally two different types, one that is close as possible in type to the natural soil, and the other a standard coir/bark compost. Seed treatments are completed where necessary, for example scarification or breaking dormancy and identifying the ideal growing conditions. The temperature, humidity, and light levels are kept as close to the native environment as possible. The number of replicates included is sometimes limited by seed availability. When possible there are four pots of seed used as control and eight pots of replicates used in the trial. Finally, members of staff are identified to take responsibility for recording germination events and undertaking observations throughout the protocol. This could take up to 6 months from the time of sowing, however, will mostly range from 4-12 weeks for germination to stop.

On the day of sowing, the seeds are first divided into replicate groups. Then any treatments required like scarification or chipping are completed. Media are prepared and put into appropriate, labelled containers. The corresponding media type and seed treatment is recorded in the nursery propagation record book. Once seed sowing is completed the pots are placed in two different propagation units. As germination occurs, cocktail sticks are used to mark each emerging seedling. These markers will ensure that germination events are not under countered, if seedlings die. The event is recorded on a dedicated germination record sheet.

Once the germination trial has been completed, the results are fully recorded. Then before starting the cultivation trial, the seedlings are hardened off for a short period. This hardening off period allows the seedling to become more robust, thus coping better with the transfer to an individual pot. Different media and climate conditions are again used for the replicates.

After potting, the seedlings are returned to the propagation units for a short period before being transferred to their cultivation trial areas. The plants are grown for a full year with observations being undertaken weekly to start with, and then monthly after approximately four weeks, to record overall health and to note any pest and disease or watering issues.

After growing for one year the protocol plants are brought together for a final recording of results. The team of UKOTs Programme Volunteers are usually involved in this process to provide exposure to the volunteers to the wider activities of the UKOTs programme (Figure 4).

Depending on the species, the results recorded differ; however, generally the main interest is in growth rates, any signs of reproduction, and overall health of each plant. These results help to identify the best methods for germination of seed and cultivation of the species using low-tech methods.

Obviously there are different approaches to employ for plants that are destined for field restoration and those for display or retail markets. This is taken into account in the protocol design and the final report.

Two examples of protocols that have been recently completed are *Acacia anegadensis*, a legume tree endemic to the British Virgin Islands (Hamilton *et al*, 2007). This protocol was the pilot and established the overall protocol practices and procedures as well as the cross departmental relationships for the programme. The second was *Rondeletia buxifolia*, a Rubiaceae shrub endemic to the island of Montserrat (Corcoran *et al* 2009). It is threatened by an active volcano, invasive species of plants and animals, and development of local infrastructure.

The results from these protocols are combined with the most up-to-date information about the species taxonomy, distribution, threats in the wild and other conservation concerns. The reports are made available to our in-country collaborators first for comment and use before being made freely available via the Kew website. (www.kew.org)

The Programme has expanded over recent years through the many successful achievements and collaborations. The next year will again see an expansion of activities with many new species being grown at Kew. Several species encountered have required specialist assistance. In these cases, the work is carried out with the staff in Kew's micro-propagation unit. These specialist protocols are undertaken due to the species being difficult to grow, they require special conditions that can only be achieved in the laboratory, or limited propagation material is available (Figure 5).

Currently growing in the micro propagation unit are species from many Territories including several Caribbean orchids, as well as many fern species from Bermuda and Ascension Island including the recently rediscovered *Anogramma ascensionis*. This fern was rediscovered on Ascension Island after not having been seen for more than fifty years (BBC, 2010).

Once the protocol has been completed plants are incorporated into public displays with interpretation that tells visitors about the significance of their conservation. The plants are also used as a teaching tool for students and visitors.

Conclusion

Through collaboration with UKOTs partners, these protocols will hopefully provide the basis for producing plants that will be used for reintroduction of the species in the wild and for the restoration of habitats. The main driver for this work is to prevent any more species extinctions. The last individual of *Nesiota elliptica* (St Helena olive) died in 2003. This resulted in the extinction of this species which now only remains as a sample in the Kew DNA bank. It is vital to ensure that threatened species are secure in well-managed collections, such as *Mellissia begoniifolia* (boxwood) from St. Helena which is now extinct in the wild. Because *Mellissia begoniifolia* is being grown at Kew this has enabled intensive hand pollination to be undertaken which has resulted in 13,000 seeds being collected in 2010, most of which are being sent back to St. Helena for local use (Figure 6).

The GSPC has provided an excellent framework to enable conservation in the UK's precious Overseas Territories and will continue to do so in the post-2010 period.

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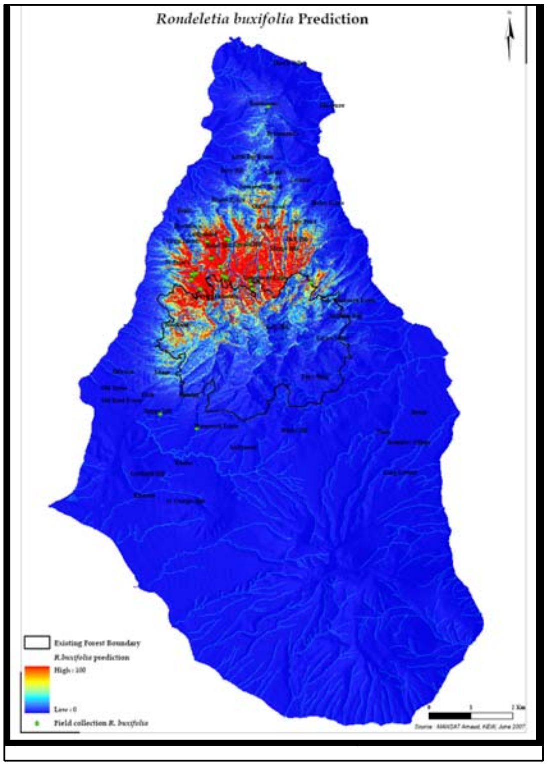

Figure 1: *Rondeletia buxifolia* Prediction Map, Montserrat

Figure 2: Field activities supporting *in-situ* conservation

Figure 3: Range of nursery facilities at RBG Kew

Figure 4: UKOT Programme staff and volunteers carry out the final recording

Figure 5: Species requiring specialist treatment in the micro-prop unit at RBG Kew

Figure 6: Hand pollination of *Mellissia begoniifolia* in the Tropical nursery at RBG Kew.

ABS and gardening

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Abstract

The impact of the Access and Benefit Sharing regime on gardening in the UK is discussed and suggestions are made for how this sector of horticulture may be encouraged and supported to operate within the framework of the CBD.

Keywords

Horticulture, gardening, ABS, *ex situ* conservation

Horticulture and gardening

Horticulture is a diverse area of activity embracing large-scale cultivation of horticultural crops, more akin to agriculture or forestry, to individual and amateur cultivation of plants for food or aesthetic reasons. It is the latter part, which might be referred to as small-scale specialist horticulture, or gardening, which covers the public parks and arboreta, private gardens and domestic gardening, specialist nurseries, garden centres and specialist societies. By and large it is interested in growing a wide range of different plants, often introducing new plants to cultivation, as well as specialising in growing as many kinds of certain groups of plants. There is a low financial motive and often interest in growing plants outweighs profit and, as such, represents a small part of the horticultural industry. In many ways – and traditionally – it is closest to the botanic gardens, and in the past botanic gardens have recognized the contribution of this sector in sharing plants. Indeed this used to be a two way flow. Practitioners in this sector (gardeners) have frequently been, and continue to be, experts in the cultivation and identification of the plants they specialize in.

It is important to make this distinction within horticulture as it is that interest in diversity and growing new and scarce plants which means this sector is impacted by ABS more than other parts of horticulture while their contribution to *ex situ* conservation is much greater. The low profit margin makes any prospect of financial return under Mutually Agreed Terms (MAT) arrangements impractical, although there is great potential for non-financial returns which are also proposed in the Bonn Guidelines (2002). For horticulture in general the suggestion of a fair trade scheme that would see financial benefits returned to source countries has been put forward (Demers, 2007).

The need for a continued introduction of new genetic diversity

It could be argued that with over 70,000 plants available in the UK (RHS *Plant Finder*, 2010-11) there is little need for further plants to be brought in from other parts of the world. Some would say that this continued influx represents a risk to the natural biodiversity of the recipient country although equally it could be said of the UK that the 'natural' habitats have been so seriously changed by human activity over the past 6,000 years, that this is nothing like the threat that invasive plants present to pristine, biodiversity-rich areas of the world. Further, as gardening and public green spaces are an important part of people's quality of life and wellbeing, it is vital that we maintain a healthy stock of plants for horticulture through the introduction of new plants. There are at least three reasons for this:

(i) Some plants are represented in cultivation by a single genotype and are consequently prone to a loss of vitality arising from repeated vegetative propagation. To maintain them new and different genotypes need to be brought in.

(ii) As pointed out earlier, specialist gardeners often have the skills to successfully cultivate difficult or rare plants that botanic gardens have not sufficient resources for. This is an actual, and potentially greater, role for *ex situ* conservation for gardeners. This is exemplified by the work of Plant Heritage in the UK.

(iii) As we face an uncertain future with climate change, there is a need for new genotypes and plants to improve horticulture's ability to adapt to a changed climate and continue to provide a healthy green environment, especially in urban areas.

The impact of the CBD on gardening

It may be disappointing to those who look to the CBD to deliver fair and equitable benefits to realise that within horticulture, certainly in the UK but probably elsewhere also, that the CBD is either regarded with indifference or as a distinct threat (for instance see Richards, 2006). This is not universally so and indeed there is considerable sympathy for the aims and intentions of the CBD although there are some who challenge the concept of the right of governments or people to "own" natural diversity which is fundamental to the CBD (Watson, 2006). More concern exists around the perceived bureaucratic barriers or even the apparent lack in some countries of any national body to process requests to collect, therefore making it extremely difficult to operate legitimately. The introduction of Certificates of Origin as envisaged in proposals for tightening the ABS regime would only exacerbate this. Tobin *et al*. (2004) in their review of the proposed certificate of origin scheme conclude, "Furthermore any system must not be so bureaucratic or costly that the transaction costs effectively consume the potential benefits." For the gardening sector, this is an acutely relevant concern. This situation encourages continued unlicensed plant collection, creating a pool of 'illegal' plants in cultivation. It is also the case that plants have been collected after the date of coming into force of the CBD in 1993 but before the implications of the CBD were more widely understood which are, in effect, 'illegal' since they are not covered by a permit to collect. These are informally referred to as 'grey' plants.

Over the past 10 to 15 years botanic gardens have introduced strict control over plant material in their collections even, in some cases, to material that is not covered by the requirements of the CBD. For similar reasons botanic gardens often will not accept plants into their collections from horticulture due to concern that these may contravene the CBD, such as the 'grey' plants mentioned above. There is awareness of new plants coming in to cultivation but restrictive Material Transfer Agreements mean that these plants remain wholly within the botanical garden network. This has ended to a greater extent the exchange of plants between botanic gardens and horticulture in the UK.

The sense of threat or scepticism seems to have arisen from a failure of both parties to engage, or even in reality, to fully understand each other. Even for those in horticulture aware of the evolving nature of CBD find it difficult to represent their views and contribute to the process, either through the lack of a forum for this to take place, or due to a lack of resources. Not only should it be possible for, it is also desirable that gardening and horticulture work within the ABS regime. There are real opportunities for benefits in kind to be provided to source countries through capacity building and training. Indeed pilot schemes for this have been run in the UK, although these have not yet resulted in any visible flow of new plants into horticulture. These issues were highlighted in the Growing Heritage Action Plan (2007) which sets out key actions for the development of the conservation of cultivated plants in the UK.

Conclusions

In conclusion, to encourage gardening and horticulture to support and work within the CBD and specifically the ABS regime, a mechanism needs to be found for more effective engagement with the CBD process. There also needs to be a greater recognition of the actual and potential benefits for *ex situ* conservation which gardening can provide, which should, in turn be reflected in the way the ABS regime is applied to gardening. However, gardening and horticulture need to demonstrate what they can do to return benefits to source countries and show that they respect the custodianship by those countries of their genetic diversity. Arising from this, it is hoped that a new partnership with Botanic Gardens can be developed.

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Non-commercial research and the ABS Protocol: what next?

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Keywords

ABS Protocol negotiations, access and benefit-sharing, certificates of compliance, Convention on Biological Diversity, DNA barcoding, genetic resources, model agreements, non-commercial research

Abstract

Countries worldwide will decide on adopting the draft Protocol on Access to Genetic Resources and Benefit-Sharing at the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity in October 2010. Public research representatives are asking Parties to consider simplified access procedures for non-commercial research. The challenge for this very diverse sector, which includes many botanical gardens, is to convince Parties that such research can be clearly distinguished from commercial research, and that material accessed for non-commercial purposes will not later be used commercially, without the original providers' consent for the new use. A key distinguishing factor is the treatment of information: non-commercial researchers share it publicly, while commercial sectors tend to withhold it. However, there are also concerns about how original providers can benefit when information placed in the public domain is later used for commercial purposes. To gain trust, researchers must show that they do obey national laws, do keep track of material and do share benefits directly with countries of origin, not only global benefits for the international scientific community. Measures in the draft Protocol that will affect botanical garden research include monitoring and reporting requirements, possibly using a 'certificate of compliance' with national rules. Other measures include model legal agreements, codes of conduct and best practice standards, and awareness-raising measures such as help desks. Ultimately it is vital for gardens to keep informed about the issues, to share their concerns and successes with their national policymakers, and to continue to work in benefit-sharing partnerships.

A new access and benefit-sharing Protocol

Countries and biodiversity stakeholders worldwide are embroiled in final negotiations to develop a new international regime under the Convention on Biological Diversity (CBD) to govern access to genetic resources and benefit-sharing (ABS). The talks are due to end in October 2010 at the 10th meeting of the Conference of the Parties to the CBD (COP10), with the adoption of a Protocol on ABS containing legally-binding and voluntary measures. The call for an ABS regime came from the World Summit on Sustainable Development in 2002. The voluntary Bonn Guidelines (adopted earlier that year) were not thought strong enough by many biodiverse developing countries to compel users to share benefits and stop 'biopiracy', or the misappropriation of genetic resources (use without the consent of, or benefit-sharing with, the provider). The new Protocol is intended to provide a more coherent framework for ABS, with tougher compliance measures, to ensure that providers' ABS laws are followed once genetic resources leave their countries of origin. It will require significant action by the users of genetic resources and their governments. Its success will depend on whether or not Parties can agree on practical and affordable measures that will deal with misappropriation but not stifle the collaborative research and innovation that generate the benefits to be shared.

Botanical gardens are key players because of their holdings and links to countries of origin and a range of research sectors. Many gardens are actively involved in non-commercial research, in areas such as taxonomy, ecology and practical conservation. This paper examines how, in particular, the non-commercial research sector has been participating in the talks, and introduces some of the most relevant measures in the draft Protocol.

Negotiators widely recognise that non-commercial biodiversity research is critical for CBD implementation, and institutional resources are limited, but there is no clear consensus about how the ABS Protocol should handle such research. The main concern is how to ensure that material does not change uses without provider consent. Material collected for non-commercial use can end up being used for commercial purposes, whether through unanticipated discoveries by the original researchers, transfer to commercial users, or commercial use of information in public databases or publications. Clearly the ABS Protocol should enable law-abiding researchers to work and share benefits, but providers fear that if access for non-commercial use is made significantly faster, cheaper and/or simpler, all users will aim for that route, and material may slip into commercial use without provider authorisation. Also, a simpler or faster process might not give indigenous and local communities enough involvement in decision-making.

Compliance issues for non-commercial researchers

Currently, though ABS awareness and experience is growing in the international scientific community, and some botanical gardens in particular are regarded as models of appropriate behaviour, researchers do not always fully follow countries' laws or ABS good practice. Some compliance issues include not getting all the right permits, not engaging with local communities, not sharing appropriate benefits, using or passing material to others without checking the provider's terms, and releasing information to the public domain without provider consent. But even ABS-aware researchers are finding that many countries' new ABS laws are confusing and cumbersome (e.g. see Kamau 2009). ABS is especially challenging when traditional knowledge is involved, as the process of gaining consent from indigenous and local communities can be very complex and the public dissemination of research results is particularly problematic. The rise of DNA barcoding is bringing many concerns into focus, as projects require the legal acquisition and transfer of millions of specimens between countries, and researchers must ultimately convince providers worldwide that they fully benefit from global information-sharing, and that benefits from future commercial use of data and tools can also be shared.

Participation in the ABS talks

Research institution representatives regularly take part in ABS meetings, independently or from within government delegations. However, until recently there has been no coordinated input to the ABS talks. The numbers of institutions and transactions involved in DNA barcoding have provided a major new impetus for involvement. The Consortium for the Barcode of Life, with other research and funding organisations, organised a workshop on ABS and non-commercial research in November 2008 (CBOL et al., 2008). It was timed to offer input to two CBD-convened expert meetings that provided technical and legal advice to the final negotiation rounds. The first expert meeting (CBD, 2008) explored problematic terms (e.g. 'derivatives' of genetic resources) and how different sectors use genetic resources. The second expert meeting (CBD, 2009) dealt with compliance issues, including whether to develop special measures for non-commercial research and how to deal with changes in use, and also looked at current voluntary measures. (A third expert meeting tackled traditional knowledge issues, but did not directly involve non-commercial research.) An ABS Business and Science Dialogue (convened by the United Nations University/Institute of Advanced Studies in December 2009) provided an opportunity for representatives from industry and science to exchange ideas with CBD negotiators. Two research representatives also participated in a 'Friends of the Co-Chairs' (of the ABS Working Group) meeting in January 2010. And 'Public Research' now has two seats at the Inter-regional Negotiation Group (ING) table, allowing representatives to provide guidance to the meeting. This is an unprecedented opportunity, though like industry and civil society representatives, they can only propose text through Parties. The ING will meet again in mid-September to resolve outstanding issues.

Simplified rules for non-commercial research?

The central proposal from the non-commercial research sector is that there should be simplified access procedures for non-commercial use. Since the same institutions and technologies and even researchers can be involved in both kinds of projects, we need to be able to distinguish non-commercial from commercial uses so that changes can be recognised. The ABS workshop described several 'communities of research practice' that are not usually involved in commercial research, and suggested that the major way in which their projects differed from commercial projects is how they willingly commit to putting their results in the public domain through data release and publication, sharing benefits globally.

The expert group on terms and sectors described a list of typical uses and explored differences between sectors and, like the workshop, agreed that willingness to share information was a specific characteristic of the non-commercial research sector. The expert group also pointed out that many commercial sectors need access for basic research before developing value chains, and that they mainly source material from *ex situ* collections and intermediaries. Unfortunately for the public research community, those points make it more difficult to argue for simplified access, though researchers highlighted their commitment to following laws and codes of conduct and using standard agreements that require benefit-sharing and provider consent for new uses.

The compliance expert group considered two possibilities for countries: simple access for both uses, with strong remedies and sanctions, or a more streamlined process for non-commercial use, using mutually agreed terms to address any later change in use. However, this group generally considered that each country should decide whether to adopt simplified procedures. The Business and Science Dialogue participants noted the danger of creating loopholes by treating non-commercial research differently, and suggested that for legal certainty the ABS Protocol should cover the whole chain of ABS, including intermediaries. At the most recent round of ABS negotiations (July 2010), the research sector emphasised its commitment to complying with the Protocol and gained support for simplified procedures, but there is not yet a consensus.

Paradoxically, problems may loom for the non-commercial research sector because of its self-defining characteristic: public sharing of information. This is a growing concern for some providers, who fear loss of control because increasingly data, not samples, are transferred between countries, then published and sometimes later mined by others for commercial benefit. The challenge is to find ways to share information for the public good that will also enable original providers to retain some control and receive benefits from downstream use. Licensing schemes such as the Science Commons may help to enable broad information sharing with links to providers and mutually-agreed terms.

Measures in the draft ABS Protocol

Though the talks are due to end soon, the treaty text is not yet finalised, and some critical issues for institutions are unresolved, such as whether the Protocol will cover new uses of pre-CBD material. Compliance is at the heart of the Protocol. Most developing countries are pushing for strong monitoring and reporting requirements, based on mandatory ‘certificates of compliance’ to accompany genetic resources (and possibly their derivatives), to show provider consent has been gained and terms have been agreed, and a web-based ABS Clearing House. The certificates would contain certain minimum information and a tracking code. A checkpoint system would ensure certificates have been obtained. Proposed checkpoints include patent offices, but also public research institutions and science publishers. Such a scheme would obviously have tremendous impact on researchers and collections – though if it were well-implemented it might compare positively to current processes for getting multiple permits, and create greater legal certainty for collections. A number of developed countries are attempting to remove detail on certificates and checkpoints from the Protocol at this stage to allow for further consideration of the considerable challenges, possibly during the Protocol’s implementation phase.

The voluntary measures in the draft are generally very positive for research. ‘Model contractual clauses’ for different sectors should help to bring down the difficulty and cost of setting up legal agreements between providers and users. The Swiss Academy of Sciences is already working on a draft model agreement for non-commercial academic research. The draft Protocol also suggests a clear role for best practice standards and codes of conduct – already widely used by gardens. The draft treaty text proposes that codes and standards should be updated and that the meeting of the Parties to the Protocol should periodically take stock of codes and model clauses, so botanic gardens and research institutions will need to keep track of ABS developments. Awareness-raising has its own article in the draft Protocol, and the suggested measures for Parties – most particularly the establishment and maintenance of help desks – would provide invaluable practical help for researchers. We must urge our governments to take these actions.

What next?

Non-commercial research has a coordinated presence at the negotiation table – and the Protocol will only be a workable instrument with our participation (see Martinez, 2010). People wishing to provide specific input on the draft should contact their ABS national focal points and also the Global Taxonomy Initiative coordination mechanism steering committee and BGCI. Meeting updates will be posted on the BGCI ABS web pages.

The research community’s credibility at the ABS talks is only as good as our commitment to complying with the Protocol, national laws and best practice, so we must keep working on ABS basics at home: using codes and guidelines (such as the Principles on ABS and the International Plant Exchange Network’s Code of Conduct), developing an ABS policy, getting the right permits and consents, keeping track of terms and using material as terms allow, and most importantly, working collaboratively and sharing benefits (see checklist in Davis, 2008). We also need to build sturdy two-way relationships with our ABS national focal points – to help our governments to understand practical issues and to design workable measures, and to ask for their assistance and support for our compliance.

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A window on the unique and fragile New Caledonian flora and habitats

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Abstract

On the occasion of the complete refurbishing of the National Natural History Museum (MNHN) facilities for the tropical plant collections, a New Caledonian glasshouse (Serre de Nouvelle-Calédonie) has been created. The implication of the past and current MNHN research teams in the study of the Flora of New Caledonia and the strong collaboration between the MNHN and New Caledonian Institutions have guided the choice of this new thematic. The new glasshouse is a showcase to present the unique and fragile New Caledonian flora and habitats through five distinctive ecosystems: the rainforest, the dry forest, the mine maquis, the savannah and the mangrove. It has become a public information platform on the conservation and research activities and programmes of the Museum and collaborating institutions, particularly the programme for the conservation of dry forests. An original scenography completes the plant and landscape presentations.

Keywords

Biodiversity, Conservation, Endemicity, Glasshouses, Handicapped public, New Caledonia, Renovation, Scenography.

Presenting the flora and habitats of New Caledonia

On the occasion of the complete refurbishing of the National Natural History Museum (MNHN) facilities for the tropical plant collections, a New Caledonian glasshouse (Serre de Nouvelle-Calédonie) has been created. The implication of the past and current MNHN research teams in the study of the Flora of New Caledonia and the strong collaboration between MNHN and New Caledonian Institutions and Conservation programmes (IRD, IAC, Maison de la Nouvelle-Calédonie and Programme de Conservation des Forêts Sèches de Nouvelle-Calédonie) have guided the choice of this new thematic.

A necessary renovation and opportunity for defining new targets

The New Caledonian collections are housed in one of the two superb metal and glass pavilions designed by Charles Rohault de Fleury, and built from 1834-1836. They are sited in the heart of the Jardin des Plantes in Paris.

The renovation project was not only the occasion to improve the security and the access of the Great Glasshouses of the Jardin des Plantes (Joly *et al.,* 2010) but it created the opportunity to redefine the conception and the thematics. Before the renovation, the New Caledonian glasshouse was the home of Mexican plants and xerophytes from arid land. In the contiguous glasshouse, a large art-deco building erected in 1936-1937, the presentation of various tropical plants has been enriched and is now dedicated to the vegetation of the Tropical Rainforest.

Furthermore**,** two other glasshouses have been opened to the public. In the second Rohault de Fleury's pavilion, the former collection of Australian, New Zealand and South

African plants has been replaced by plants from very ancient families and fossil casts of extinct groups and is now devoted to the history of plants. The long gallery which was used for multiplication, care and storage has become the glasshouse of desert and arid land plants.

New Caledonia, an archipelago with an exceptional endemicity

Discovered by James Cook in 1774 and situated in Oceania, New Caledonia is composed of the islands of Grande Terre, Ouvéa, Lifou, Tiga and Maré, the Archipelago of Belep, Ile des Pins and a few remote islands. Attached to France in 1853 and part of the French overseas territories, the statute of New Caledonia was redefined in 1999 on the basis of the Noumea Agreement (1998) which increases its autonomy.

With exceptional endemic flora and fauna species and natural habitats (Violette, 2009; Joannot, 2008; Jaffré *et al*., 2001; Jaffré & Veillon, 1994), it is the smallest of the hotspots of biodiversity in the world. The lagoons received a UNESCO recognition as an *exceptional heritage* on 7th July 2008 under the name “Lagoons of New Caledonia: reef diversity and associated Ecosystems” for their exceptional natural beauty and diversity of coral and fish species, a continuum of habitats from mangroves to sea grasses.

With an area of 18,575 km^2, New Caledonia (NC) is the home of 2,430 endemic species (76% of the flora), five endemic families: Amborellaceae, Oncothecaceae, Paracryphiaceae, Phelliniaceae, Strasburgeriaceae, and 108 endemic genera among which are *Arthroclianthus, Austrotaxus, Beauprea, Codia, Pancheria, Strasburgeria*, etc. It claims the world's only parasitic conifer (*Parasitaxus ustus*) and nearly two-thirds of the world's species of Araucaria trees, all of which are endemic.

The threats to this unique flora are numerous: fires, land development exploitation such as intensive nickel mining, forest destruction and the spread of invasive plant and animal species to count but a few.

Five contrasted ecosystems

The new glasshouse is a showcase to present the unique and fragile New Caledonian flora and habitats through five distinctive ecosystems: the rainforest, the dry forest, the mine maquis, the savannah and the mangrove. Characteristic species, mostly endemic, come from the MNHN plant collections, have been shipped by air from the archipelago, or have been provided by the Royal Botanic Gardens Edinburgh and Kew and the Paris Auteuil greenhouses. The plants have been installed in the five different habitats and are now growing well. In addition, this glasshouse has become a public information platform on the New Caledonian conservation and research activities and programmes of the Museum and collaborating institutions, particularly the “Programme de Conservation des Forêts Sèches” (PCFS). An original scenography completes the plant and lansdcape presentations.

1. The humid forest

The humid forest is a paradise for botanists, counting around 2,000 plant species, with 82% endemics. Its covers an area of 4,000 km^2 (21% of the archipelago) and receives 1,500mm annual rainfall. Conifers, palms, tree ferns and orchids are characteristic elements of the flora, most of them endemics, along with many trees and shrubs, herbs, mosses, lichens, epiphytes and parasites. The humus and root system holds the soil (acid, *ultramafic* or limy), an essential role against erosion.

Iconic species include the shrubby *Amborella trichopoda* (Amborellaceae), already present for 140 million years, and thought to be the most ancient flowering plant on the planet. The Kagu bird, the emblem of the country, whose song is a sort of high pitched bark, is a vulnerable species as it doesn't fly and it is the only surviving bird in its family.

Araucaria, Agathis and some other conifers and tree species come from the MNHN collections and from other botanic gardens. Most other species have been introduced from New Caledonian nurseries: palms (*Alloschmidia glabrata, Cyphophoenix elegans, Kentiopsis* spp…), tree ferns (*Cyathea intermedia*), trees and shrubs from several families: Araliaceae, Cunoniaceae, Hernandiaceae, Myrtaceae, Pittosporaceae, Rubiaceae...

2. The dry forest

The 'sclerophyllous' or dry forest receives less than 1,100mm annual rainfall and comprises more than 450 plant species, with no palms, no conifers, few orchids but a wealth of remarkable plants with rare, ornamental and medicinal species. 57% are New Caledonian endemics and 13% are dry forest endemics. A rich but understudied fauna with insects, birds, reptiles and gastropods (*bulimes*), with numerous endemic species also live in this unique formation.

The dry forest is one of the most threatened ecosystems on the planet (Gillespie & Jaffré, 2003), only remaining in a surface area of 50 km² (1% of its original size!). Today it is very much reduced and fragmented due to human activities (fires, firewood) and the establishment of introduced species (invasives).

An ambitious conservation Programme of Dry Forests (Programme de Conservation des Forêts Sèches de Nouvelle-Calédonie, PCFS; Gunther/IAC, 2004) was implemented in 2002 to inventory, preserve, restore, enhance and manage sustainably the remnants of dry forests now considered as ecological, patrimonial and economical treasures.

Some characteristic species are planted in the glasshouse, such as: *Pittosporum tanianum*, a very rare species that has been saved from extinction, and many other *Pittosporum* species (*P. brevispinum, P. cherrieri, P. coccineum*...), *Terminalia cherrieri*, one of the dry forest's tallest tree, *Turbina inopinata,* a vine with pink trumpet flowers, *Ixora (Captaincookia) margaretae,* a rare and small monocaulous and cauliflorous treelet with abundant pink flowers, and also other botanic treasures such as *Arthroclianthus sp., Oxera pulchella, Oxera sulfurea, Jasminum spp.* and the New Caledonian endemic rice, *Oryza neocaledonica.*

3. The mine maquis

It spreads over 4,500 km² (24% of the archipelago) and receives 800 to 4,000mm annual rainfall. The mine maquis hosts 1,200 plant species with an exceptional endemicity rate of 90%!,

It is made of slow growing, shrubby, and herbaceous species. This is a result of the repeated fires and the slow destruction of the humid forest. This vegetation grows on *ultramafic* soils, rich in nickel, chrome, iron, and cobalt forming a unique vegetation, essential against erosion.

The soil shows low levels of water, azote and phosphore and high concentrations of minerals toxic to plants. Remarkable adaptations and even nickel accumulation are observed in some maquis species like the beautiful tree *Geissois pruinosa* (Cunoniaceae*).* The rehabilitation of sites destroyed by mine exploitation uses such species, which also help to detoxify the soils.

The mine maquis is home of unique conifers like *Retrophyllum minor,* the 'bois bouchon' a species with a very light wood, *Neocallitropsis pancheri*, *Araucaria muelleri* and the very rare *Dacrydium guillauminii.* Some other very characteristic families are represented in the glasshouse including the Myrtaceae (*Xanthostemon laurinus, Sannantha leratii…)*, the Proteaceae (*Stenocarpus milnei*, *Beauprea spathulaefolia…)* and the Cunoniaceae (*Geissois pruinosa*).

4. The savannah

The savannah spreads over an area of 6,000 km² on the North and West coast of Grande Terre (31% of the archipelago) and includes 130 plant species representing 6% of endemic species. It receives about 1,000mm annual rainfall. It is a secondary formation resulting from the degradation of the humid and dry forests, after fires. The 'niaoulis' *Melaleuca quinquenervia* (Myrtaceae) are emblematic trees of the savannah while invasive plants like *Lantana camara, Psidium guajava, Leucaena leucocephlala* and the 'gaiac' *Acacia spirorbis* are locally well developed. Some orchids are found like *Spathoglottis vieillardii (S. plicata).*

The wild pigs, rats and goats are also threatening the equilibrium of the natural environments and local biodiversity, as well as the electric ant *Wasmannia auropunctata.* The deer *Cervus timorensis russa*, introduced in 1870 is a pest for forests and cultivated ground. It is now part of a monitoring programme.

5. The mangrove

The mangrove covers 200 km² (1% of the archipelago) and receives 1,000mm of rain per year. It is formed of very few (about 20) tree or treelet species which form large populations. This ecosystem constitutes a wealth of biodiversity where birds, fishes (260 species inventoried) and crustaceans abound. It is highly threatened by urbanization and mining pollution. Some species are used by the local populations, such as the bark of *Bruguiera*, rich in tannins, which is used to paint the hairs of the great bats used in the local ceremonies.

Sonneratia alba, Bruguiera gymnorrhiza, Avicennia marina, Rhizophora apiculata and some other characteristic species are shown to the public, despite difficulties in maintaining the necessary environmental conditions for their cultivation.

A link with the MNHN studies and conservation projects

For more than 150 years the MNHN botanists have highly contributed to the knowledge of the New Caledonian flora and habitats, enriching at the same time the Paris Herbarium and publishing the 'Flore de la Nouvelle-Calédonie' and many other articles. MNHN is pursuing taxononomic studies on the archipelago's flora (e.g. in the Fabaceae genus *Arthroclianthus*) and on the biodiversity of fish and corals. The new glasshouse has created an opportunity for the MNHN researchers to participate in the pedagogical project and present their research to the public.

It has also strengthened a collaboration with people engaged in conservation actions on the New Caledonian flora and endangered habitats like the 'International Conifer inventory and conservation programme , ICCP' initiated by the Royal Botanic Gardens Edinburgh, the 'Programme de Conservation des Forêts Sèches de Nouvelle-Calédone' and other local initiatives such as mangrove preservation.

Scenography and educational targets

Presenting the New Caledonian Flora to the public on a small scale was a real challenge, the landscaping and the selection of species should provide a good evocation of the New Caledonian habitats. Additionally, the scenography highlights specific aspects of the local environment of each relevant habitat:

- the humid forest: with a focus on endemism,
- the dry forest: on plant richness and extreme threats
- the mine maquis: on exploitation (mines), soil degradation, endemism and exceptional plant adaptations
- the savannah: on biological invasions, transitions and degradation of habitats
- and the mangrove: on the importance of the fauna and environmental threats

A steel *vine*, integrated in the presentations, is the conducting thread that supports the information. It is completed by high definition large screens that display a selection of photos of New Caledonian plants. An innovative technology simulating plant growth on small screens applied to three New Caledonian plants has also been developed in collaboration with a French scientific team specialised in plant architecture.

The glasshouse scenography and plant presentation have also given us a unique opportunity to demonstrate the very strong links existing between the New Caledonian population (especially the Kanaks) and nature. Other aspects of their very rich culture are represented with totems, Kanak designs and architectural features. These presentations have been made possible through the expertise and financial support of the 'Maison de la Nouvelle-Calédonie' in Paris and the Political Authorities of New Caledonia.

Conclusion

2010, the International Year of Biodiversity, has been the perfect timing for reopening the glasshouses of the Jardin des Plantes of Paris and redefining the thematic. These significant developments better serve all our public including the handicapped, and embrace new ways of communication to emphasize the new commitments of the Institution towards the preservation of biodiversity. The New Caledonian glasshouse, in particular, is emblematic since it concentrates all these different aspects in one volume and attempts to sensitize the public to the exceptional biological richness and the crucial environmental problems affecting this unique territory. In this project, the research and conservation initiatives have not been forgotten**.**

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The Ethiopian Flora Project: Lessons learnt

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Abstract

The Ethiopian Flora Project was initiated in 1980 as bilateral agreement between the Ethiopian and Swedish governments and implemented through Addis Ababa and Uppsala Universities. There was an international support from many institutions, but the major ones include the Royal Botanical Gardens, Kew, UK; the Universities of Copenhagen, Denmark; Oslo, Norway and Uppsala, Sweden. By the end of the project, all the intended 10 volumes of the Flora of Ethiopia and Eritrea covering the ferns and gymnosperms and all flowering plants with ca. 6,000 species were published. During the Flora Project the herbarium collections grew from 18,000 in 1980 to over 80,000 in 2009. The success of the Project was mainly due to the involvement of local expertise in the flora writing, and the publication of the Flora locally, that reduced the cost of publication which in turn encouraged institutions and individuals to buy and use these publications. The project was planned for 15 to 20 years when it was initiated in 1980, but took nearly thirty years to complete (in 2009). This was due to the fact that some contributors did not provide the contributions on time as planned. In the future there is a need to digitize the 80,000 or so specimens at ETH - that requires support, and to avail the Flora electronically - that requires permission to do so by Addis Ababa University.

Keywords

Flora of Ethiopia and Eritrea, overview, lessons learnt

Introduction

The Ethiopian Flora Project (EFP) was initiated in 1980 as a collaborative project between the Universities of Addis Ababa, Ethiopia and the University of Uppsala, Sweden. The leaders of the project were Prof. Tewolde-Berhan Gebre-Egziabher on the Ethiopian side and Prof. Olov Hedberg with Prof. Inga Hedberg on the Swedish side. Over the years the project received international support from many institutions, the major ones including the Royal Botanic Gardens, Kew, UK; the Universities of Copenhagen, Denmark; Oslo, Norway and Uppsala, Sweden (Sebsebe Demissew, 2006a, Hedberg, 2009).

Objectives of the Ethiopian Flora Project

1. Write up a Flora of Ethiopia within the shortest time possible;
2. Build-up a National Herbarium and a related library to be used as reference centres for pharmacognosists, agriculturists, foresters, wild-life specialists, etc. and
3. Promote scientific activities in taxonomic botany, economic botany, forestry, plant ecology, plant physiology, etc. through training

1. Write up a Flora of Ethiopia within the shortest time possible. At the start of the project, the leaders of the project felt the need for training of nationals before embarking on the writing of the Flora. Thus the initial phases of the project were mainly devoted to the training of nationals (Table 1) and the preparation of the first volume to be published.

Deneen Powell Atelier, Inc. (DPA) - Educational Garden Design

Special Note

Our paper is best told through multiple images and graphics. In our work, the written word is a supportive element of our educational garden designs. By no means are signs and copy the focus or the critical element. The gardens themselves and the artistic supportive elements are the primary focus of the educational message. This same concept holds true for this paper. It is best told visually with support copy adjacent to the images. We invite you to view the entire presentation with corresponding support images at the following. Thank you.
http://www.dpadesign.com/Ed_Garden_Design.html

Abstract

As the leading designers of water conservation and sustainable tutorial gardens - including the Desert Living Center (DLC) at the Las Vegas Springs Preserve, The Conservation Garden Park outside Salt Lake City, Utah and The Water Conservation Garden in Southern California - Deneen Powell Atelier, Inc. is fully versed in teaching water conservation and sustainable landscape design on an informative, easy to understand, yet entertaining level. Normally water-conserving and sustainable landscapes are believed to be rocks and cactus, but these gardens are lush and colourful. DPA organizes the educational gardens into teaching topics - design, planting, irrigation and maintenance. We utilize native plants as well as plants naturally adapted to their particular climates to create botanical garden gems.

Unique features include whimsical icons, artistic signage, comfort/gathering spaces and amphitheatres with hands-on opportunities for children and adults. Good planning helps set sustainability components firmly in place. Artistically handling these components initiates a desire to learn.

Keywords

Deneen Powell Atelier, Inc., Design, DPA, Educational Garden Design, Immersion Design, Sustainable Gardens, Sustainability, Tutorial Gardens

DPA Specialty - Immersion Design

Immersion Design is the creation of space with a comprehensive and interactive approach, utilizing visual clues, subtle messages, sculptural reinforcements and architectural enhancements to influence the visitor’s natural experience. We develop curiosity while educating through landscape and art. Whether the space is a quiet respite or an interactive revelry, we engage multiple senses with multi-level learning techniques to create beautiful, entertaining spaces and the desire to learn and return.

This is accomplished by combining several different but related professional fields. Our principals and staff are educated and trained in the following disciplines - landscape architecture, architecture, advertising and marketing, environmental graphic design, interpretation, and sculpture. We immerse and educate through a range of techniques in multiple layers.

The Process

DPA begins planning the visitor experience with the overall design of the site.

The design process begins with client meetings, site analysis, related research, etc. to gather as much background information as possible. After this process we begin bubble diagramming. We design the gardens much like you would write a book. First a basic outline, selecting the major topics or "chapters" then determining how these "chapters" relate and interact with one another while keeping in mind site grading issues, best entry and exit points, parking lot placement, maintenance requirements, road access, etc.

Once the garden has been organized into the main "chapters", we continue by designing the "subjects" that relate to these and design how they will interactively and visually teach. As this process plays out we pay close attention to reality, creating ADA access, planning for maintenance, events, etc. Each of the "subjects" is then illustrated in plan and elevation. These are wonderful tools for clients and donors.

The Water Conservation Garden, near San Diego, California, U.S.

This is the entry to the Water Conservation Garden near San Diego, California in the U.S. As this is a teaching garden, you literally walk through a living textbook, experiencing, seeing and interacting with the lessons.

Within view of the entry are 11 different teaching elements. These elements are interesting, engaging, attractive and educational.

San Diego is a desert. Over 90% of the water comes from thousands of miles away and is located literally at the end of the water pipeline. This sculptural main entry feature is a giant water pipe protruding from a hillside. A tiny trickle of water drips from its depths and a fine mist floats through the air. Seeing this literal expression reinforces the dire need to conserve water.

Whimsy plays an important role in this water conservation, sustainable garden. Such a "dry" subject needs a little drama to engage visitors. DPA designed iconic pencils for the design area, shears for the maintenance area, and a pop-up head for the irrigation area. These icons signify the entry into each "chapter" of the garden.

We utilize countless ways to relay messages. Here we cast images into the concrete and had fun with shadows too.

Signage is designed sculpturally and specifically for each of our projects. These signs are designed in layers. Quickly read, fun titles describe the exhibit; the light colour leaf feature sketch renderings and short captions; and the dark green, recessive colour panel tells the in-depth story. The signs also act as wayfinding elements. Gardens are continuous and it can be somewhat difficult to recognize one educational display from another, so these also serve to mark an exhibit.

At The Water Conservation Garden in San Diego, there are 36 different outdoor exhibits that fall under the categories of Design, Maintenance and Irrigation. In Design, there are several exhibits on how to design a landscape. In addition to "How-To" exhibits we also included specialty garden exhibits to show homeowners a few of the endless garden styles. This is a formal garden layout with pollarded *Lagerstroemia indica* (crape myrtles) set in a grid of different colour mulches to accentuate the pattern.

How many times have we heard “don’t step on the grass”? The exhibits are designed to be hands on but this gentleman was concerned, so he looked around first to see if anyone was looking before he finally stepped right on the grass, little did he know he was being photographed.

This exhibit in the Maintenance area shows how to properly stake and guy trees. Knowing that using living trees would become an incorrect lesson very quickly, we used dead trees painted in crazy colours.

Within the Irrigation area is a fountain exhibit displaying a spray irrigation system. Popup heads calliope up and down to demonstrate full, half and quarter head coverage.

Also within the Irrigation area is an exhibit on how weather effects irrigation. DPA designed a sculptural weather vane to introduce this subject. It has wind chime raindrops, lightning bolt supports, patina clouds and a cow that swings through the moon.

As you continue to view these gardens, please note the consistent use of fonts, materials, colours, etc. These are the marketing and graphic design elements incorporated into the overall design. Cohesiveness and consistency are key components to the design and ease learning curves.

This exhibit utilized recycled water pipe as bins to display mulches. Dig in with your hands to see, feel and smell the differences.

We also included many areas for events and repeat visitation to pull in visitors that might not otherwise be interested in visiting a conservation/sustainable garden. This amphitheatre showcases different ground covers.

The children like the garden as a whole, but we’ve also included special children’s activities and information within the entire garden.

As previously mentioned within these educational botanical gardens, the plants are the main focus; art, sculpture and signage step back into the landscape when viewed from a distance but stand out when appropriate.

The Desert Living Center at The Las Vegas Springs Preserve, Certified LEED Platinum, Las Vegas, Nevada, U.S.

This is a very constrained, hourglass shaped site; one side has an archaeological site and the other a 10 million gallon water reservoir. We worked hard on the design so visitors never feel the pinch point.

After a thorough study of local nurseries DPA found that well over 90% of their stock was not climate appropriate or water conserving plants, so we researched at length to locate and source over 1200 different plant species that grow in this harsh desert climate to force nurseries to change.

DPA designed a tightly controlled visitor entry into the Desert Living Center (DLC) and exit without the need of directional signage. We funnel guests while offering teaser views into the garden.

The large main orientation plaza is centred within the desert region.

Careful attention was paid in design to make sure all views of and within the garden are attractive, eliminating unsightly back of house views. Shown is the secondary back entrance into the gardens. Working very closely with the project architect our site features match exactly to the facility architecture.

One of the most significant sustainable features in this garden is the Constructed Wetlands Machine. Here all the wastewater from over 45,000 square feet of building is captured and directed through these wetlands where plants clean and filter the water for reuse for irrigation and flushing toilets.

Desert wetlands are a vital, natural feature in the Las Vegas area. Although our site actually traverses up hill in some areas, as well as over pipes, vaults, etc, as this is a working water district site the gardens appear to flow downhill creating the “natural” wetlands feature.

At the end of the wetlands is a teaching node for school groups to test the water to see just how incredibly clean it is.

Whimsy also played a key role in this garden. Several teaching nodes/visitor comfort areas/storage facilities were included in the garden. A small amphitheatre flanks the watering can kiosk with irrigation parts as decorative architectural features.

Tool Shed teaching node/visitor comfort area/storage facility.

The small teaching amphitheatre was designed into the gardens for programmes and located adjacent to the resource library.

Another major sustainable site component are our solar trees designed to capture the energy needed to light the garden at night.

Within the maintenance area of the DLC are sculptural tool and pest control display walls.

A large chequered pattern of hardscape design ideas are included to show the limitless opportunities available.

Several specialty gardens are incorporated into the design as well. This first one is a teaching kitchen garden, the Library Garden adjacent to the Resource Room, the Oriental Garden, and the Cactus Garden.

Las Vegas, Nevada generally experiences two months of beautiful weather. One in the spring and one in the autumn. Winters are generally windy, cold and dry. Summers are very hot and dry. Yet a huge variety of beautiful plants thrive in this climate.

This garden is open year around for visitors to see and experience the great variety of climate appropriate, water conserving plants.

The Conservation Garden Park, Salt Lake City, Utah, U.S.

Phase 2 Visitor Centre and additional gardens are on track for LEED Silver.

This view is of the site prior to beginning our garden expansion project. The Wasatch Mountains serve as a dramatic backdrop.

The Garden was designed in the same planning manner as we practice for all of our gardens.

Once the basic plans were set we also included comprehensive illustrations. These illustrations were valuable tools for both clients and donors.

The tutorial gardens begin with an overall explanation of what the garden teaches, the region's history, as well as the Seven Principles of Xeriscape.

Design styles, colours and materials are consistent throughout the gardens.

Upper Café Terrace, overlooking the Tool Shed in the How to Plant section of the garden. This photograph was taken during the Phase I opening in the spring of 2009.

Each area of the garden is introduced with sculpture and signage.

The interpretive signs are colour-coded to their overarching subjects.

The wayfinding signage is easy to understand and a fun element in the gardens.

This exhibit teaches composting. DPA fully understand that guests visit gardens in their free time so the exhibits are designed to be interactive, fun and informative. Here the composting exhibit is a "salad bowl". Guests are invited to select "ingredients" from the surrounding condiment bowls and add them to the salad and "toss", teaching the basic principles of composting.

Irrigation is often referred to as "irritation" because it seems complicated. We break down the basic elements with multiple displays on how to build different irrigation components. This basic understanding promotes educated choices when planning a for an irrigation system.

These sculptural buckets make for a great looking wall but they also invite guests to touch and feel different types of soil.

Children's exhibits are placed throughout the garden; here they have a sand box to dig in and sculptural plants to set.

Education is key in our gardens, but they're also beautiful spaces where the plants are the primary focus.

Building sustainable botanic gardens: A simple silvicultural method adopted to turn wood trees into a productive arboretum in the dry zone of Sri Lanka

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Abstract

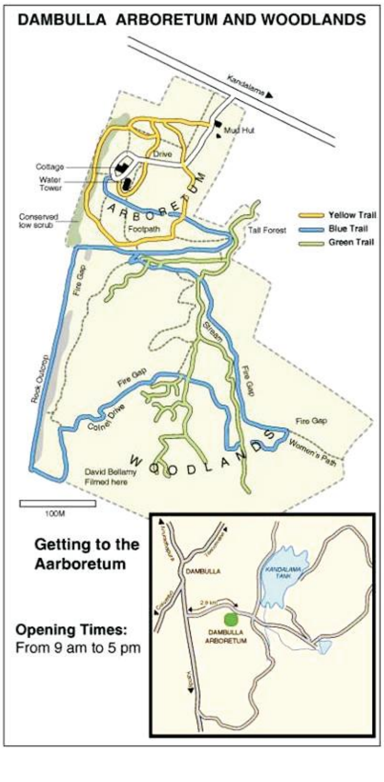
Over exploitation is the obvious phenomenon that degrades natural forest, by altering the structure and composition of the landscape. Therefore, rehabilitation and restoration of degraded forests is a most challenging task for forest managers. Under the direction of Mr. Sam Popham, an abandoned area of thorns is being turned into a field of trees such as Satinwood at the barren land in Dambulla, in the dry heartland of Sri Lanka. Efficient management of undergrowth and controlling the growth of creepers are the main silvicultural practices adopted at Popham. The policy is not to plant, but to release tree seedlings from competition and suppression by thorn scrub and creepers. This promotes re-colonization of indigenous and endemic species. Spontaneous seedlings will be released from the scrubland and encouraged to survive through childhood to adulthood. Therefore, the Popham method would be useful for accelerating natural plant regeneration towards secondary climax vegetation, while facilitating rich biodiversity compared to shifting cultivation land in Sri Lanka. This could also be adopted to degraded land in other parts of the world.

Key words : Popham arboretum, silvicultural management, Sri Lanka

Introduction

Dambulla Arboretum, which is commonly known as Sam Popham Arboretum, is unique because it harbors plenty of typical dry zone key plants. The Arboretum is situated in Dambulla (7^0 51' 34" N and 80^0 40' 28" E), which is located in the dry heartland of Sri Lanka. This is the only dry zone arboretum in Sri Lanka and a living museum, a sanctuary for tropical trees that provides refuge for wildlife.

The arboretum was established in 1963 by Mr. Sam Popham, who is an Englishman. He bought a piece of land (3.6 ha), and it was silviculturally managed to form a natural forest. In 1989 the arboretum was extended up to 14.4 ha by acquiring adjoining land, which is now called as being woodland (Fig. 1). The vegetation types covered by the arboretum were scrubland, dry mixed evergreen forests, grasslands, rock outcrops, and woodlands. This variety of habitats contributes in increasing the biodiversity of the arboretum.



Methodology

Low cost Silvicultural method / Popham Principal

The policy is not to plant but to release tree seedlings from competition and suppression by thorn scrub and creepers (Popham, 1993). It promotes desired indigenous seedlings to re-colonize, through excluding creepers and thorny shrubs from the scrubland. Once in progress, spontaneous seedlings will be released from the scrubland and ultimately would have a better chance of surviving through childhood to adulthood. Removal of excessive tillering, dead branching and pruning growing tree seedlings are enhanced to accelerate regeneration. Then positions of saplings are marked with stakes, to avoid damage from subsequent ground cleaning. Their process is monitored. The new recruits in each season are marked by different identification pegs. They help seedlings to gain height through trunk-stemming and crown-thinning (Figure 1)

Strategy behind the Popham Principal

1. **Silvicultural method manages small blocks**

The scrubland is divided into 12 blocks and at least five grass cutting rounds were implemented for a block per year. The average cost for the Popham method is US$ 143/ha/year (Dilhan *et al*., 2009). The cost for this method is comparatively very low with compared to the rehabilitation project of Bintulu, Sarawak (Miyawaki, 1993), Malaysia (US$ 15, 329 /ha/year).

Figure 1. Demonstration of Popham method: grass cutting enhances release of spontaneous seedlings from the soil seed bank

2. **Thorn and climbers are banned**

3. Growing up seedlings from the sweetest soil seed bank

Creepers and grasses in the ground may slow down the germination of seeds buried under the soil. Once these are managed, spontaneous seedlings are released.

4. Dead wood branches are chopped

Frequent slash and burn agriculture causes the formation of sick soil. Therefore, conversion of sour soil into fertile soil was vital. Mr. Popham overcame this problem by chopping down the dead wood into the soil and enhancing the accumulation of organic matter in the soil.

5. Watering the seedlings

At the initial stage watering was done.

6. Maintain fire breaks

Since local communities practice slash and burn agricultural farming, maintenance of fire breaks at the boundaries were done to prevent fire hazards.

Results and Discussion

Silvicultural management for restoration

Popham method promotes indigenous and endemic species to re-colonize the dry zone landscape and improve the biological diversity; it provides a habitat for native fauna, enhances the soil water retention properties and also decreases the fire hazards in the dry zone (Samarasinghe, 1995).

The aim of Popham method was to 'conserve', to clean but not to clear, to rid the grounds of the daunting rubbish created through the repeated slash and burn cultivation (Popham, 1985). Since grasses and competitive thorn, which occupied at the abandoned shifting cultivation land, suppress the development of tree seedlings and therefore ground sanitation through grass cuttings was adopted. Climbers were also banned because of the distortion they inflict on tree crowns (Popham, 1985). Furthermore, young trees were thinned out in overcrowded areas under the supervision on Mr. Popham. The above silvicultural practices at the arboretum boost the natural regeneration of tree seedlings *viz*., satin wood and ebony.

Significant contribution to biodiversity

Popham method facilitates the increase in richness of plants, where we documented 225 plant species comprised of 58 families. Of them; 94 were trees, 42 were shrubs, 66 were herbs, 19 were climbers and 4 were parasitic plants. Eight species were endemic to Sri Lanka (Dilhan *et al*., 2009 & Dilhan *et al*., 2006).

Biodiversity of the arboretum includes, 85 bird species comprising of 69 residents, 9 migrants and 7 endemic species. Two endemics namely jungle fowl and grey hornbill are commonly seen at the arboretum. Of the migrants indian pitta is frequently abundant during the migratory season. Diverse habitats at the arboretum are home to increasing herpatafaunal diversity comprised of 6 amphibians and 36 reptiles (Vitarana & Weerarathna, 2008). Twenty species of mammals were reported at the arboretum including grey slender loris, toque monkey (Endemic), grey langur, Sri Lanka mouse-deer (Endemic), pangolin, and spotted deer (Vitarana & Weerarathna, 2008, Weerakoon and Goonatilake, 2006). General observations on invertebrate fauna depicted that the arboretum is home to a variety of insects such as bees and butterflies. Of these, 40 butterflies including rare species *viz*., *Papilio* sp. were recorded at the arboretum (Dilhan *et al*., 2009). The stratification and the diversity of indigenous flora helped to increase the faunal diversity of the arboretum.

Conclusions

Replanting is the most widely practiced method to rehabilitate the degraded forests in the world. However, Popham method ensures colonization of indigenous seedlings, when the degraded land is managed through simple silvicultural methods. Since the method is low cost and sustainable, it is ideal for implementation as a pilot project in forest rehabilitation. Taking the model of Popham arboretum in Sri Lanka is especially useful for third world countries. This will lead to biological wealth in rehabilitated forests within a few decades.

Acknowledgements

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Diversity and geographic origin of *Gymnospermeae* represented in Russia's botanical gardens in various climatic conditions

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Abstract

The main task of the researchers includes information support for the coordination of efforts to mobilize genetic resources of plants in Russia. The analysis of collections of Russian botanical gardens encompasses: estimation of taxonomical diversity of collections in relation to the world diversity of plants; evaluation of the influence of key climatic factors on the spatial distribution of genetic resources of vascular plants. According to the Information System «Botanical collections of Russia» 474 species of Gymnospermeae belonging to 62 genera, 15 families, 12 orders, 6 classes and 4 divisions are cultivated in 67 botanical gardens. Species from the Northern hemisphere are dominant: Asia (35%), North America (25%) and Europe (8%). According to Takhtajan's Floristic Regions of the World, Conifers are represented in 29 floristic regions with the following predominance: East-Asia (22%), Madrean (10%), Circumboreal species (9%). 362 of the species grow in the open ground, 289 grow in greenhouses and 177 grow in both. We also studied the influence of minimum winter temperature, frost-free period duration and summer temperatures on collection diversity. The analysis of species according to geographical origin allows to correlate their natural habitat with the cultural one and to give recommendations for cultivation and conservation in botanical gardens.

Keywords

Botanical gardens of Russia, geographic origin, *Gymnospermeae*, influence of a climate, information technologies

Introduction

Botanical gardens are multi-functional institutions: collecting plants, they preserve them from extinction and create collections for scientific research as well as education, they create reserve banks of genetic resources of plants which are suitable for practical use in various areas; these plants are adapted to new habitats. In Russia the latter task is very relevant due to insufficient diversity of plant species valuable for household use (Vavilov, 1992) and insufficient biodiversity of plants in general (Barthlott *et al*., 2000). N.I. Vavilov's Institute of Plant Industry has been dealing with useful genetic resources since the times of Nicolay Vavilov, botanical gardens are involved in work with numerous wild species, medical and ornamental plants.

According to the data of the Information-Analytical System "Botanical collections of Russia" (IAS) (http://garden.karelia.ru) collections of the Russian botanical gardens represent more than 24,000 species and 25,000 cultivars of vascular plants (Prokhorov, Nesterenko, 2001). IAS was created for the comparative analysis of botanical collections. The analysis of collections of Russia's botanical gardens includes evaluation of the taxonomic diversity of botanical gardens in relation to the worldwide diversity of plants as well as an assessment of the effects of key climatic factors on the spatial distribution of genetic resources of vascular plants.

The Information-Analytical Center of the Council of Botanical Gardens of Russia began its work on summarizing and pinpointing prospects for the introduction of plants in Russia from representatives of *Gymnospermeae*. The analysis of the gymnosperms collections data performed by Yu Karpun, A. Bobrov and M. Romanov showed that synonyms and misspellings in cultivar names make 18 percent of the total number of taxa.

Gymnospermeae are widely spread throughout the world mainly in temperate and subtropical latitudes of both the Northern and Southern hemispheres. In Russia more than 60 species of the following genera grow in the wild: *Taxus* (2 species), *Pinus* (13), *Picea* (8), *Larix* (9), *Abies* (8); *Juniperus* (23), *Platycladus* (1), *Microbiota* (1) belonging to three families of *Taxaceae*, *Pinaceae*, *Cupressaceae* (Cherepanov, 1995). 474 species, 70 infraspecific taxa and 675 cultivars are cultivated in collections of 67 botanical gardens. 15 families are represented: *Araucariaceae, Cephalotaxaceae, Cupressaceae, Cycadaceae, Ginkgoaceae, Gnetaceae, Ephedraceae, Pinaceae, Podocarpaceae, Sciadopityaceae, Stangeriaceae, Taxaceae, Taxodiaceae, Welwitschiaceae, Zamiaceae.* 62 of 87 genera are exhibited in the collections. As for large families, it refers to *Cupressaceae* and *Pinaceae* (Fig. 1). *Pinus sylvestris* L., *Thuja occidentalis* L., *Picea ab*ies (L.) H. Karst., *Pinus sibirica* Mayr are cultivated in more than 50 botanical gardens (Fig. 2). *Larix sibirica* Ledeb., *Picea pungens* Engelm., *Picea glauca* Regel, *Juniperus sabina* L., *Abies sibirica* Ledeb., *Pseudotsuga menziesii* (Mirb.) Franco and *Picea pungens 'Glauca'* are more rarely represented in the collections.

Geographic origin of cultivated species was defined based on the Floristic Regions of the World (Takhtajan, 1986) shown in the map (Fig. 3). According to the Biodiversity Information Standards his approach is regarded as the Prior Standard (http://www.tdwg.org/). Plants belonging to a certain floristic region generally defines the climatic requirements of the species and, consequently, the possibility of its cultivation in one or other climatic conditions in the open ground or in greenhouses.

Nowadays 362 species of the collections are cultivated in the open ground, 289 species are grown in greenhouses, and 177 species are grown in both. According to the geographic origin, species of *Gymnospermeae* of East Asian and Madrean areas dominate (Fig. 4). Species of Circumboreal and Iranian-Turan areas (41) are also well represented in the open ground, in greenhouses – the area of Guyana highlands (22). Mediterranean species (13) can be cultivated in the open ground in the south of Russia, in greenhouses they can be grown everywhere.

We studied climatic preferences of the cultivated plants for each floristic area using 5 climatic characteristics: the average annual minimum temperature (HZ); duration of frost-free period (FF) – which determines the duration of vegetation, duration of sun light (SL) related to efficiency of photosynthesis, the annual number of days with temperature higher than 30C (HT) – the factor that limits the spread of frost-resisting species to the South; average temperature in July (JT) – the parameter defining intensity of vegetation for many species. **Error! Reference source not found.** gives characteristics of climatic zones as well as the number of botanical gardens in each of them.

The average annual minimum temperature and frost-free period are the most significant climatic factors for the arboreal species. Hardiness zones are determined according to Rehder, 1949 and hardiness zones maps (Plantideas.com, 2003). There are 9 determined hardiness zones from HZ1 to HZ9 in the territory of Russia (while botanical gardens are located in 8 zones excluding HZ8). HZ1 which coincides with the subarctic climate is considered to be the coldest zone; HZ9 including the Black Sea coast to the south of Tuapse is the warmest zone in the territory of Russia. Also there are 8 determined frost-free period zones (FF) in the territory of Russia (Kobisheva *et al*., 2001) which define duration of the vegetative period. Botanical gardens are located in FF3– FF8 zones.

The diagrams (Fig. 5, Fig. 6) show climatic preferences of species of Asian and North American flora. We could observe similarity of distribution of East-Asian and Iranian-Turan species which are most completely represented in botanical gardens of middle and southern latitudes. Circumboreal species of both continents are better exhibited in botanical gardens in the North of Russia in zone HZ3-HZ4, FF4 where successful cultivation of other floristic area species lacks duration of the vegetation period. The clearest preferences are represented by the species of Madrean which collections are mostly located in botanical gardens of Sochi. In this case it is difficult to define which factor is the decisive one. Species of the Rocky Mountains are quite plastic, which is natural for plants of mountainous regions; they are cultivated in many botanical gardens.

Many species are cultivated far beyond the climatic borders of their natural habitat. On the one hand, it witnesses their high plasticity; on the other hand, it speaks about the role of botanical gardens in evolution of plants. The plants cultivated in marginal climatic conditions are interesting for selection.

The goal of our future research is to define in detail climatic preferences of species which are not exhibited in collections of Russia's botanical gardens and to model climatic habitats in the territory of Russia. Botanical gardens located in a certain habitat have the biggest opportunities for successful cultivation of a species.

Our work supports the targets of the Council of Botanical Gardens of Russia to organize and coordinate research work of botanical gardens in the area of plant cultivation in various environmental conditions as well as to coordinate activities of botanical gardens in the field of conservation and mobilization of plant genetic resources.

The project supported by Ministry of Education and Science of Russia.

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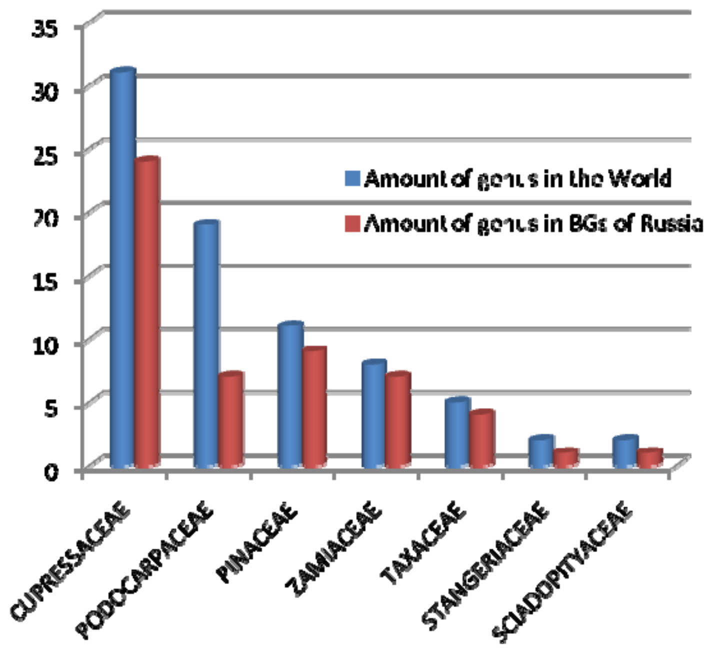

Fig. 1. Genus diversity of *Gymnospermae* in the world and in Russia

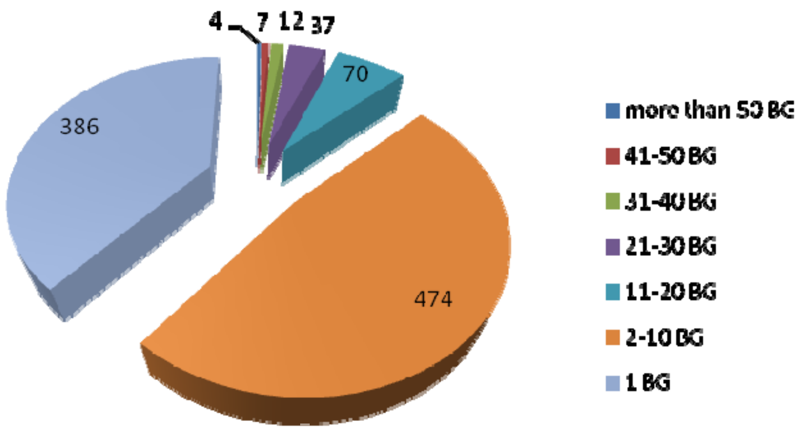

Fig. 2. Frequency of occurrence of *Pinopsida* taxa in botanical gardens (BG)of Russia.

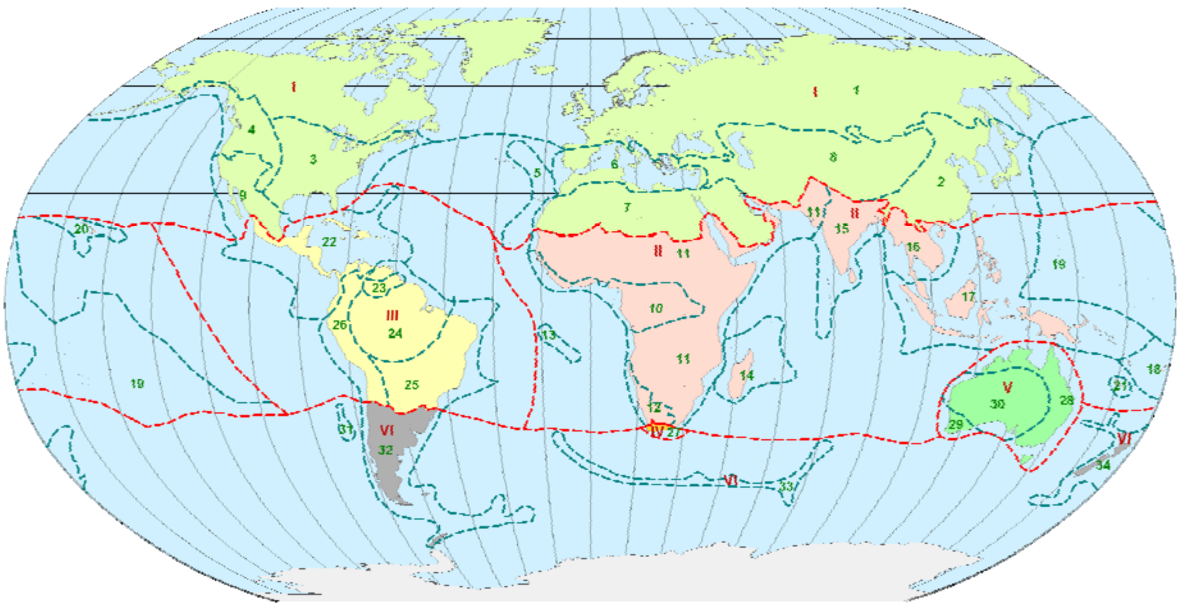

Fig. 3 Map of Froristic Kingdoms and Regions of the World (Takhtajan, 1986) in edition of the Information-Analytical Center of the Council of Botanical Gardens of Russia for GIS-analysis (MapInfo Professional 9.5)

I. *Holarctic Kingdom*: 1. Circumboreal; 2. Eastern Asiatic; 3. Atlantic North American; 4. Rocky Mountain; 5. Macaronesian; 6. Mediterranean; 7. Saharo-Arabian; 8. Irano-Turanian; 9. Madrean (Sonoran)

II. *Palaeotropical Kingdom:* 10. Guineo-Congo; 11. Sudano-Zambezian; 12. Karroo-Namib; 13. Region of St. Helena and Ascension ; 14. Madagascan; 15. Indian; 16. Indo-Chinese; 17. Malesian; 18. Fijian; 19. Polynesian; 20. Hawaiian; 21. Neocaledonian

III. *Neotropical Kingdom*: 22. Caribbean; 23. Region of Guayana Highland; 24. Amazonian; 25. Brazilian ; 26. Andean

IV. *Cape Kingdom*: 27. Cape Region

V. *Australian Kingdom*: 28. North-East Australian; 29. South-West Australian; 30. Central Australian, or Eremaean

VI. *Holantarctic Kingdom*: 31. Fernandezian; 32. Chile-Patagonian; 33. Region of the South Subantarctic Islands; 34. New Zealand

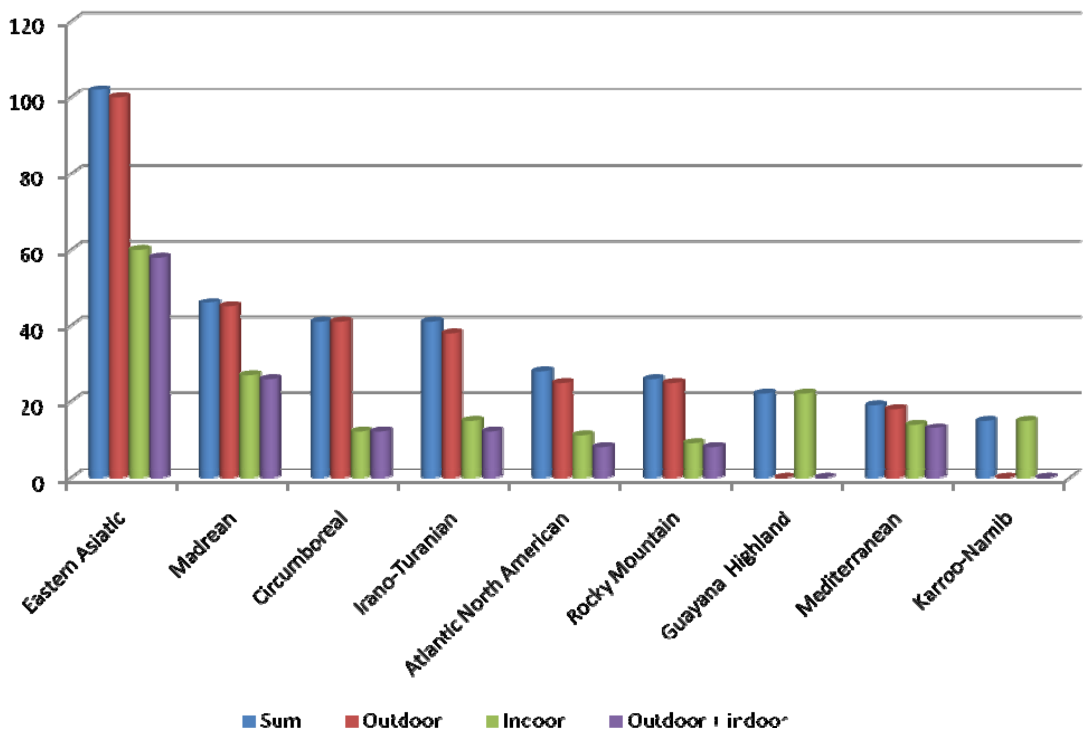

Fig. 4 The main floristic regions (Takhtajan, 1986) of geographical origin of *Gymnospermae* and their representation in botanical gardens of Russia

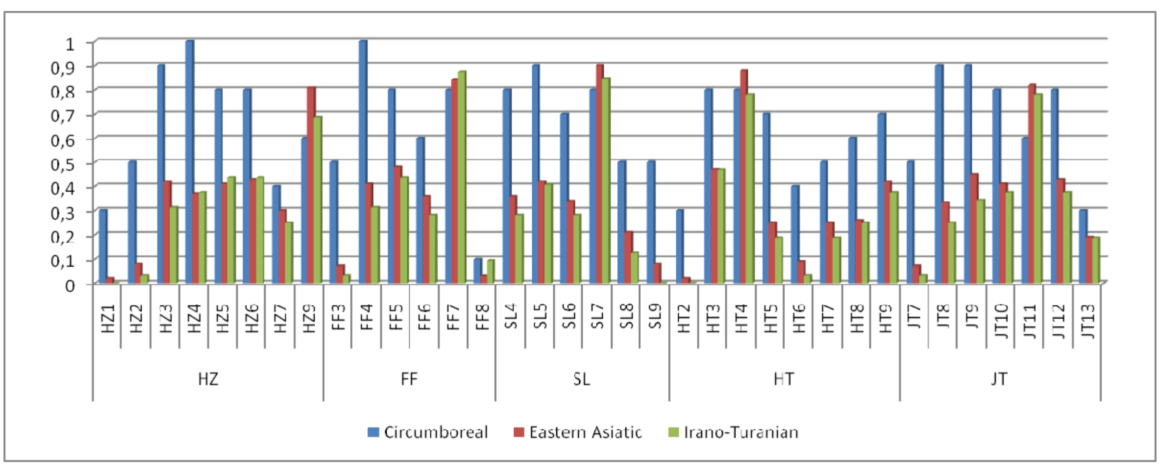

Fig. 5. Distribution of East Asian species throughout climatic zones

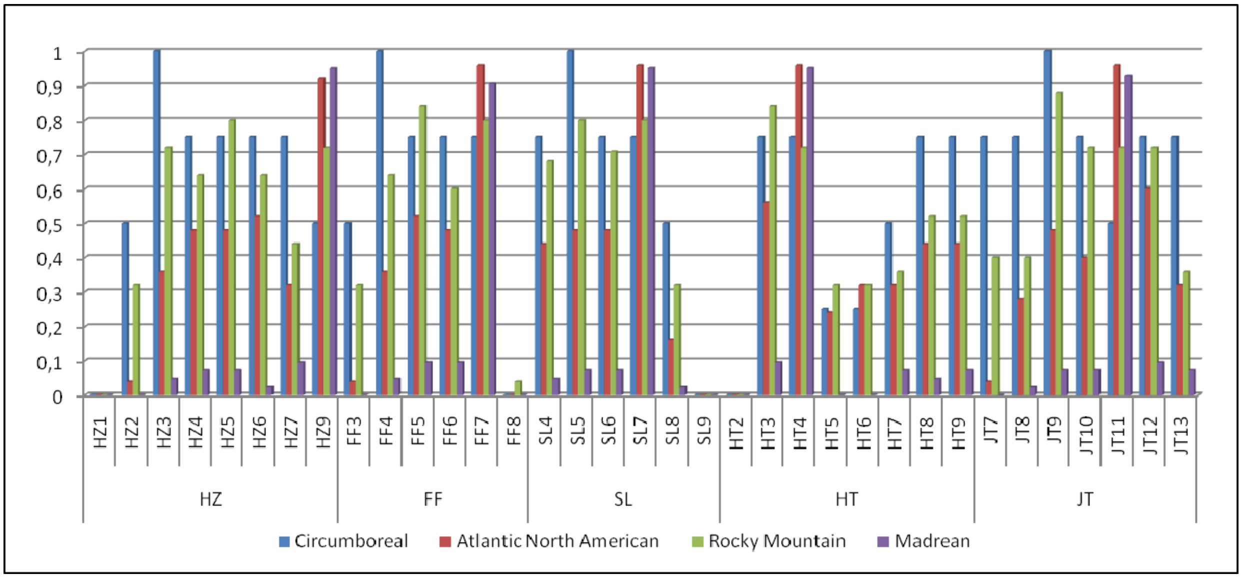

Fig. 6. Distribution of North American species throughout climatic zones

Table 1. The characteristics of climate and the number of botanical gardens (BG) in each zone.

Average minimal annual temperature			Duration of frost-free period			Duration of sun light			Average number of days with air temperature above 30^0c			Average July temperature		
zone	°C	BG	zone	days	BG	zone	hours per year	BG	zone	days	BG	zone	°C	BG
HZ1	< - 45,5	3	FF1	< 45	0	SL3	1200-1400	1	HT2	0-1	10	JT07	12-14	5
HZ2	-40,0 - 45,5	6	FF2	45-59	0	SL4	1400-1600	11	HT3	1-5	42	JT08	14-16	4
HZ3	-34,5 - 40,0	34	FF3	60-89	8	SL5	1600-1800	38	HT4	5-10	35	JT09	16-18	35
HZ4	-28,9 - 34,4	41	FF4	90-119	37	SL6	1800-2000	30	HT5	10-15	13	JT10	18-20	42
HZ5	-23,4 - 28,8	17	FF5	120-149	46	SL7	2000-2200	39	HT6	15-20	6	JT11	20-22	24
HZ6	-17,8 - 23,3	13	FF6	150-179	20	SL8	2200-2400	10	HT7	20-30	8	JT12	22-24	17
HZ7	-12,3 - 17,7	11	FF7	180-199	18	SL9	2400-2600	1	HT8	30-40	4	JT13	>24	4
HZ9	-1,2 - 6,6	6	FF8	> 200	2	SL10	>2600	1	HT9	40-50	12			
									HT10	50-60	1			

Sensible seasons

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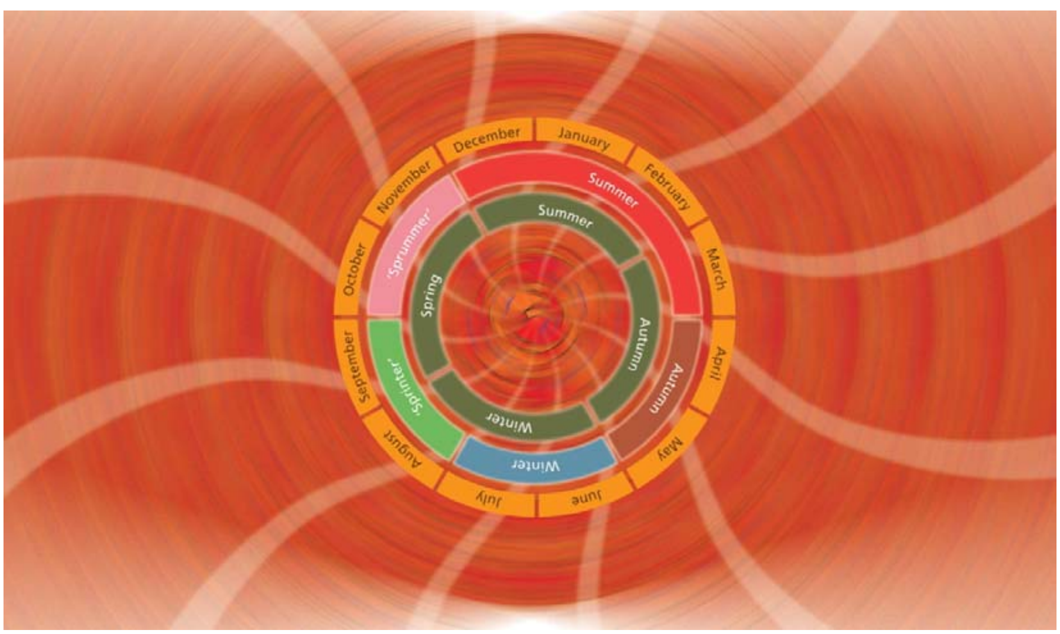
Abstract
To detect and measure changes due to global warming, it helps to be 'in tune' with our environment. One excellent way is to use seasons that relate to significant changes in the biological world, and particularly in our gardens and native vegetation. Most people around the world use the European-devised system of four seasons – summer, autumn, winter and spring – even though these seasons often have little relevance to the biological changes in their region. Indigenous communities in Australia have long had systems of six or more seasons. I've recommended a five-season system for the coastal Sydney region, including an early spring ('sprinter' – beginning with the mass flowering of wattles in southern Australia) in August and September, a pre-summer season ('sprummer') in November and December, a longer summer (December to March), and a short autumn (April and May) and winter (June and July). While every year is different, this system better reflects the environmental changes around Sydney. We need better phenological data and a willingness to untie ourselves from four seasons based on the distance of the sun from the earth and/or environmental changes in a distant land. Botanic gardens can lead this debate, but clearly poets or Indigenous people should provide the new names…

For more information see talkingplants.blogspot.com/seasons.



The role of botanic gardens in academic and community-based restoration

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Abstract

Ecological restoration that is performed, sponsored, or overseen by a botanic garden can have a number of positive effects for the garden, but the community that the garden serves is also benefited. And of course the ecosystem that has been damaged by human activity is improved. Two examples of restoration work sponsored by the University of Washington Botanic Gardens show how reaching out to the community can be effective and can show positive results.

Keywords

Capstone, community participation, curriculum, ecological restoration, public programmes, students, swamp, watersheds

Introduction

Ecological restoration is an activity that repairs damage, mostly human-inflicted, that decreases the viability of the earth as a living space. Botanic gardens are places where collection and research are done to enrich the human population and to educate them about how the biological world works. Restoration works well in the botanic garden setting because the involvement of gardens results in positive benefits for the garden, the community that uses the garden, and the environment.

Benefits to the garden

Engaging in restoration is a major benefit for botanic gardens for a number of reasons.

1) Participating in restoration requires the staff and administration of a garden to actually learn the skills required. Currently, gardens have abundant capability in the fields of horticulture, seed collection/processing, and propagation, but successful restoration requires a working knowledge of an ecological component that may not have been required by gardens in the past.

2) The next generation of restoration ecologists is trained, especially if the garden has an association with a university that has a restoration curriculum. As a consequence, better restoration is done, but another benefit to the garden is the increase in influence, as time goes by and careers blossom, of people trained by the garden (it is always good to have well-placed friends).

3) There are opportunities for public education. Restoration is a hands-on activity that provides opportunities for educating the public about food webs, plant-soil interactions, pollination, water relations, succession, ecological services and other important elements of the biology of natural systems.

4) Community support develops. People begin to see the importance of natural systems when they understand the relationship between the human environment and the natural environment. And, when they are involved in a restoration project, they feel a sense of ownership.

Benefits to people in the community

Members of the community often benefit from being involved in restoration. The degree to which they become invested in projects or in the ethos of restoration often surprises them.

1) There is often a feeling of reconnection to the land. Urban and suburban life often causes us to forget that we are an integral component of a living system (Jordan, 2003). Much of our cultural history is based upon this connection.

2) People in the community learn how to do restoration. Restoration is a skill and requires some knowledge of a real discipline. With this skill, the community can continue to do other restoration projects.

3) People engage in helpful and invigorating work with plants and nature. We go hiking, we go to the lake, and we play sports…why not engage in restoration? Restoration is active, strenuous, and engages all of the senses. It is a great way to keep mentally and physically healthy.

4) Community members improve their community. Not only do they improve the environment of their community, but they improve the structure of community interactions by doing useful, helpful work in a communal fashion.

Benefits to restored ecosystems

Natural systems, particularly in urban environments, have been destroyed, degraded, fragmented and isolated. These negative changes have occurred incrementally, and the restoration of ecological functions is likewise occurring in an incremental fashion.

1) Fragmented ecosystems are being reconnected. Urban creeks and riparian zones are especially appropriate for restoration supported by botanic gardens because they can be restored piecemeal, they constitute functioning corridors, and they are close by in urban neighbourhoods.

2) Invasive species are controlled. Invasive species removal is a good activity for community restoration because it requires little training, and stewards or community members find it easy to determine when additional work is needed.

3) Continued stewardship is much more likely in a community environment. Lack of follow-up is a major cause of restoration failure (National Research Council, 2001). When restoration is done in a neighbourhood, there are many eyes on a project. People comment and react when it appears that more work needs to be done or attention needs to be paid.

4) We are learning how to restore efficiently and effectively. The easier it is to restore, and the more effective that restoration efforts are, the more likely it is that restoration will be incorporated as public policy and damaged ecosystems will be repaired as a matter of course.

Case Studies

A good way to examine how botanic gardens, the actions of community volunteers, and environmental improvement are interrelated is by looking at the functioning of successful programs. We offer two examples that demonstrate the integration of academics, botanic garden resources and community involvement in the successful implementation of restoration projects

I. Restoration in an academic setting

The University of Washington has a curriculum in restoration ecology, and has involved students in hands-on restoration courses since 1995. The curriculum features plant-based courses such as Plant Propagation, Nursery Management, and Landscape Plant Management. There are also ecosystem-based courses that include Restoration of North American Ecosystems, Wetland Ecology and Management, and Biology of Plant Invasions. Recently a Restoration Design course has been introduced; it requires the preparation of designs in a team environment. A Project Management course is in the planning stages to complement the design course and provide more tools for project implementation. Finally, there is a three-part Restoration Capstone; it is human-community based and emphasizes working with a client, engaging volunteers, interacting with local governments, contacting the business community, and generally encourages students to become comfortable with working with the community around them (Gold *et al*. 2006).

The capstone course is a critical part of community-based restoration education in our curriculum, and it has run successfully for eleven years, so its structure and timing will be described here. The course lasts an entire academic year (nine months), though much of the groundwork is laid during the summer months by instructors who interact with potential clients and evaluate potential sites. This means that planning for each project happens in the fall, plant installation happens in the winter, and the project is finished in the spring. This timing works well in the mild and wet climate of the Pacific Northwest part of the U.S.

Students join teams that usually have a total of five or six members. They are allowed to review potential projects and vote for those they would prefer and those that they would not want to participate in. Eventually teams are formed; they get a project and a client. Clients are expected to provide a site and a project. They also sign an agreement that commits them to review and comment on the work products of the class (proposal, work plan, as-built, stewardship plan). Clients must also provide a work-ready site, which means that any engineered modifications or earth moving must be done by the client. Clients are also encouraged to provide assistance in the form of plants, mulch, transportation, tools and other forms of assistance, if they can. Some course fees are available to buy plant materials if client resources need to be augmented; plant propagation and nursery courses may also be able to contribute plants.

Student teams are encouraged to engage the community and find community resources. They are expected to seek out and work with volunteer groups; for instance, local middle and high schools may have community service requirements so that their students are looking for projects. Teams are encouraged to apply for small local grants, and ask for donations of plants, food or equipment from local businesses. Team members are expected to speak to community meetings and to local government groups such as planning commissions or city councils. Teams may also create interpretive signs, environmental art, or wildlife structures on site.

At the end of each academic year, there is a poster session at which projects are presented to the public. Web documents that students have been producing all year are used to create good graphics for posters. Present, former and prospective students and clients are invited, as are members of the media, faculty, school administrators, local politicians, neighbours and interested members of the public. The end-of-year poster sessions have turned into good networking events, and food and beverages are provided by students and faculty to encourage a good time.

The gains from the capstone class are many.
1) We restore community sites that need to be restored.
2) We produce confident graduates.
3) We have happy neighbours in the neighbourhoods where the work is done.
4) We have developed a good reputation for our program and the University.
5) We have developed many good contacts in local government and the environmental community.
6) We have actually encouraged many of our clients and some neighbourhood groups to become more environmentally active.

II. Community Partnerships: non-academic restoration (working with community groups)

Another way in which botanic gardens can work with the community to achieve restoration and to accomplish other goals is by working with engaged community groups. The University of Washington Botanic Garden (UWBG) manages a 76 acre natural area that showcases restoration (it is a retired landfill). Several times a year we conduct guided tours of the site, and talk about plants, animals, restoration and the history of the site. On one such walk, several neighbours became enthusiastic about a potential restoration project on the edge of the natural area, adjoining the residential neighbourhood where they live.
The project was an urban wetland that had developed on the site of a historic sawmill, any remnants of which had disappeared half a century ago. It was at the mouth of an urbanized creek (Yesler Creek), which had long ago been covered, filled and put into pipes. On the edge of Lake Washington, the site had developed on its own to become a true swamp, with standing water under a canopy of black cottonwood and willow trees. It was infested with the non-native *Rubus armeniacus* (Himalayan blackberry.)

The group and UWBG staff decided that building a trail was an important first step. The trail would allow access for restoration, would support the education mission of the University, and would attract neighbours to the site. Because of the fluctuation of the adjacent Lake Washington, a section of boardwalk would be necessary to complete a loop trail. A spur trail to a bird viewing platform was also proposed.

Although this project is less than a year old, several positive results have been produced. Three public events have been hosted (a winter walk, a children's "Swamp Mystery Tour", and a walk from the headwaters of the creek to the mouth). Neighbourhood councils have formally stated their support. Some money has been raised and grant proposals have been submitted. A trail has been cleared and surfaced with wood chips. Work parties are held on a monthly basis and the restoration of the site continues.

Conclusion

Ecological restoration is a new academic discipline and public pursuit arising from mankind's historic relationship with the land. This relationship has in the past been one of husbandry, of taking care of the land you use. Botanic gardens can use the energy that restoration generates to increase their visibility and augment the role they have in solving natural world problems.

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Compiling the Global Compositae Checklist in the age of biodiversity informatics

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Abstract

The days of manually compiling checklists are coming to an end as the options offered by biodiversity informatics change the systematic landscape. The Global Compositae Checklist is a project that utilises the possibilities of computer assisted checklist generation by integrating existing electronic datasets from around the world for this large plant family (approx 24,000 species). A purpose built computer program (C-INT) retains all original data and links names that are deemed the same to a 'consensus' name which reflects a summary of all contributed data. Insights from this process will be presented, discussing the advantages and pitfalls of trying to meld taxonomy and nomenclature with informatics technology. Issues that have arisen include how to obtain data and standardise the multitude of formats that data is contributed in, how to match names allowing for author variants, name orthographic variants, typographic errors and electronic artefacts as well as accommodating conflicting taxonomies.

Keywords

Asteraceae, Biodiversity Informatics, Checklist, Compositae, Data Aggregation, Systematics, Taxonomy, TDWG Standards

Introduction

The burgeoning field of biodiversity informatics is having a large impact on the manner of compiling taxonomic checklists. This paper is part of a symposium assessing the lessons learnt by the different approaches taken by various projects around the world to contribute to Target 1 of the Global Strategy for Plant Conservation (GSPC) - "A widely accessible working list of names of known plant species, as a step towards a complete world flora."

As part of this effort the Global Compositae Checklist (GCC) project has been running for four years, taking an electronic approach to the issue. As encapsulated in the name this project is global in scale and treats one of the largest flowering plant families, the Compositae (or Asteraceae), estimated to represent 10% of the world's vascular flora and containing approximately 24,000 species (Funk *et al*., 2009). The GCC utilises computer assisted checklist generation by integrating existing electronic datasets from around the world to create a global list. The purpose built program (C-INT, Wilton & Richards, 2007) retains all original data and links names that are deemed the same to a 'consensus' name which reflects a summary of all contributed data. This result is then available as web-based output to allow wide access (www.compositae.org/checklist).

We have received more than seventy individual datasets (Figure 1, Table 1), ranging from local checklists to scanned flora entries to regional databases to global repositories. A number of these data providers were present at the 4th Global Botanic Gardens Conference. Fifty-three of these datasets have been integrated to date. Currently the Total number of individual Provider Name records included is 426,130 and the Total number of consensus Names across all ranks is 152,538. Species is arguably the most important rank and the current data contains 28,969 accepted species, 45,178 synonyms and 35,135 with no taxonomic concept. There is a known element of duplication in the accepted names that is likely to account for a few thousand names which are currently being dealt with.

Discussion

The first issue worth noting in this process is that of expectations. There is currently a plethora of electronic based projects, all of which are collaborations between two different fields: Systematics/Taxonomy and Biodiversity Informatics. These fields have different focuses and priorities. Broadly speaking taxonomists desire definitive information reflecting the current taxonomic viewpoint (i.e. data content quality), while biodiversity informaticians are primarily interested in utilising computer tools to aggregate data in the most logical way, using the current standards for exchange of biodiversity data (i.e. the processes to deal with the data). Ultimately the lesson here is that it is very important to make sure the needs of all parties involved are covered and everyone is on the same page.

Communication is an integral issue as these two fields have different ways of communicating, using different languages eg SQL server scripts compared with the International Code of Botanical Nomenclature (McNeill *et al*., 2006). Each side has to learn to know if we do actually want to inner join on the homonyms or not. A major lesson has been that a good relationship between the taxonomist and biodiversity informatician involved is fundamental and vital to the success of the project. The importance of the collaborative relationship built between the two authors in achieving the results we have so far cannot be stressed enough.

Communication between computers is also not as easy as it may first appear. At the beginning of this project there were many groups working on aggregation software and the prospects of avoiding reinventing the wheel seemed positive. However, the reality of reusing code designed for a slightly different purpose is that there are many computer languages, systems, programs, and setups, and making things truly interoperable is seldom practical. Despite this, we have successfully used an author thesaurus from IPNI (The International Plant Name Index, 2008) and a name de-duplication tool by Julius Welby (EPU, 2009). The lesson is that everyone wants to work together and it is possible, but not quite to the degree that would be ideal.

Now a series of related issues regarding the data itself, the names and taxonomic concepts, will be dealt with. First, obtaining the data to aggregate has been slow and patchy. Some data has been promised and not delivered, some data has arrived years later than expected, and data for some regions has not been easy to find. At the time of the Gardens Conference, the GCC owed a download of data to another project presenting in the symposium. This has since been delivered, but these deadlines have a tendency to get moved. Part of the issue is that there is little leverage available when asking people to contribute their data voluntarily and time needs to be allowed for delays.

The most problematic issue encountered is that of data format. Every dataset is different as they were all made for slightly different purposes. Fundamentally they are all files full of plant names, but some have all name elements parsed into separate fields, some have everything in one field, some have authors abbreviated, some have year of publication separate to the citation and so on. The step of standardising data in order to be able to integrate it has been a huge bottleneck. The lesson here is that there is a need for standards.

The Taxonomic Databases Working Group (TDWG) would agree with this, but there are also issues with standards. They have a tendency to be more fluid than standard. There is continually new best practice. In 2006 the Taxon Concept Schema was the standard so we adopted it, now it is not strictly considered a current standard by TDWG themselves, but a "Current (2005) Standard" (TDWG). Biodiversity informatics is an innovating field by definition, which continually improves the tools it works with. Much of the data used in this project was developed before TDWG and it is unlikely that for example, a taxonomist's private Cuban endemic checklist is ever going to be set up according to any standard. The lesson here is that standards only help when widely used and stable.

Details about the approach to matching taxonomic name data can be found in Richards *et al*. (in press). The problems encountered include dealing with author variants, orthographic variants and typographic errors as well as accommodating conflicting taxonomies. There are tricky cases such as 'ex' authors and misapplied names which data sources have dealt with in varying manners. Regardless of how good the matching algorithms used are, the approach needs to account for straight-out mistakes and electronic artefacts. To successfully encompass all of this makes matching algorithms a non-trivial matter.

After negotiating all of the above mentioned issues and having successfully achieved a standardised dataset that has been integrated into the database through matching with the data previously received then you come to the data content vetting. At this stage in assessing the aggregated summarised consensus data that should cover the global group and has been sorted using logical rules we have found unexpected inconsistencies. For example, accepted genera with no accepted species; or the opposite, genera coming up as synonyms while species in the genus are accepted. These cases are often the result of a difference of scale in datasets, one dealing only in genera, another only in species. Other issues have also become apparent, such as multiple accepted homonyms and more author abbreviation variants than covered by the included thesaurus leading to duplication of names in the database. The lesson here is to expect the unexpected and that data aggregation may not be the panacea we wish it to be.

Is aggregation enough? The simple answer is no. Regardless of how smart your algorithms are, having got all of the data together, it still has to be checked by experts. This is always a voluntary vetting process. The GCC website has been internally released to The International Compositae Alliance (TICA) community for a few months now and Google Analytics show 278 unique visitors who, on average, spend around 10 minutes on the site and look at about 8 separate pages. These visits have come from 46 different countries covering all continents, which is very positive. However, the majority of concrete content feedback has come from two workshops where experts were asked to look at the website and check the content for their groups. After this around 100 individual feedback emails were received from seven experts. We are very pleased by this response. However, for a group with 24,000 species, this is a drop in the ocean in terms of producing an expert validated list. The lesson is that checking the quality of data content is a huge task that is necessary and we are expecting taxonomic experts to do this on a voluntary basis.

Conclusion

In conclusion, this is progress towards a list of known species for this significant plant family, which has a decent looking output to contribute to Target 1. This data is contributed to the Species2000 Catalogue of Life, the Encyclopedia of Life and has been added to the Target 1 project also discussed in this symposium by Chuck Miller and Bob Allkin. The current funding for the GCC is coming to an end and while this is an impressive base, it is only ultimately worthwhile if the project is continued and vetted.

Acknowledgements

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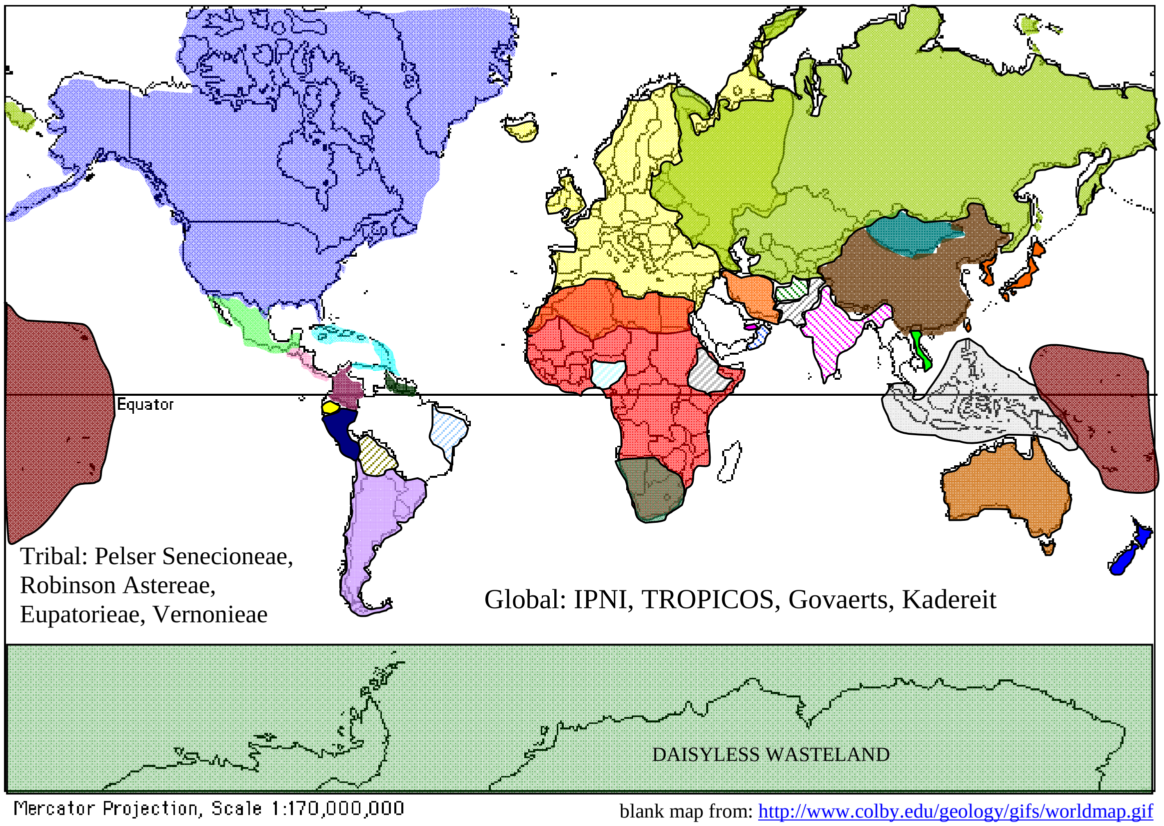
Figure 1 – Map of Data Provider coverage for Global Compositae Checklist, September 2010
Key to Colours provided in Table 1.



blank map from: http://www.colby.edu/geology/gifs/worldmap.gif

Table 1. Original Data Provider Sources by Country or Region for Global Compositae Checklist, September 2010
Key to colours in Figure 1; *online; ^received but not yet integrated; AU - Australia

Key	Country/Region	Data Provider/Source	No. Names
	Abu Dhabi Emirate	Brown & Sakkir 2004	36
	Afghanistan	Checklist of Afghan Plants^	687
	Africa	African Plants Database*	14862
	Australia	Naturalised Australian Asteraceae^	434
	Australian Capital Territory, AU	Lepschi et al. 2008*	182
	Bolivia	Hind 2009^	1044
	Bonin Islands	Toyoda 2003, Enomoto 1992	40
	Caribbean	Caribbean Checklist	1181
	China	Flora of China Checklist	2630
	Colombia	Colombia Database	2078
	Cuba	Database of Cuban Endemic Plants	220
-	Dolomite, Spain	Mota et al. 2008	18
	Ecuador	Ulloa Ulloa & Neill 2005	73
	Ethiopia & Eritrea	Tadesse, Mesfin 2004^	473
	Europe, Mediterranean	Euro+Med PlantBase*	18881
	Guiana Shield	Funk et al. 2007*	1043
	India	Draft Checklist^	1061
	Iran	Rechinger 1906 – 1998	1154
	Japan	Flora of Japan Database*	1704
	Korea	Flora of Korea	403
	Malesiana	Veldkamp 2006	2981
	Mesoamericana	Flora Mesoamericana*	6733
	Mexico	Castelo et al. 2005*	7920
	Mongolia	Gubanov 1996	595
	New South Wales, AU	New South Wales Flora Online*	1049
	New Zealand	New Zealand Plant Name Database*	2967
	Nigeria	Asteraceae in Nigeria^	315
	Northeastern Brazil	Hind & Miranda 2008^	486
	Northern America	Preliminary Checklist of North American Compositae	10878
	Northern Territory, AU	Kerrigan & Albrecht 2007	284
	Oman	Flora of Oman^	119
	Pacific Islands	14 individual data sources	483
	Pakistan	Flora of Pakistan Compositae (partial)^	194
	Panama	Flora of Panama	400
-	Paramo	Luteyn 1999	1299
	Peru	Ulloa Ulloa et al. 2004	359
	Queensland, AU	Bostock & Holland 2007	512
	Russia	Czerepanov 1995	7248
-	Siberia	Baikov 2005^	600+
	South Africa	Plants of Southern Africa: an online checklist*	3384
	South Australia	Electronic Flora of South Australia*	1121

Key	Country/Region	Data Provider/Source	No. Names
	Southern Cone	Zuloaga et al. 2008*	8360
	Taiwan	Flora of Taiwan	342
	Tasmania, AU	Flora of Tasmania Online*	474
	Victoria, AU	Walsh & Stajsic 2007	715
	Vietnam	Le Kim Bien 2005	860
	Western Australia	Western Australia Census	1058
-	World	Hind & Jeffrey 2001^	
-	World	Govaerts World Compositae Checklist A-G	61035
-	World	International Plant Name Index*	159046
-	World	Kadereit & Jeffrey 2006	1620
-	World	Pieter Pelser Senecioneae Database	10020
-	World	Robinson Astereae^	9000+
-	World	Robinson Eupatorieae^	10650
-	World	Robinson Vernonieae^	7000
-	World	Tropicos*	74405

Preparation of a list of Brazilian plant and fungal species: methods and results

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Abstract

The latest estimates on the richness of the Brazilian flora vary from 61,710 to 70,208 species of bryophytes, pteridophytes, gymnosperms and angiosperms. Over the last decades many new species have been described and there was no national effort to update the knowledge on the country's plant diversity. The only major work to treat it in a comprehensive way was *Flora Brasiliensis*, published by Carl von Martius over one century ago, covering 22,000 species. Besides the academic interest in the matter, the elaboration of a list of formally described species is the first target of the Global Strategy for Plants Conservation (GSPC), and Brazil as a signatory of the Convention on Biological Diversity (CBD), has assumed this commitment. The development of the 'Lista do Brasil' began with a meeting at the Jardim Botanico do Rio de Janeiro in September 2008. By the end of March 2010 the list included 40,989 accepted species and was being corrected and prepared for publication with the help of more than 400 Brazilian and international specialists. The actual number of species of our flora, with the amount of endemisms, and its distribution around the six biomes is presented here.

Keywords

Brazilian flora; GSPC targets; endemism

Introduction

Brazil is one of the most biodiverse countries in the world, encompassing some 15-20% of species known to science. The most recent publications estimate that the Brazilian flora includes 3,100 species of bryophytes, 1,200-1,400 species of ferns, 5-16 species of gymnosperms and 50-60,000 species of angiosperms (Shepherd, 2005; Giulietti *et al.*, 2005). Despite these estimates, the only major work to treat the Brazilian flora in a comprehensive manner was the Flora Brasiliensis by Carl von Martius (1846-1906), which covered c.19,958 species with confirmed occurrence in this territory (Martius 1833, Urban 1906). Since that major work, only regional treatments have been published, and many new species have been described, making it almost impossible to calculate precisely how many species are recorded for the country. The work of Sobral & Stehmann (2009) shows that in the last 16 years, 2,875 new species of angiosperms were described for Brazil, indicating a real need for a revision of all information available on our biodiversity.

Beyond the academic interest in the question, Brazil, as a signatory to the Convention on Biological Diversity assumed a number of commitments for the year 2010. Consequently, on 21st December 2006, the National Biodiversity Committee (CONABIO), the collegiate body of deliberative and consultative groups that coordinates the implementation of commitments made by the country under the Convention, as well as the principles and guidelines of the National Biodiversity Policy, published the resolution specifically stating the Brazilian targets for 2010. This includes the preparation of a list of formally described species of plants, animals and micro-organisms.

To achieve this goal, in August 2008 the Rio de Janeiro Botanic Garden (JBRJ) was designated by the Ministery of Environment (MMA) to coordinate the preparation of the list of species of the Brazilian flora. This nomination was followed by a meeting in September at the JBRJ, where it was determined that the list would include fungi, algae, bryophytes and vascular plants.

Methodology

The development of the list began with a meeting on 18-19th September 2008, which gathered 17 taxonomists of several institutions around Brazil and coordinators of regional lists. The coordinators of families and/or major taxonomic groups and the minimum fields that the list should contain, according to Species 2000, adapted to the country's reality were established at this meeting.

The first step consisted in integrating the lists already published or made available by experts in different groups (e.g. Hennen *et al.,* 2003; Gradstein & Costa, 2003; Barbosa *et al*., 2006; Maia *et al*., 2006; Queiroz *et al*., 2006; Procopiak et al., 2006; Mendonça *et al*., 2008; Stehmann *et al*., 2009). Through a partnership between the JBRJ and the Royal Botanic Gardens - Kew, data on the Brazilian flora from the World Checklist of Selected Plant Families (2009) and The International Plant Names Index/IPNI (Authors of Plant Names, 2009) were also made available.

All the information was merged into a system developed by the Centro de Referência em Informação Ambiental (CRIA) to manage the data. After this step, experts (indicated by the coordinator of the family or group) received a password so that they could, on-line, add new data or correct those existing in the system. Once the taxon had all the information needed, the specialist would indicate that the record was "checked".

The list has an on-line version (http://floradobrasil.jbrj.gov.br/2010), which is dynamic and will be periodically updated to include new species and taxonomic changes over time. The other product is a book that will be released in September 2010 and presented at the 10th Conference of the Parties (COP 10) in Nagoya, Japan.

Results

During 2009, more than 400 taxonomists worked on a single database, revising about 90,000 names, from which 78,723 were marked as "checked" and are available on-line for public consultation.

As a result of this work, 40,989 species of plants and fungi were documented for Brazil, of which 18,932 (46,2%) are endemic. In the catalogue 3,608 species of fungi, 3,496 algae, 1,521 bryophytes, 1,176 ferns, 26 gimnosperms and 31,162 angiosperms (Forzza *et al*., 2010) are presented.

Notably, the total number of species reaches only 55% to 65% of the recently published estimates that vary from 61,710 to 70,208 (Lewinsohn & Prado, 2005). If analyzed separately, the results show that the groups are also below the previous evaluations. Fungi represent 26-28%, and algae, 33-46% of the estimations suggested by Lewinsohn & Prado (2005). For bryophytes, for which the values varied from 1,660–3,200 species, it was only slightly below the accounts made by Costa (2009).

The estimates of 1,200-1,400 species of ferns were consistently cited by several studies and the numbers are not very far off (84–98% of the evaluations of Prado, 1998, Shepherd 2005, Lewinsohn & Prado 2005 and MMA, 1998). The richness of Gymnosperms increased, from the previous 14-16, to 26 species, of which three are subspontaneous (*Pinus* L.). The angiosperms are just above the lowest published prior estimate, but far below recent estimates that revolved around 40,000-45,000 species. This is the largest group among plants, holding 76% of the total diversity sampled.

The richest region is the Southeast (21,682), followed by the North (14,615), Northeast (14,054), South 11,350 and Midwest (9,950). The most diverse biome is the Atlantic Forest, with 19,355 species. Amazonia comes in second place, with 13,317 species, followed by Cerrado with 12,669, Caatinga with 5,218, Pampa with 1,964 and Pantanal with 1,240. The Atlantic Forest is also the one with highest endemism, 7,646 (39%), contributing significantly with the country's high values. This pattern is also found in each group separately, the only exception beeing gymnosperms which are more diverse in the Amazon.

These data show that regions with the highest concentration of active researchers match the domain that presents the greatest diversity of species, the Atlantic Forest. The pattern for fungi is slightly different because the main research groups are in Recife and Rio de Janeiro and Sao Paulo.

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A Basis for Change – a novel way to evaluate and re-align living collections to meet the changing focus of a botanic garden in the modern world

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Abstract

Living collections in older Botanical Gardens often develop idiosyncratically, governed by fashion or driven by individuals. The Royal Tasmanian Botanical Gardens (RTBG) is an older colonial era botanical gardens (est. 1818) with collections dating from the early 1800s. In 2008 the RTBG developed a suite of 5 linked plans. The plans refocus the Gardens: key strategic directions, major interpretive themes, conservation targets and heritage values and 're-brand' the RTBG to be more regionally and globally relevant. To both evaluate and realign the living collections with the Garden's new directions a unique method of assessing each collections status and value was developed. Living collections have a range of attributes that can be used for evaluation. These attributes were clustered into three principle attribute classes: Defining attributes, Use attributes and Managerial attributes. Collections were evaluated against each attribute via a formula and a simple table. The table provides an easy means of assessing how aligned the collections are with the organisation's strategic directions and also indicates where improvements can be made. This paper analyses the method from development through to delivery of a whole collection review and demonstrates how this rigorous approach gives clarity and authority to the decision making process.

Keywords

Botanic Gardens Horticulture, Collections Management, Evaluation, Living Collections, Strategic Planning

Background

Established in 1818 the Royal Tasmanian Botanical Gardens (RTBG) is Australia's second oldest botanic garden. The heritage landscape at the core of the Gardens holds a collection of nationally significant trees. The RTBG is also home to the unique Sub-Antarctic Plant House, The Tasmanian Seed Conservation Centre, collections of Tasmanian flora, conservation collections, southern hemisphere and ornamental conifers, taxonomic collections including the southern heaths and the Tasmanian ferns as well as ornamental and horticultural collections.

Our planning process

As part of a long term strategic planning process in 2008 the RTBG developed five critical plans in parallel to ensure a strong connection between all the plans. Each plan provided key information toward the development of the other plans and was in turn influenced and directed by the companion plans. At the core of the planning process the Strategic Master Plan (SMP) redefined the Garden's vision, mission, objectives and strategic directions.

The Living Collections Plan provided significant direction towards the SMP's redefined objectives. An important aim of the Living Collections Plan was to establish how well aligned the living collections were with the RTBG's new directions and further to develop an evaluation process and a methodology to enable staff to actively improve the collections to ensure better alignment.

The Plans

The Strategic Master Plan serves the Gardens as a strategic management and decision making tool. It responds to and connects the information provided by 4 ancillary plans and provides a full complement of functional management strategies.

The Interpretation Plan delivers a range of broad thematic foci, a media matrix linking the themes to audience via a range of potential methodologies, an upper level implementation plan and an interpretation policy.

The Living Collections Plan evaluates all aspects of the Gardens living collections, providing: an overview of current issues affecting the living collections before setting out a policy framework and a series of recommendations to facilitate decision making and the management of the Gardens living collections over the next 20 years.

(The two other plans were a (Heritage) Conservation Management Plan and a Community and Visitor Report)

Three Key Goals:

Three key goals were developed to forge the RTBG's new directions. These goals in turn support a range of specific strategies established to achieve each goal. The RTBG's goals are:

Goal 1. To sustainably manage the core values of the RTBG as Tasmania's botanical garden.
This goal addresses the definition of the RTBG as a 'Tasmanian botanical garden' and recognises the significant values embodied in the Gardens (this could be regarded as our 'point of difference' or 'brand') and determines that these values must be managed in a sustainable manner if the SMP is to be considered successful.
Goal 1. also addresses a principle requirement to maintain the integrity of the RTBG as a true botanical gardens through appropriate curation of living collections, involvement in the conservation of the world's flora and the conduct of targeted research.

Goal 2. To promote and manage the Gardens to ensure its users have the opportunity to attain a quality experience of the place and its values.
This goal addresses the use value of the Garden and the benefits to be derived from the successful management of the RTBG as an education and training centre, a community asset and a tourism destination.

The management of the visitor experience is directly related to people's expectations for the Gardens as a destination for daily life and/or for tourism.

Goal 3. To ensure there is sufficient capacity to sustainably manage the RTBG.
This goal addresses the core operational activities of the Gardens.

Why Evaluate?

Living collections are the raison d'etre for botanic gardens, in older botanic gardens the genesis of collections is sometimes obscure and not well documented. In some cases collections are opportunistic or driven by the interests of a staff member or Director. Often the value and purpose of each collection in relation to a botanic garden's broader aims and objectives is either not considered or poorly understood.

Living collections are generally managed over extended periods of time, with the inherent potential for a gradual erosion of focus and quality.

RTBG staff developed the evaluation process initially to ensure that the decisions and directions proposed in the Living Collections Plan were:

- based on quantifiable information and a reasoned process, and further
- To establish how well aligned the collections were with global policies and the RTBG's Strategic Directions.

Understanding the living collections

As part of the development process for the Living Collections Plan, RTBG staff and the project consultants reviewed the living collections. To do this staff used the Living Collections Situational Analysis a document established in 2003 and regularly updated which provides background information and reviews the current status of the RTBG's collections and their associated infrastructure. Staff also researched the historical context of the living collections.

Our evaluation process

Step 1.Categorising the Collections -

Today there are over 40 discrete living collections at the RTBG including: in-ground, potted nursery and seed bank collections comprised of over 6,000 species, varieties and cultivars.

The collections can be broadly divided into four major categories of collections:
Tasmanian Collections, Conservation and Research Collections, Southern Hemisphere Collections: and Cultural Heritage and Ornamental Collections.

Step 2
Sorting Collections by focus (see Table 2.)

Within these categories and in common with other botanic gardens, collections can be sub-grouped based on principle focus, that is, whether they have a geographical basis – a collection of plants based on a defined geographical area or biome; taxonomic basis - a collection of plants that demonstrates principles of plant classification; demonstration purpose - a collection that displays specialised areas of botanical or horticultural interest or horticultural techniques; heritage basis - a collection that exhibits a linkage with historic periods, cultural events, people or horticultural practices or periods; or horticultural basis - a collection that is based on horticultural selections of species or display principles.

Providing more definition

Step 3. Sorting by attribute

Living collections have a range of attributes that can be used to distinguish one collection from another and determine value. These attributes can be clustered into three principle attribute classes. In the RTBG's case these are aligned with the SMP's three key goals:

Defining attributes: These define what it means to be the Royal Tasmanian Botanical Gardens i.e. the relevance to the region's flora and those collections with historical significance to the Gardens and/or those attributes that more generally define a botanic garden including plants having conservation or botanical attributes of interest.

The RTBG's Defining attributes are:

- Regional
- Conservation
- Botanical
- Historical

Use attributes: These attributes relate to the ways that a collection is interpreted and used by both the public and the RTBG itself.

The Use attributes are:

- Interpretational
- Educational
- Tourism
- Recreational
- Commercial
- Spiritual (Social wellbeing)

Managerial attributes: Are those that relate to the amenity aspects of a collection and the suitability of local conditions for the collection. These are seen to include horticultural management and site suitability considerations.

The Managerial attributes are:

- Horticultural
- Site suitability
- Management

Establishing values

Step 4. Developing Assessment Criteria
To determine how well the collections performed against each attribute class a set of specific assessment criteria were developed. In some cases the criteria are prescriptive and enable clear evaluation (for example, Conservation) in others they function as guides to assist evaluation.

Table 2. - Shows each of the attribute classes, their distinguishing attributes and the assessment criteria for each attribute.

Scoring against attributes

Step 5. Rating and Weighting
Each attribute was then scored on a scale from 1 to 5 using the criteria with a score of 1 representing collections that did not meet or poorly met the listed criteria for that attribute and 5 for those that met the criteria well.

The scores were then weighted by multiplying the Defining Attributes x 3, Use Attributes x 1.5 and Managerial Attributes x 1.The weighting gives:

An emphasis to the defining values as these represent the principle reason for the continued existence of the Gardens (as opposed to say, converting the area to a park); a lesser emphasis to the use benefits, in part to balance the effect of the total tally of benefits, given the number of attributes grouped in this class; and a base rating to the managerial attributes as these are a fundamental to any botanic garden.

Results:

Table 3. Provides an opportunity for an overview of the RTBG's collection and clearly indicates each collections strengths and weaknesses.

Analysing the Results:

A high level analysis of the collections indicated a disconnection between many of the existing collections and the mission, objectives, goals and interpretation themes that are stated in the SMP. By contrast the assessment also shows the great benefits to be gained by bringing the collections into alignment with the strategic direction of the SMP.

At the individual collection level the table provides an easy visual method of assessing each collections strengths and weaknesses and clearly hjghlights areas for improvement.

Issues Identified by the Evaluation of the Collections:

At the broad level, the analysis of the collections shows the relatively low total scores achieved by any one collection, the highest rating collections amassing only slightly more than half of the available score – While there is no suggestion that all collections should rate highly across all attribute classes, the results suggest room for improvement in even the most highly valued of the collections.

More specifically this demonstrated a need to:

- strengthen the defining attributes in each of the collections if the Gardens is to clearly differentiate itself from other botanic gardens;
- gain greater return from the collections in terms of their use benefits, and
- better interpret the collections as the principle means of deriving greater benefit from them.

Direct outcomes of the Living Collections plan:

- The establishment of 3 Curators positions (Curator Tasmanian Flora, Curator Rare and Threatened and Subantarctic Flora and Curator Arbor) to manage key collections -
- The development of a Whole of Collections review (with the intention of making clear decisions about each collection and its future development).
- A Plant Conservation Policy - Guidelines to establish the RTBG's conservation role.

Acknowledgements:

This paper is closely based on the RTBG's Living Collections Plan developed by Inspiring Place and the Staff of the Royal Tasmanian Botanical Gardens

Table 1. The RTBG Collections

Category	Focus	Collection
Tasmanian	**Geographical Focus**	Subantarctic Greater Hobart East Coast Tasmanian Foreshore Remnant Grassland
	Taxonomic Focus	Epacridaceae Tasmanian Ferns
	Demonstration Focus	WSUD Garden
	Heritage Focus	French Memorial
	Horticultural Focus	Visitor Centre Beds
Conservation and Research	**Geographical Focus**	Tasmanian Seed Conservation Centre Conservation Collections (Potted)
Southern Hemisphere	**Geographical Focus**	New Zealand Gondwana Terraces Southern Hemisphere (Potted)
	Taxonomic Focus	Southern Hemisphere Conifers (Potted)
	Horticultural Focus	Protea
Cultural and Ornamental	**Horticultural Focus**	Bedding plants - including Floral Clock Conservatory Deciduous Trees – (incl. Oak Woodland) Conifer Cultivars Mixed Border (Friends Border, Rills, Lily Pond, Iris) Rhododendrons & Camellias Fuchsia House Palm Collection Asian Woodland Salvia Collection Magnoliaceae Grey Foliage plants

	Taxonomic Focus	
		Eucalypt Lawn
	Demonstration Focus	Conifer Species Herb Garden Pete's Patch/Economic Easy Access Garden Cacti & Succulents
Cultural and Ornamental (cont.)	**Heritage Focus**	Heritage Apples Significant Trees Cottage Garden
	Geographical Focus	Japanese Garden Chinese Australian

Table 2. Attribute Assessment Criteria

Class of Attributes	**Attribute**	**Assessment Criteria**
Defining	Regional	collections with valid connections to our region; collections that are Tasmanian in origin (including Macquarie island); collections that are Australian in origin; collections that have a southern hemisphere distribution; and collections with Gondwana origins.
	Conservation	viable potted and seed *ex-situ* collections; collections of Tasmanian species that are listed on the IUCN Red List and/or under the Tasmanian *Threatened Species Protection Act 1955* and/or the Federal *Environmental Protection and Biodiversity Act 1999*; *ex-situ* potted and seed collections with a representative number of genotypes from within or between population/s; and collections of listed species in DPWI Threatened Species Recovery Plans.
	Botanical	collections with scientific integrity; collections of known wild provenance; collections with detailed field collection records; collections with herbarium voucher specimens; and collections based on taxonomic principles with a comprehensive representation of taxa.
	Historical	collections originating from or representing the heritage fabric of the Gardens or elements of Tasmania's botanical history; the mature canopy of trees originating from Victorian plantings; the Gardenesque Victorian elements in the landscape such as the palms; plantings based on records of early plant lists from the RTBG; and collections relating to Tasmania's botanical history.
Use	Interpretive	collections currently covered by interpretive media other than plant labels; collections with in-ground interpretive signage; collections with associated pamphlets; collections interpreted in RTBG displays; and collections interpreted on the RTBG web site.
	Educational	collections currently used for education purposes; collections used for the schools program; collections used for the community garden program; and collections used for Green Thumbs and Explore programs.
	Tourism	collections that specifically draw tourists to the RTBG; collections that are unique to the RTBG such as the Subantarctic Plant House and Tasmanian collections; collections of high ornamental value such as the Conservatory; and collections centred on events such as the Tulip Festival.
	Commercial	income generating collections; collections used as sites to for income generating activities such as weddings, naming ceremonies and memorials and other functions; and collections providing material for income generating activities such as plant sales.
	Spiritual	collections that have spiritual associations (Note: this attribute was not

Class of Attributes	**Attribute**	**Assessment Criteria**
		assessed due to the difficulty and costs of gaining information about reliable indicators).
Managerial	Horticultural	collections with high amenity value; collections with strong visual appeal; collections displaying a range of horticultural selections; and collections that display current trends in horticulture.
	Site Suitability[1]	local environmental and artificial factors which influence the cultivation of collections; soil type and drainage; water availability and type of irrigation; slope and aspect; local climate; adjacent plants; and adjoining infrastructure.

Table 3: The values of the individual collections

	Defining Attributes					Use Attributes							Managerial Attributes				
Collection	**Regional**	**Conservation**	**Botanical**	**Historical**	**Sub-Total (weighted by 3, highest possible score 60)**	**Interpretation**	**Educational**	**Tourism**	**Recreational**	**Commercial**	**Spiritual**	**Sub-Total (weighted by 1.5, highest possible score 37.5)**	**Horticultural**	**Site Suitability**	**Management**	**Sub-Total (unweighted, highest possible score 10)**	**Overall Scores (out of 107.5)**
TASMANIAN																	
Geographical Focus																	
Subantarctic	5	1	5	1	**36**	5	5	5	1	1		**25.5**	4	3		**7**	**68.5**
Greater Hobart	5	2	5	1	**39**	3	1	1	1	1		**10.5**	3	3		**6**	**55.5**
East Coast	5	2	5	1	**39**	1	1	1	1	1		**7.5**	3	3		**6**	**52.5**
Tasmanian	5	1	5	1	**36**	3	5	5	1	1		**22.5**	3	3		**6**	**64.5**
Foreshore	5	2	3	1	**33**	1	1	1	1	1		**7.5**	1	4		**5**	**45.5**
Remnant Grassland	3	2	3	1	**27**	1	1	1	1	1		**7.5**	1	4		**5**	**39.5**
Taxonomic Focus																	
Epacridaceae	5	1	5	1	**36**	1	1	1	1	1		**7.5**	2	1		**3**	**46.5**
Tasmanian Ferns	5	1	5	1	**36**	1	3	2	1	1		**12**	4	3		**7**	**55**
Demonstration Focus																	
WSUD Garden	5	1	1	1	**24**	3	2	1	1	1		**12**	2	1		**3**	**39**
Heritage Focus																	
French Memorial	4	1	3	1	**27**	3	1	1	2	1		**12**	3	3		**6**	**45**
Horticultural Focus																	
Visitor Centre Beds	5	1	3	1	**30**	1	1	1	1	1		**7.5**	3	3		**6**	**43.5**
CONSERVATION & RESEARCH																	
Geographical Focus																	
Tasmanian Seed Conservation Centre	5	5	5	1	**48**	2	3	1	1	1		**12**	1	5		**6**	**66**
Conservation Collections (Potted)	5	5	5	1	**48**	1	2	2	1	1		**10.5**	1	3		**4**	**62.5**

SOUTHERN HEMISPHERE																
Geographical Focus																
New Zealand	4	1	1	4	**30**	1	2	1	1	1		**9**	2	3		**5**	**44**
Gondwana Terraces	4	1	3	1	**27**	1	1	1	1	1		**7.5**	3	3		**6**	**40.5**
Southern Hemisphere (Potted)	4	3	4	1	**36**	1	1	1	1	1		**7.5**	2	1		**3**	**46.5**
Taxonomic Focus																
Southern Hemisphere Conifers (Potted)	4	3	3	1	**33**	1	1	1	1	1		**7.5**	2	1		**3**	**43.5**
Horticultural Focus																
Protea	1	1	1	1	**12**	1	1	1	1	1		**7.5**	1	3		**4**	**23.5**
CULTURAL & ORNAMENTAL																
Horticultural Focus																
Bedding plants - including Floral Clock	1	1	1	4	**21**	1	1	5	1	5		**19.5**	5	3		**8**	**48.5**
Conservatory	1	1	1	3	**18**	2	3	5	5	5		**30**	5	4		**9**	**57**
Deciduous Trees – (incl. Oak Woodland)	1	1	1	2	**15**	1	3	4	3	3		**21**	3	3		**6**	**42**
Conifer Cultivars	1	1	1	1	**12**	1	1	1	1	1		**7.5**	2	3		**5**	**24.5**
Mixed Border (Friends Border,Rills, Lily Pond, Iris)	1	1	1	1	**12**	3	2	3	2	1		**16.5**	5	4		**9**	**37.5**
Rhododendrons & Camellias	1	1	2	1	**15**	1	1	2	1	1		**9**	3	2		**5**	**29**
Fuchsia House	1	1	3	2	**21**	1	1	3	1	1		**10.5**	3	4		**7**	**38.5**
Palm Collection	1	1	2	4	**24**	1	1	1	2	1		**9**	3	4		**7**	**40**
Asian Woodland	1	1	1	1	**12**	1	1	1	1	1		**7.5**	3	3		**6**	**25.5**
Salvia Collection	1	1	3	1	**18**	1	2	2	1	1		**10.5**	4	4		**8**	**36.5**
Magnoliaceae	1	1	2	1	**15**	1	1	1	1	3		**10.5**	3	3		**6**	**31.5**
Grey Foliage plants	1	1	1	1	**12**	1	2	1	1	1		**9**	4	4		**8**	**29**
Taxonomic Focus																
Eucalypt Lawn	5	1	1	1	**24**	1	1	1	3	1		**10.5**	3	3		**6**	**40.5**
Conifer Species	1	1	4	5	**33**	1	4	3	3	3		**21**	4	4		**8**	**62**
Demonstration Focus																
Herb Garden	1	1	1	1	**12**	3	3	3	2	1		**18**	3	4		**7**	**37**
Pete's Patch/Economic	1	1	1	1	**12**	3	5	5	2	3		**27**	4	4		**8**	**47**
Easy Access Garden	1	1	1	1	**12**	1	5	1	4	5		**24**	2	2		**4**	**40**
Cacti & Succulents	1	1	3	1	**18**	2	5	1	1	1		**15**	3	1		**4**	**37**

Heritage Focus																	
Heritage Apples	3	1	1	1	**18**	1	2	1	1	1		**9**	2	2		**4**	**31**
Significant Trees	1	1	1	3	**18**	3	3	2	3	1		**18**	4	4		**8**	**44**
Cottage Garden	1	1	1	5	**24**	2	1	1	1	1		**9**	4	4		**8**	**41**
Geographical Focus																	
Japanese Garden	1	1	1	1	**12**	2	3	5	4	4		**27**	4	3		**7**	**46**
Chinese	1	1	4	1	**21**	2	2	3	2	1		**15**	4	4		**8**	**44**
Australian	4	1	1	1	**21**	1	1	1	1	1		**7.5**	1	2		**3**	**31.5**
Sub-Total	112	58	104	65		68	87	84	66	65			122	128			
Possible Total	**210**	**210**	**210**	**210**	**60**	**210**	**210**	**210**	**210**	**210**		**37.5**	**210**	**210**		**10**	**107.5**

Vertical plant production as a public exhibit at Paignton Zoo

Kevin L Frediani

Paignton Zoo Environmental Park, United Kingdom

Abstract

Paignton Zoo has undertaken a novel project together with a multinational plant technology group to build Europe's first vertical growing facility. The project represents the first garden-based sustainable growing laboratory, showcasing an evolutionary step in the way crops can be grown to the public. It provides the means to cultivate crops on the organisation's own site when space is a premium and where traditional methods of crop production cannot be used. The project is an example of change in the nature of zoos as they move towards becoming fully integrated conservation organisations and demonstrates an integrated approach to zoo horticulture. It is an example of how zoos and botanic gardens can demonstrate sustainability to their visitors through reducing their own impacts on the environment with plant based solutions to offset the impact of anthropogenic global change on biodiversity.

VertiCrop is a technological solution to a sustainable urban agriculture. It is compatible with low input production systems such as permaculture as being advocated in urban agriculture. Urban agriculture itself is a technology which zoos and botanic gardens are well placed to showcase through public exhibits. Urban agriculture and High Density Vertical Growing technology should be seen as an essential element which can help to achieve Millennium Development Goals, most specifically number one, end poverty and hunger and number seven, ensure environmental sustainability by taking pressure off habitats to service unsustainable cities through agricultural domestication or otherwise unsustainable land use.

Keywords: Zoological Garden, Botanic Garden, Collections Management, Sustainable Development, Vertical Farming, High Density Crop Production, Botanical Exhibit & Sustainable Interpretation, Millennium Development Goal, Urban Agriculture.

Introduction

Paignton Zoo Environmental Park is a zoo and botanic garden in the south west of England, UK. It was established in 1923 and twenty years later opened to the public as a private collection of animals and plants by Herbert Whitley, the heir to a brewery fortune (Baker, 1988). The garden was entrusted upon Whitley's death in 1958 and since that time has operated as an education and research charity dedicated to wildlife conservation. It achieves its objectives through undertaking *in situ* and *ex situ* work abroad, and through managing population work on its own site in collaboration with other scientifically managed reserves and collections (Anon, 2009). To demonstrate congruence in its site operations and in undertaking new developments the zoo gained external recognition in 2005 for its work by undertaking internationally recognised Environmental Management System ISO 14001, a reiterative standard that requires rigorous annual auditing under external auditors to retain (Turner, 2009).

Plant use in the zoo

Paignton zoo has over the years built up a large botanic collection which today hosts over 5,000 plant accessions growing in its pubic areas outside its animal exhibits, representing 2,500 species that are set in a 30 hectares of rolling Devon landscape. While the zoo is internationally recognised for the integrated nature of its work, the gardens has not had the same directed focus for its plant collections until fairly recently, having instead developed an emphasis on accumulating plant diversity and displaying naturalistic landscapes. Since 2008 the garden collections have been provided with a new vision that looks to optimise the potential for plants to support the zoos mission: to educate, research and conserve in support of the world's animals, plants and their habitats. Through this new initiative the garden is progressing a new botanical direction through following an integrated approach to zoo horticulture (Frediani, 2009a; Frediani, 2010).

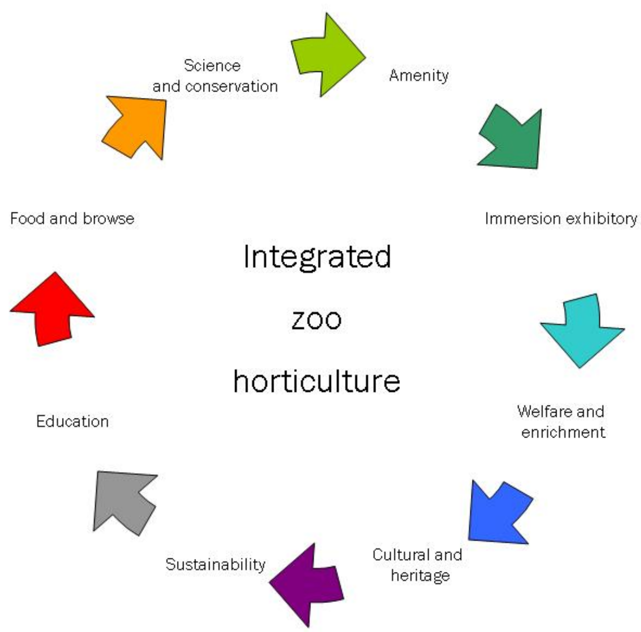

Figure 1. Eight plant use themes that define the breadth of zoo horticulture after Frediani, 2009.

Many of the plant use themes are well established roles of botanic gardens around the world such as research, display and education. A small number however, required exploration and innovation to realise. Food production needs land to be made available and could potentially conflict with evolving animal exhibits. Enrichment first had to be defined in terms of the use of landscape and plants to encourage natural behaviour in animals (Frediani, 2009b); while Sustainability as a concept proved rather difficult to interpret in terms of tangible developments for visitors to see, interpret and enjoy.

Sustainable food production as a public exhibit

Addressing the nutritional requirements of zoo animals through selection of the right types of food stuffs requires intimate knowledge of the animal. Nutritionists can be supported in this work by exercising more control over the nutrient content of the food crops (Morgan, 2009). This is achievable with modern horticultural crop production technology that can also bring other benefits from providing increased control. Consider the roots of plants which are traditionally left behind in the ground or removed and composted at cropping time. They can be fed into the animals as part of an enrichment or welfare programme reducing waste and increasing fibre intake. These benefits could also be achieved through the contract growing of specialist crops that the zoo specifies, but this often incurs a large cost and takes time to manage successfully. Hence in reality it is seldom undertaken to any great degree.

Reduced costs, greater control and flexibility can be gained through localised crop production where organisations grow their own food plants to serve their own needs. In zoos, animal food provision is a priority, however it has to date been heavily subsidised through outsourcing from a human dominated supply chain that undervalues the use of carbon based fuel to grow, transport, maintain post harvest and store until purchased and used. With the development of the new VertiCrop™ in the zoo it is now possible to grow food on a site limited for space that provides animal management support services and has the potential to service some of the visitors needs for fresh leafy salad crops year round in a sustainable, low impact but highly interpretational manner. Additional benefits have been gained from in-house growing at the zoo that was not necessarily fully understood at the onset of the project (Frediani, 2009c). These have included: the ability to grow a larger diversity of crop plants than were commercially available; the provision of plants year round without concern for the changes in weather and impacts on field grown crops; the ability to provide crops that are out of season or out of the price range of the organisation and have led to the reduction of overall food bill and led to an increase in the food security of the organisation.

VertiCrop™ - High Density Vertical Growing

VertiCrop uses hydroponic growing technology in a vertical conveyor driven system. Hydroponics is the science of growing plants without soil. Instead of soil, plants are grown in solutions containing all the necessary mineral elements. Methods used to get the nutrients to the roots, along with the needed oxygen, include bare-root systems and systems using inert substrates to support the plants. The Paignton zoo system comprises a closed loop conveyor system suspended from an overhead rack that carries seventy hangers that hold 8 pairs of bespoke growing trays using a water based bare root system contained in a plastic tray (see figure 2 below). This allows an even airflow over plants and, importantly, equal exposure to light. It is integrated with the most advanced hydroponics technologies to automatically supply water and nutrients at a central feeding station; the run-off solutions are captured, filtered and recycled through the whole irrigation system. In a little over 100 meters of floor space it has the capacity of growing 11,200 plants at any one time (Frediani, 2010). Where the system currently produces around 112 lettuces per square metre, per crop on a 3m high pilot system at Paignton Zoo; however, optimal production with up to 250 lettuces per m^2 can be obtained if the vertical dimension is 6m high. VertiCrop™ forecasts based upon this modelling suggest annual yields of lettuce around 50 times higher per square metre than typical field grown crops (Bayley *et. al*, 2010).

Figure 2. The VertiCrop growing production system with its first crop of lettuces @ Kevin Frediani

The global context of the modern zoo and botanic garden

Over the last five decades, the pursuit of growth has been the single most important policy goal across the world. The global economy growing to almost five times the size it was only half a century before. This growth is increasingly being seen as unsustainable. Projections estimating that continued growth at the same rate will result in an economy 80 times the size by the year 2100, leading to a suggested redefinition of our age as following a myth of economic growth (Jackson, 2009). Jackson's report, authored as chair of the UK government's sustainable development commission, states that the extraordinary ramping up of global economic activity has no historical precedent, being totally at odds with scientific knowledge of the finite resource base and the fragile ecology on which we depend for survival. The past pursuit of growth having already been accompanied by the degradation of an estimated 60% of the world's ecosystems (Jackson, 2009). This is an unsustainable misuse of the world's life support systems essential for the well being of man kind (Odum, 1993).

Given the state of the impact on the world by man, there seems to be a moral duty for zoos and botanic gardens to showcase sustainable use of resources such as energy, land and water, on their own sites to directly make the link between the global and local impact of sourcing, growing, housing and displaying collections of rare plants and animals. How otherwise can conservation organisations educate about the loss of biodiversity due to habitat destruction or anthropogenic global change without themselves having demonstrated a commitment to work within the limits of sustainable growth and development? (Frediani, 2009a). To undertake this change in focus gardens must audit there own impact on the environment by understanding how they obtain and use their resources. This information can then be used to measure the impact as the environmental footprint of the organisation or indeed that each new exhibit has.

Environmental footprint is an important means to measure an organisations ability to work within sustainable limits where carbon is an indirect measure of the environmental cost of operations and activities (Weidema *et al*. 2008). When this method is applied to on-site growing of food crops using the VertiCrop, there is little or no carbon expended in between crop production and delivery, as transportation will be eliminated and therefore the environmental costs are reduced to a lower level than would otherwise be the case. The zoo exhibit is housed within a low energy polythene structure that has is double skinned with a smart polythene film on its roof to retain heat, reduce scorch and provide optimal light levels in winter months (Chester, 2010). Rain water is harvested from the roof and under floor heating is used to provide minimum winter temperatures. Further reductions can be made through integration of compatible green technologies to generate and efficiently utilise the energy required to operate it. These include biogas, solar thermal, air, ground and gas source heat pumps, photovoltaic, geothermal and wind power. The resultant exhibit has the potential to require no carbon-based energy and provides the organisation with a reduced ecological footprint that can be communicated to its visitors in a visually graphic and physically ingested way, through literally eating the view.

Figure 3. VertiCrop™ exhibit interpretation at Paignton Zoo showcasing sustainable food production

Urban food production

Energy inputs are critical to agricultural production and the increased use of fossil fuel based energy resources has become increasingly important, particularly in developed countries and increasingly in the developing countries. Even though agriculture requires only a very small percentage of all the fossil fuel resources used in the world, long-term sustainability of global agricultural production will require renewable alternative energy resources (Mears, 2007). With an increasingly urban world where the majority of people now live in cities localization requires that food and fuel be produced in an urban context (Crane & Kinzig, 2005). At present, there are no examples of a locally sustained urban community anywhere in the world (Odum & Garret, 2005; Newman & Jennings, 2008)). Urban agriculture is increasingly being recognized as one of the activities with the potential to contribute towards socio-economic development in urban areas of the developing world. However, urban sustainability is yet to be realised primarily because urban agriculture presents a number of technological challenges (Fischetti, 2009, Vogal, 2008). The main challenge is a lack of growing space and limits to water and has to date only be successfully applied with the large scale conversion of green space in Havana, Cuba following the collapse of its external political support by former communist countries in the late 20th century.

The Cuban experience showed that with massive political support, and through the use of more sustainable land management practices based upon core permaculture principles, it was possible to make a huge improvement in local food production. Although the daily food intake per person remained below the recommended daily recommendation, it did support the urban population without massive external inputs and imports of food (Cruz & Medina, 2003). In developing countries urban agriculture is increasingly being seen as a progressive way forward. In Zambia, urban agriculture has played a key role as one of the key community responses to the after-effects of economic restructuring and therefore has the capacity to contribute in alleviating food insecurity and poverty (Hampwaye *et. al.* 2009).

Vertical growing beyond the zoo

Vertical growing systems are proposed as possible solutions for increasing urban food supplies without increasing the need for additional areas of land to be put aside for agriculture (Despommier, 2010). They can have a role alongside permaculture systems in cities and low impact agriculture in soils around cities. The primary advantage of vertical growing is the high density production it allows using a much reduced physical footprint and fewer resources relative to conventional agriculture. The figures suggest a water use efficiency of 1/6th conventional agriculture and provision of 20 times the crop per unit of land (Bayley *et. al*. 2010).

Vertical growing is compatible with existing hydroponics and greenhouse technologies and can embrace emerging sustainable technologies such as LED and Plasma lighting. Together these solutions address many aspects of the sustainable urban production challenge (i.e., soil-free, organic production, closed loop systems that maximize water and nutrient efficiencies, etc.). Such systems have major potential for the realization of environmentally sustainable urban food and fuel production to benefit human kind and have a very real place to play in adding value to society through zoo and botanic garden horticulture in the 21st century.

Figure 4. VertiCrop™ is a modular high density growing system suited to serving the needs of an urban agriculture.

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Russian botanical gardens and the Global Strategy for Plant Conservation

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Abstract

The work of 90 Russian botanical gardens on the conservation of plant diversity is coordinated by the Council of Botanic Gardens of Russia and the Russian Division of Botanic Gardens Conservation International (BGCI). The Global Strategy for Plant Conservation (GSPC) has served as a considerable stimulus for strengthening this work. The botanical gardens of Russia have contributed considerably to the achievement of the targets of GSPC. They play an active role in programmes for the conservation of plants *ex situ* and *in situ*. About 64% of species included in the Russian Red List are contained in the living collections of botanical gardens.

Keywords
Ex situ and *in situ* plant conservation, Global Strategy for Plant Conservation, rare plants, Russian botanical gardens.

Over recent decades, botanic gardens have become increasingly involved in plant conservation. These activities have been raised to a new level and were stimulated by the adoption of the GSPC. According to the text of the Strategy the countries which have signed this document, including Russia, have to develop national strategies for plant conservation.

In 2003, "The Strategy of the botanical gardens of Russia for the conservation of plant diversity" was prepared and published. There are 90 botanic gardens in Russia; their work on plant conservation is coordinated by the Commission on Rare Plant Species of the Council of Botanic Gardens of Russia and the Russian Division of BGCI. Russian botanic gardens have contributed significantly to the achievement of the GSPC targets.

Target 1. A widely accessible working list of known plant species, as a step towards a complete world flora. In accordance with this target a number of specialists from botanic gardens have contributed to such publications as “Flora of Eastern Europe”, “Siberian Flora”, “Summary of Siberian Flora”, “Vascular plants of the Soviet Far East” etc. At the present time many efforts are concentrated on studying the flora of various regions in Russia (North-West, Altay region, centre of the European territory, Russian Caucuses, Western Siberia etc.).

Target 2. A preliminary assessment of the conservation status of all known plant species, at national, regional and international levels. The new Red Data list of plants has been affirmed in 2005 by the Ministry of Natural Resources of the Russian Federation. This document provides a legislative base for plant conservation and protection in our country. In 2008 the new “Red Data Book of the Russian Federation: Plants and Fungi” was published. A major role in the preparation of the updated list was played by specialists from botanic gardens. The list numbers 676 species of plants and fungi. An important new feature of the list is the inclusion of algae (30 taxa of sea algae and 5 taxa of freshwater algae). At the same time 48 plant and fungi species were excluded from the national Red Data Book. Botanical gardens also initiated and played a leading role in the preparation of a number of regional Red Data books: Altay, Murmansk, Tver, Rostov, Volgograd, Sakhalin and other regions.

Target 3. Development of models with protocols for plant conservation and sustainable use, based on research and practical experience. Many botanical gardens in Russia have developed advanced methods for the maintenance of living collections which make genepool conservation effective and secure. Such methods include:

1. Creation of modeled artificial communities as a way of endangered species conservation on the basis of florogenetic and phytocenoetic principles. This is widely applied in the following gardens: Main Botanical Garden, Central Siberian Botanical Garden, Botanic Garden of the Urals State University, Botanic Garden of the Urals Branch of RAS etc.
2. Introduction of endangered species into natural vegetation. Developed in the Polar-Alpine BG this method includes creation of plots with endangered species among natural vegetation being conserved on the territory of a garden or park. No special care is needed as a micropopulation of endangered species is created. Similar work has been done in other botanic gardens with protected areas of natural vegetation – Main Botanical Garden, Yakutsk Botanic Garden, and the Botanic Garden of the Urals State University.
3. Introduction and recovery of plant communities. This method developed in Stavropol Botanic Garden combines *ex situ* and *in situ* conservation approaches: multispecies mixtures of seeds collected mechanically in natural grassy ecosystems of steppe and semi-desert areas are sowed into cultivated soil; recovered grassy communities are used as the basic ecosystems for introduction of certain endangered species in the form of seeds, tubers, bulbs or rhizomes. On the basis of experimental studies the Stavropol Botanic Garden has developed the full technological line for the rapid recovery of steppe ecosystems on the basis of widely available agricultural equipment. This technology received a positive response on being approved by the creation of agrosteppes similar in floristic diversity and structure to zonal ecosystems used as hayfields or pastures.

Target 5. Protection of 50 per cent of the most important areas for plant diversity assured. The most important areas for plant biodiversity conservation, so called “hot spots” or “key botanical territories” should be selected in accordance with such criteria as the level of endemism, species diversity, uniqueness of habitats, and relict features of ecosystems. In 2004 the first issue of “Key botanical territories of North Eurasia” discussing conservation in Belorussia, Russia and Ukraine was published. There are 101 state preserves and 35 national parks in Russia. Specially protected natural territories of federal, regional and local levels cover 11.7% of the whole territory of Russia. These numbers are rather impressive. However, the plant diversity on protected areas is a long way from being representative. Only half of the species listed in the Russian Red Data Book occur in the territory of reserves. Thus, a major number of species with federal protection level are not conserved *in situ*.

A number of Russian botanical gardens work actively and successfully with conservation in the wild. They officially propose certain areas and vegetation sites to be selected as territories with various levels of state protection, study flora and vegetation on already protected areas, reveal and study populations of rare plants. In our opinion, a common action plan for the conservation of rare and endangered species in the wild should be developed including a selection of “key botanical territories” with species from the Red Data Book.

Target 8. 60 per cent of threatened plant species in accessible ex situ *collections, preferably in the country of origin, and 10 per cent of them included in recovery and restoration programmes.* In 2002-2005, an inventory of botanic garden collections was carried out to identify rare plants in cultivation in botanic gardens. In 2005, the reference book «Plants of the Red Book of the Russian Federation, growing in botanical gardens» was published. In 2005, in the botanic gardens of Russia, 249 of the 461 species of higher plants included in the Russian Red Book were cultivated in botanic garden collections, making 54 % of threatened plants. Of these, 34 species were classified in category 1 (E), making 48 % from the general number of species of this category. 20 species were represented in collections of three and more botanic gardens (i.e. they had a sufficient numbers in cultivation to provide an insurance fund for the future).

Now we are working on the creation of a new database on rare plants. A preliminary comparative analysis of two databases was developed by the Commission in 2005 and in 2010 was carried out. Results of the analysis show that for the period between 2005 and 2010 there has been a growth in the number of the botanic gardens in Russia maintaining collections of rare species, as well as a marked increase in the overall number of conserved species and samples. According to preliminary data, the living collections of botanic gardens now contain about 64 % of rare species of the Russian flora. A further 73 species of the Red Data book of Russia are contained in *in-vitro* culture at five botanic gardens. The largest tissue culture collections are available in the Main Botanical Garden and the Volgograd Regional Botanical Garden. Thus, Russian botanic gardens have already achieved their main goal at the national level as stated by Target 8.

As for plants included in recovery and restoration programmes, until recently we did not have enough information. In 2007 the Commission on Rare Species of the Russian Botanic Gardens, together with the Russian Division of BGCI conducted a questionnaire regarding the reintroduction of plants conserved in botanic gardens. Fifteen institutions provided information. The list of species reintroduced by botanic gardens in recent years comprises about 100 species. However, only 28 of these species are listed in the National Red List that makes 4 % of the total number of threatened species. Other species are referred to regional levels of protection. In the near future various botanic gardens in Russia are going to develop reintroduction projects for further rare species. However the lack of a general methodology on reintroduction was a major impediment in the success of these activities. In order to stimulate recovery and restoration programmes “Methodological recommendations for botanic gardens on the reintroduction of rare and threatened plants” was prepared and published in 2008 in English and Russian.

Target 14. The importance of plant diversity and the need for its conservation incorporated into communication, educational and public-awareness programmes. It is evident, that this target coincides with the main functions of botanical gardens – being educational centres. The GSPC is widely used among Russian botanical gardens in implementation of educational programmes. The most active in developing original educational programmes are the botanical gardens of Tver and Moscow State Universities.

Conclusion

We would like to make several comments on the new GSPC project for the period of 2010-2020.

1. In order to facilitate the development of National and Regional SPCs in countries still lacking such strategies we need to prepare (on the basis of already existing strategies) “Model or standard national (regional) strategy” or recommendations on compilation of such strategies.
2. Target 2. Coordination between Russian botanical institutions and international ones should be strengthened. For example, only a small number of Russian Red Data Book species, including endemics, are listed in the European list and IUCN Red List. Suggested projects such as the “Rapid list” make evaluation of species status less time consuming, but does not really solve the problem of compilation of the global endangered species list.
3. Target 3. Methodological recommendation for botanical gardens should be developed, for example general methodological principles of rare species conservation *ex situ*. This particularly concerns the procedures for material collection for conservation and evaluation of genetic diversity of conserved material. International experience on reintroduction and recovery of rare species populations should be examined and summarized in a general manual on plant reintroduction (on the basis of already published manuals in the UK (BGCI) , Australia, Russia).
4. In Russia, most problems in plant diversity conservation are experienced in steppes and mountainous regions. In steppe reserves the science based regime of vegetation maintenance should be developed. In mountainous regions there are a small number of reserves. We need more close international cooperation to develop general methodological approaches to plant diversity conservation in this ecological region.

5. Target 5. It is not always possible that botanically important territories are protected by government on national and regional levels. As for Russia it is much easier to obtain protection status for zoological objects. Thus it is increasingly important that "key botanical territories" receive international conservation status. In this situation it will be much easier to engage local conservation institutions and people in the protection of selected territories. It could activate the work on Target 14 as well. We suggest that a special protocol on registration of "key botanical territories" should be developed under the IUCN umbrella.

6. It is necessary to include the Russian botanical gardens network, coordinated by the Russian Botanic Gardens Council and BGCI, into the Global Partnership for Plant Conservation. Botanical gardens have sufficient resources and highly professional staff for implementation of work directly correlated with the GSPC's targets on plant conservation *ex situ* and *in situ*. The Russian Botanic Gardens Council can play a coordinating role in implementing the GSPC.

Monitoring plant species response to climate change

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Abstract

Plant traits and reproductive capability of the natural *Bidens cernua* population at Posta Fibreno Lake Reserve and a newly introduced population were analysed. *Bidens cernua* was included in the Red List of Italian Flora as a critically endangered species (CR) for *Latium* (Italy), because of its extremely local distribution and lack of representation in other protected areas in Italy. At phenological level, the life cycle phases of the new population (P), originating from the seed of the reintroduced plants, were not significantly different in length from those of the natural one (P_{nat}). However, P relative growth rate was 4 per cent higher than of the natural population and P plant dry mass was significantly higher than that of P_{nat}. Moreover, P produced 17 per cent more flower heads per plant than those of P_{nat}. The relatively high SLA (228 ± 27 cm^2 g^{-1}, mean value of P_{nat} and P) underlined *B. Cernua*'s strategy to invest mostly in leaf area over mass, thus increasing the potential capability of light interception. P had the potential to function in a manner that was demographically similar to P_{nat}. The newly created population of *B. cernua* will be monitored over subsequent years to evaluate plant traits and reproductive capability variations in the long term.

Keywords: conservation, growth analysis, reintroduction, threatened species

Introduction

Monitoring plant species' response to climate change has been identified as a crucial component of global change research programmes. Botanic gardens can play a major role in monitoring the conservation status of threatened species, outlining practices for reintroduction. The need for an integrated approach, utilizing both *in situ* and *ex situ* techniques to support wild populations has been promoted by botanic gardens and the European Botanic Garden Strategy underlines the need for specific regional conservation collections linked to protected area activities (Maunder *et al*., 2001). The reintroduction of species into natural or semi-natural habitats is becoming an increasingly popular strategy for conservation, especially when wild population number and size are small and habitat is fragmented (Münzbergová *et al*., 2005). Nevertheless, the success of plant species reintroduction remains a question of population viability, involving demographic, genetic, behavioural and ecological processes (Jusaitis *et al*., 2004; Münzbergová *et al*., 2005). Life history traits of wild species are rarely known, so reintroduction can be risky, leading to high mortality (Drayton & Primack, 2000). Reintroduction of threatened species can be used to either secure or improve the status of protected areas.

Numerous attempts have been made to create new populations of threatened species by translocation (Jusaitis, 1997; Mueck, 2000; Husband & Campbell, 2004). Nevertheless, only a few studies demonstrate their self-sustainability through growth capability, reproduction, and long-term persistence (Jusaitis *et al*., 2004). Knowledge of population trends is an important element in the evaluation of the real extinction risk (Kozlowski, 2008). Thus, the newly created populations should be monitored in subsequent years.

Bidens cernua L. is a nitrophilous species, growing on river banks, lakes and in wet ditches, preferring rich muddy soils, usually with its roots submerged: it is distributed in Europe, Asia and North America (Brändel, 2004). *B. cernua* is included in the Red List of Italian Flora as a critically endangered (CR) species for *Latium* (Italy) (Conti *et al*., 1997), because of its extremely local distribution and the lack of representation in other protected areas in Italy.

The main objective of this research was to compare plant traits and reproductive capability in the *Bidens cernua* natural population growing at Posta Fibreno Lake Reserve, and the reintroduced population in the same area. To this aim, we have also used data collected by Gratani *et al*. (2008) and Gratani *et al*. (2009). A significant threat to small, isolated populations such as this one, is their sensibility to environmental, genetic and demographic stochasticity, according to Morgan (2000). The establishment of plants in secure and managed conservation reserves is crucial both to the survival of many species as their habitats continue to be destroyed, and to increase the number of individuals in a population (Jusaitis *et al*., 2004).

Materials and Methods

Study site

The study was carried out at Posta Fibreno Lake Reserve (*Latium*, 41°42' N, 13°41' E; 290 m a.s.l.), and at the Botanic garden of Rome (41°53′53″ N, 12°28′46″ E; 53 m a.s.l.). *Bidens cernua* wild population grew in a limited area (46.7 m^2), localized along the eastern lake coast ('Pantano Papiro' area).

Climate

The climate of Posta Fibreno Lake Reserve is of Mediterranean type, and most of the total annual rainfall (1150 mm) occurs in autumn and winter (Meteorological Station of Arpino and Frosinone, Regional Agency for Development and Agricultural Innovation, data for the period 2004–2007). The mean annual air temperature was 14.6°C.
The climate of Rome is also of Mediterranean type, and most of the total annual rainfall (676 mm) occurs in autumn and winter (Meteorological Station of the Collegio Romano, data for the period 1995–2007). The mean annual air temperature was 16.8 °C.

Seed collection and seedling cultivation

Freshly-matured seeds of *Bidens cernua* L. were collected at the beginning of November 2005 from 100 representative plants growing naturally at Posta Fibreno Lake Reserve, in the 'Pantano Papiro' area, and were transported to the Botanic Garden of Rome.

The collected seeds were stratified in a cold chamber at 5 °C for 4 months. Then they were placed in 4 fine-mesh polyester cloth bags, 30 seeds in each, and the bags were buried in moist sand in 9 x 9 cm diameter plastic pots with drainage holes (Brändel, 2004). Seed germination was carried out in light- and temperature-controlled chambers (Type CC7, Amcota), at 15–30 °C and 12-hour day-length, equipped with cool-white fluorescent tubes providing a PFD of 80 µmol m^{-2} s^{-1}.

150 randomly selected seedlings were grown and cultivated in a greenhouse, in black polyethylene plastic pots filled with peat (pH 7). At the beginning of May 2006 they were placed in 5 pools (1 m in diameter and 0.30 m deep), filled with water and put outdoors (Baskin *et al*.,1999).

Reintroduction

At the beginning of June 2006, 150 cultivated seedlings were transferred back to the original area, near the provenance population at Posta Fibreno Lake Reserve ('Pantano Papiro' area). Three plots (1 x 1 m), subdivided into 100 grids (10 x 10 cm), were used as a planting template (Jusaitis *et al*., 2004).

New population monitoring

In 2007, the new population (P) originated from the seeds produced by the reintroduced plants was analysed. The phenological cycle, structural plant traits, morphological leaf traits, and reproductive capacity of P were analysed and compared with those of the natural population (P_{nat}) (Morgan, 2000).

Phenology

Phenological observations were carried out weekly, on 30 selected plants of P and P_{nat}, respectively. The times of seedling emergence, stem elongation, flowering, fruiting, and plant senescence were observed.

Flowering head production was analysed at the end of September by counting the number of heads on 100 plants each of P and P_{nat}, respectively. Seed production was determined in November by counting the number of seeds on 50 flowering heads each of P and P_{nat}, respectively.

Growth analysis

Observations were carried out weekly, on 30 selected plants, during the study period. Plant trait measurement included height (H, cm), total plant dry mass (PDM, g), and total leaf area per plant (TLA, cm^2) of P and P_{nat}, respectively. H was measured until its maximum was attained (end of August) in both P and P_{nat}.

At the beginning of September, 30 plants each of P and P_{nat} were harvested and separated into stems, leaves, and roots, and they were transported immediately to the Botanic Garden. Stems, leaves and roots dry mass was measured after oven drying at 80°C to constant mass, and PDM was determined. The above/below dry mass ratio was calculated.

TLA: calculated by multiplying total leaf number per plant by mean leaf area (LA, cm^2). LA was measured with the Image Analysis System (Delta-T Devices, UK).
Specific leaf area (SLA, $cm^2\ g^{-1}$): calculated as LA to leaf dry mass (LM, g).
The relative growth rate in plant height (RGR_H , $cm\ cm^{-1}\ d^{-1}$): calculated, as $RGR_H = \ln H_2 - \ln H_1/t_2-t_1$, where H_1 and H_2 were plant height at time t_1 (seedling emergence) and t_2 (maximum plant height).
The relative growth rate in plant dry mass (RGR_m, $g\ g^{-1}d^{-1}$): calculated as: $RGR_m = \ln PDM_2 - \ln PDM_1/\ t_2-t_1$ where PDM_1 and PDM_2 were the total plant dry mass at time t_1 (emergences) and t_2 (maximum total plant dry mass).

Statistics

Differences in the considered variables were determined by the analysis of variance (ANOVA), and Tukey test for multiple comparisons. All statistical tests were performed using a statistical software package (Statistica, Statsoft, USA).

Results

Phenology

There were no significant differences in the length of phenological phases between P and P_{nat}: seedling emergence took place in early May, when mean minimum air temperature was ≥ 10.0 °C. Leaves were produced from mid May to end August, when mean maximum air temperature was 29.8 ± 2.6 °C. Flowering started at the end of August, and fruiting from end September to end November. Seed dispersion started at the end of October and the senescence phase was from end October to mid December. Flower head production was significantly ($p \leq 0.05$) higher in P than in P_{nat} (4.2 ± 0.3 and 3.6 ± 0.2 flower head per plant, respectively). Seed production per flower head was not significantly different in P and P_{nat} (116 ± 11 seeds per flower head, mean value) (Table 1).

Plant traits

There were significant ($p \leq 0.05$) differences in H and TLA between P_{nat} and P, the latter having the higher values (47.1 ± .0 cm and 82.7 ± 6.0 cm^2, respectively) (Table 2). There were no significant differences of SLA in P and P_{nat} (228 ± 8 $cm^2\ g^{-1}$, mean value). PDM was 41 per cent higher in P than in P_{nat}, and the above/below dry mass ratio was 6.7 ± 0.4 and 4.7 ± 0.2 for P and P_{nat}, respectively (Table 2).

Growth analysis

RGR_H and RGR_m were significantly ($p \leq 0.05$) higher in P (0.047 ± 0.001 cm cm^{-1} d^{-1} and 0.057 ± 0.001 g g^{-1} d^{-1}, respectively) than in P_{nat} (0.045 ± 0.001 cm cm^{-1} d^{-1} and 0.055 ± 0.001 g g^{-1} d^{-1}, respectively) (Table 1).

Discussion

At phenological level, the life cycle phases of the newly created *B. cernua* population are not significantly different in length from those of the natural one. Seedling emergence occurs when mean minimum air temperature is ≥ 10.0 C°, and the maximum plant height is reached four months later. Vegetative activity finishes when mean maximum air temperature is 29.8 ± 2.6 °C. Plant senescence begins at the end of October and seedlings are completely dry by the middle of December. *B. cernua* flowering starts at the end of August and fruits from the end of September to the end of November. Nevertheless, the new population produces 17 per cent more flower heads per plant than those of the natural one, suggesting that it has some potential for longer-term persistence in the area, according to the results of Morgan (2000).

Plant growth is the result of the interaction between environmental factors and biomass allocation capability. RGR is a useful indicator of the extent to which a species is using its photosynthate for growth (Groeneveld, 1998). Plant species with a high intrinsic capacity to grow possess structures to efficiently capture and process resources from the environment (Cornelissen *et al*., 1998). The mean RGR, averaged over the assimilation period, can be used to characterize a species in terms of productivity (Larcher, 2003).

B. cernua RGR_m (0.055 ± 0.001 g g^{-1} d^{-1}, mean value over the study period of the natural population) is in accordance with the value calculated by Almeida-Cortez *et al*. (1999) for the same species. Nevertheless, RGR_H and RGR_m are 4 per cent higher in P than P_{nat}. Posta Fibreno Lake is a nutrient-rich environment (Montelucci, 1979) favouring a higher *B. cernua* dry mass allocation to leaves and stems (85 per cent of the total plant dry mass) than roots, according to the results of Müller *et al*. (2000). Moreover, the relatively high SLA (228 ± 27 cm^2 g^{-1}, mean value of P_{nat} and P) underlines *B. Cernua*'s strategy to invest more in leaf area than mass, increasing the potential capability of light interception, according to Gratani and Ghia (2002).

The results largely underline that the newly created population of *Bidens cernua*, characterized by a significantly higher plant dry mass than P_{nat}, has the potential to function in a manner demographically similar to the natural one at Posta Fibreno. The establishment of this new population is considered essential for long-term survival of *B. cernua* because its limited distribution in the *Latium* makes it vulnerable. Such a population would spread the risk of localized catastrophic failures, according to the results of Jusaitis *et al*. (2004) in other threatened plant species. The newly created *B. cernua* population will be monitored over subsequent years to evaluate plant traits and reproductive capability variations in the long term. Knowing the potential growth capability of the wild species is an asset in the conservation of native populations, monitoring the conservation status of threatened species and outlining practices for the reintroduction projects.

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Table 1 Mean values (± standard error) of plant traits in *Bidens cernua* newly created population (P) and the natural population (P_{nat})

	Population	
	P	P_{nat}
RGR_H (cm cm^{-1} d^{-1})	0.047±0.001	0.045±0.001
RGR_m (g g^{-1} d^{-1})	0.057±0.001	0.055±0.001
Number of flower head	4.2±0.3	3.6±0.2
Number of seeds per flower head	116±10	115±12*

RGR_H = relative growth rate in plant height, RGR_m = relative growth rate in plant dry mass. Mean values are significantly different ($p \leq 0.05$), except *

Table 2 Mean values (± standard error)of plant traits of *Bidens cernua* in new created population (P) and natural population (P_{nat})

	Population	
	P	P_{nat}
H (cm)	47.1±9.0	41.1±5.4
TLA (cm^2)	82.7±6.0	71.2±10.5
SLA (cm^2 g^{-1})	222±19	233±32*
PDM (g)	2.09±0.3	1.48±0.2
Above/below plant biomass ratio	6.7±0.4	4.7±0.2

H = plant height, TLA = total leaf area per plant, SLA = specific leaf area, PDM = total plant dry mass. Mean values are significantly different ($p \leq 0.05$), except *

Phenotypic plasticity for physiological and life-history traits of *Quercus ilex* L.

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Abstract

Seedlings of *Quercus ilex* germinated from seeds of parent plants from four different localities within the distribution area in Italy were analysed. The plasticity index for physiological leaf traits is higher than for morphological ones. The most favourable environmental conditions of Castelporziano increase the plasticity index, while the climate of Nago, Bellegra and Frassanito allows the specialization of leaf traits, determining a higher efficiency of the resource use in response to specific stress factors. Because plasticity influences environmental tolerance, different plastic responses may contribute to differences in the range of environments that species inhabit, and in the specific capability to maintain functioning in contrasting conditions.

Keywords: climate change, *Quercus ilex*, plasticity index, seed, seedling

Introduction

Drought, high air temperatures and high irradiance, for short or long periods influence Mediterranean species productivity (Gratani & Varone, 2004, Ósorio *et al*., 2006). Nevertheless, plant response may vary among species, and among populations of the same species, depending on their adaptive capability. Considerations of adaptability involve an interest in plant species' response to the forecasted increase of air temperature and drought in the Mediterranean Basin.

Among the Mediterranean evergreen species, *Quercus ilex* L. is widely distributed in the Mediterranean Basin, extending longitudinally from Portugal to Syria, and latitudinally from Morocco to France (Valladares *et al*., 2000a). It seems to be limited in its southern range by increased summer drought and in altitude by factors associated with low air temperature. Michaud *et al*. (1992) observed a homogeneous genetic structure of *Q. ilex* in the Mediterranean region, with only slight geographic variations due to isolation (i.e. North Africa and Sicily). *Q. ilex* is used for restoration of heavily deforested areas and abandoned croplands of the Mediterranean Basin; nevertheless its seedlings have a low survival in plantations compared to other Mediterranean woody species, depending on their vulnerability to water stress in early life, particularly during the first summer drought following planting (Villar-Salvador *et al*., 2004).

The main objective of this research was to analyse the plasticity index of *Quercus ilex* seedlings developed from different populations of acorns in Italy. Plasticity is considered a measure of the phenotypic difference of a species in various environments (Valladares *et al*., 2000a), and it may also play a critical role in the response of natural populations to selective pressure in variable environments in respect of global change. In the last 15 years there has been an increasing interest in the capacity of a given genotype to express different phenotypes in different environmental conditions, nevertheless, only recently has plasticity been recognized as a significant way to evaluate diversity.

Materials and methods

Study localities

Four different localities along a gradient from the north to the south of Italy were considered: Nago (site N, 45°55' N, 10°53' E, 260 m a.s.l.) at the northernmost distribution limit, characterized by a transitional climate with intermediate characteristics between the pre-alpine and the Mediterranean climate (low winter air temperatures and frequent frost periods); Bellegra (site B, 41°53' N, 13°01' E, 815 m a.s.l.) under a temperate type of climate (low air temperature in winter); Castelporziano (site C, 41°45' N, 12°26' E, at sea level) under a Mediterranean type of climate (moderate drought stress); Frassanito (site F, 40°13' N, 18°26' E, at sea level) under a Mediterranean type of climate (strong drought stress).

Acorn collection and measurements

Quercus ilex acorns were collected at the end of November 2006 from 10 representative shrubs per locality. The acorns were transported to the Botanic Garden of Rome. The Botanic Garden area's climate was of the Mediterranean type.

The acorn fresh mass (FM) and the maximum acorn diameter (D, mm) were measured, this last by a digital micro calliper (Haglöf, S). The acorn volume (V, cm^3) was calculated (Aizen & Patterson 1990).

Acorn sowing and germination

At the beginning of December 2006, 20 acorns per locality were sown in plastic pots and filled with a sandy-peat mixture, according to Aranda *et al*. (2004). Acorns were sown at approximately 2 cm depth in the topsoil, and covered with the respective litter collected in the original localities. The pots were kept outdoors under natural conditions and watered regularly to the field capacity.

Seedling measurements

Seedling height (H) was monitored 18 months after germination on 10 seedlings for each locality. The relative growth rate in height (RGR_H) was calculated by the equation: $RGR_H = (\ln H_2 - \ln H_1) / t_2 - t_1$, where t was the time in days and H_1 e H_2 were the seedlings' height at t_1 and t_2.

Leaf morphology and anatomy

Morphological and anatomical traits were analysed on 20 fully expanded leaves (per locality). Measurements included leaf area (LA, by the Image Analysis System Delta-T Devices, LTD, England), leaf dry mass (DM, oven-dried at 90°C to constant mass), leaf mass area (LMA, leaf dry mass per unit leaf area). Leaf tissue density (LTD) calculated by the ratio of DM, and leaf volume (V, by the product of LA and leaf thickness). Leaf thickness was measured by leaf sections hand-cut from fresh fully expanded leaves per locality and analysed by light microscopy.

Gas exchange measurements

Net photosynthesis (P_N), stomatal conductance to water vapour diffusion (g_s), transpiration rate (E) and leaf temperature (T_l) were monitored in January, April and July 2009, with an infrared CO_2 gas analyser (ADC-LCA4, UK), equipped with a leaf chamber PLC4 (ADC, Hoddesdon, UK). Measurements were made on cloud-free days, in the morning (08:30 to 10:30 a.m.), on four leaves per seedling (per each sampling occasion). The collected gas exchange data (P_N, g_s) were grouped in sequences of air temperatures (Gratani *et al*. (2003).

Experiment of imposed water stress

The experiment of imposed water stress was carried out in July 2009. Water was withheld from 5 seedlings per locality to generate stress. The control seedlings were watered regularly to field capacity. During the experiment, diurnal air temperature was 24 to 29°C, and air humidity 70 per cent in the early morning and 40 per cent at midday.

P_N, E and g_s were monitored during the imposed water stress experiment on fully expanded leaves.

Predawn leaf water potential (Ψ_{pd}) was measured the first and the last day of the experiment on fully expanded leaves (control) and on fully expanded stressed leaves, with a pressure chamber (SKPM 1400 Skye Instruments, UK).
Relative water content at predawn (RWC_{pd}) was determined on the same leaves used for Ψ_{pd} measurements. RWC_{pd} was calculated as RWC = (FM – DM)/(TM – DM) x 100, where FM was the leaf fresh mass, TM the leaf mass after rehydration until saturation for 48 h at 5°C in the darkness.

Index of phenotypic plasticity
The index of phenotypic plasticity was calculated for each variable as the differences between the minimum and the maximum mean values divided by the maximum mean value, according to Valladares *et al*. (2000b).

Statistics
The differences of acorn and seedling traits were determined by the analysis of variance (ANOVA), and Tuckey test for multiple comparisons.

All statistical tests were performed using a statistical software package (Statistica, Statsoft, USA).

Results

Acorn traits
F and B acorns had the significant ($p \leq 0.05$) highest V and FM, while N acorns had the lowest. C acorns were in an intermediate position.

Seedling growth
Seedling growth occurred when mean minimum air temperature was 10.2±1.0°C at the middle of March for B, F, and C seedlings, and at the end of March for N seedlings. The observation of seedling growth finished at the middle of June when mean maximum air temperature was 29.9±1.9°C.

B and F seedlings had the highest RGR_{max} (0.235±0.028 mm mm^{-1} d^{-1} and 0.203±0.011 mm mm^{-1} d^{-1}, respectively), while N seedlings had the lowest (0.087±0.005 mm mm^{-1} d^{-1}). C seedlings had intermediate RGR_{max} value (0.140±0.005 mm $mm^{-1}d^{-1}$).

B, F and C seedlings showed the highest H (258±21 mm, mean value), and N seedlings the lowest (118 ± 37 mm)

Leaf morphology
LMA was the highest in B and F seedlings (14.1±0.8 mg cm^{-2}, mean value). LMA of C and N seedlings was 15 per cent lower than B and F ones. LTD was 729±25, 602±29, 538±35 and 534±39 mg cm^{-3}, in N, B, F and C, respectively.

Gas exchange
At the lowest air temperatures (7 to 9 °C) N and B seedlings had the significant ($p \leq 0.05$) highest P_N (7.8±0.2 μmol CO_2 m^{-2} s^{-1}, mean value), while at the highest air temperatures (29 to 31 °C) F seedlings had the significant ($p \leq 0.05$) highest P_N (7.5±0.4 μmol CO_2 m^{-2} s^{-1}).

g_s had the same P_N trend, with the highest g_s rates for N and B seedlings (0.05±0.01 mol H_2O m^{-2} s^{-1}, mean value) at the lowest air temperatures, and for F seedlings (0.11±0.01 mol H_2O m^{-2} s^{-1}) at the highest air temperatures.

Experiment of imposed water stress
By day four of the experiment, P_N of N stressed seedlings had the highest decrease (37 per cent) and F the lowest (10 per cent). By day five, P_N of all the considered seedlings was near zero.

g_s of the considered seedlings had the same P_N trend.

On the first day, ψ_{pd} did not significantly differ among the considered stressed seedlings (0.9±0.1 MPa, mean value). By the fifth day, ψ_{pd} had decreased on an average 74 per cent in N and B seedlings, and 67 per cent in C and F seedlings.

By the fifth day of the experiment, RWC_{pd} was 86±2 per cent in F, C, and B seedlings (mean value) and 81±1 per cent in N seedlings.

Plasticity index

The plasticity index of the seedlings was the lowest for the considered morphological traits (0.24, mean of the considered traits) than for the physiological ones (0.68, mean of the considered traits). The mean plasticity index (morphological and physiological traits) was the highest in C seedlings (Table 1).

Discussion

The results on the whole indicate that *Quercus ilex* seedlings grown in a common garden and developed from seeds of different provenance in Italy are characterized by several features, which seem to be the expression of the climate of the original localities, according to Baquedano *et al*. (2008) and Zheng *et al*. (2009).

The Nago acorns' small size could be related to the scarce plant assimilates for the developing acorns at the original locality (Gratani *et al*., 2000). At the other extreme, the large size of the Frassanito and Bellegra acorns might be justified by the drier climatic conditions of their original localities. Castelporziano intermediate acorn size is the result of the favourable climatic conditions of the original localities, according to the results of Valencia-Diaz & Montaña (2005). Seedling height and RGR_{max} are significantly related to FM; in particular, Frassanito seedlings have the highest RGR_{max} because there are sufficient acorn reserves to allow growth for a much longer period (98±3 days from acorn germination to the end of the spring vegetative period), according to Pons & Pausas, 2007).

At physiological level, N, C and B seedlings have a different response to air temperature and water stress. Frassanito seedlings show the highest stomata sensitivity to changes in leaf water potential, i.e. they adjust to drought by the best stomatal control of transpiration. The decrease of water loss per transpiration by stomatal closure paralleled by the water potential, allows Frassanito seedlings to maintain a sufficiently high RWC at predawn determining sufficient P_N rates. Moreover, drought stress has selected for more scleromorphic leaves (i.e. the highest LMA).

Seedlings from parent plants acclimatized to Nago and Bellegra are able to sustain sufficient P_N rates at the lowest air temperatures; moreover the small LA and the highest LTD appear to be the best adaptation in response to winter cold stress at both these localities.

Phenotypic plasticity for physiological and life-history traits may allow plants to grow and reproduce in spatially or temporally variable environments (Gratani *et al*. 2003). Traits involved in the same function are also more highly correlated at phenotypic and genetic levels than they are with traits which have different functions or developmental origins; selection for photosynthetic traits may often operate indirectly via correlations with other traits (Arntz & Delph, 2001). Because adaptive plasticity influences environmental tolerance, different plastic response may contribute to differences in the range of environments that species inhabit in the field (Ackerly *et al*., 2000).

The results underline that the plasticity index of the considered seedlings is significantly lower for morphological traits than for physiological ones. The mean plasticity index (morphological + physiological plasticity) is the highest in C seedlings, reflecting the most favourable environmental

conditions, while the climates of Nago, Bellegra and Frassanito allow the specialization of leaf traits determining a higher efficiency of the resource use in response to specific stress factors**.**
Climate change may act as a potent agent of natural selection among *Quercus ilex* populations (Alistair & Peñuelas, 2007). Box & Choi (2000) indicate an expansion of *Q. ilex* northward and inland under warming. Thus, plasticity index may be used to draw the species response to increasing stress factors. *Q. ilex* acorn size and seedling traits from different localities in Italy might be used in afforestation and restoration programmes; in particular, Frassanito ecotype could have great potential in resource-limited areas of the Mediterranean; its high RGR and low vulnerability to water stress could be advantageous in the establishment phase during the first summer drought following planting in afforestation projects.

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Table 1. Plasticity index for *Quercus ilex* morphological (LA = leaf area, DM = leaf dry mass, LMA = leaf mass area and LTD = leaf tissue density) and physiological traits (P_N = net photosynthesis, g_s = stomatal conductance, *E* = leaf transpiration, WUE = water use efficiency, $\square_{pd}$ = leaf water potential at predawn)

Morphological traits	Seedlings			
	N	C	B	F
LA	0.16	0.44	0.25	0.28
DM	0.18	0.47	0.32	0.35
LMA	0.17	0.24	0.12	0.11
LTD	0.17	0.26	0.10	0.11
Mean value	0.17	0.35	0.20	0.21
Mean value of considered traits	0.23			

Physiological traits	Seedlings			
	N	C	B	F
P_N	0.39	0.40	0.41	0.45
g_s	0.75	0.83	0.73	0.88
E	0.76	0.78	0.77	0.75
WUE	0.82	0.75	0.82	0.57
$\square_{pd}$	0.72	0.73	0.70	0.65
Mean value	0.69	0.70	0.69	0.66
Mean value of considered traits	0.68			

N = Nago, C = Castelporziano, B = Bellegra, F = Frassanito

Cycad collections development in the modern context: Challenges, opportunities, investments and outcomes.

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Abstract

This case study explores 21st Century living collections development within four modern contexts, analyzing several examples, united by three critical components. The modern contexts – Challenges, Opportunities, Investments, and Outcomes – provide an approach to decision making and evaluation for the collections development process. These examples illustrate the intersection of Collaboration, Research, and Development, three inseparable components of the modern collections development process. This case study is focused on the cycads, as these living treasures exemplify the role of *ex situ* conservation work.

Keywords

Collaboration; cycads; decision making; evaluation; planning; plant collections; research.

Collections development in the modern context

Gardens are built fundamentally around plant collections, and do not exist without them. The nineteenth and twentieth centuries saw tremendous effort and success in developing these collections. This work was difficult, fraught with mortal danger (Short, 2003). Modern plant collecting is thankfully much safer, but broader in scope as shown below.

Discussion on plant collection ethics and philosophy is well developed. We assume readers of this volume are familiar with the relevant canon and best practice. Here, we focus on the functional aspect of collections development in an organizational framework, and illustrate how this work moves forward in the 21st century.

Methods of modern strategy development are often advanced and criticized (Piercy & Giles, 1993; Hill & Westbrook, 1997). We employ four parameters in strategic decision making for cycad collections. The first of these are **Challenges** to plant populations and species. We consider how **Opportunities** influence the collections development process. **Investments** and **Outcomes** are the remaining parameters for decision making, representing efforts required versus results obtained.

Components of modern collections development

In traditional plant collecting referenced above, both investments in and outcomes from plant collections were narrowly focused on obtaining living plants for cultivation elsewhere. Current plant collecting is embedded in a broader framework. Three basic inseparable parts of current plant exploration practice are **Research**, **Collaboration**, and **Development**. The current study discusses how these interdigitate to produce parallel outcomes.

Case study: MBC cycad collections.

Montgomery Botanical Center (MBC) is organized around living collections of cycads, which contribute broadly to science, education, and conservation (the palm collection is an equal, parallel focus; Noblick *et al.*, 2008). This cycad collection has great breadth (Table 1), and especially significant depth in *Dioon* and *Zamia*. Two thirds of cycad species are represented, and 60% of taxa and over 85% of accessions and plants are of known wild provenance. Although the collections date back to 1932, the majority were developed since 1994, with an accelerating rate of development since 2007 (Calonje *et al.*, 2009a). Three examples of recent collections development work are presented below.

First Example: *Cycas micronesica*

Cycas micronesica is Endangered and native to western Pacific islands (Figure 1). An invasive insect (*Aulacaspis yasumatsui*) has reduced populations on Guam by up to 80% since 2003 (Griffith and Calonje, 2007).

Rapid decline presents a clear crisis for this species. One result of this rapid decline is intense research interest in this cycad. MBC participated in extensive fieldwork (Figure 2) for population genetic research (Cibrian et al., 2008; 2010). A broad, multi-institutional team involving the University of Guam (UoG), New York Botanical Garden (NYBG), and MBC performed an intense month-long field sampling project, which also developed *ex situ* collections for MBC. MBC recently planted its most extensive single-species cycad collection derived from this fieldwork (Griffith and Husby, 2010). Further information is on the MBC website.

Analysis

This project reveals how the modern contexts (in this paper's title) guide decision making and evaluation for current collections development. Additionally, clear interlocking of collections development, research and collaboration is apparent. Here, the *challenge* is obvious: population extirpation, and possible extinction. An *opportunity* for extensive collections development fieldwork was located. This was coupled to scientific research, and was accomplished strictly within a clearly outlined collaborative framework. MBC, NYBG and UoG each made significant *investments* of resources in the work. *Outcomes* included important and novel research papers, and focused development of vitally important conservation collections.

Second Example: *Zamia decumbens*

For a Palaeozoic order with relatively few extant species, much cycad diversity remains unexplored. The Sinkhole Cycad is one such example. Fieldwork from 1997-2000 in Belize produced a few living collections, some herbarium specimens, and photographs of an intriguing *Zamia* which was known only from the bottom of two sinkholes. Total wild plants were estimated at less than 100, with only 7 plants in *ex situ* collections, and only at one garden (MBC). Wild-harvested seed were reportedly being traded, although origin of the material was uncertain. These plants were determined as *Z. prasina*, authored by William Bull in 1881. Yet, close examination of the *Z. prasina* type specimen showed some differences with the sinkhole cycad.

In short, here was a poorly understood, unique, very rare cycad, with inadequate *ex situ* representation. These factors prompted reaching out to collaborators in Belize. Jan Meerman, ecologist at Green Hills Botanical Collections (GHBC), Belize, had studied diversity in Belizean cycads since the 1990s, and with Jan we organized a joint project to evaluate, collect, and study this diversity. Partnering also with cycad expert Dr. Miguel

Angel Perez-Farrera from the Universidad de Ciencias y Artes de Chiapas, MBC developed funds, obtained permission, and performed fieldwork in 2008.

Obtaining these data and collections from remote field sites was challenging (although it could be much worse; see Griffith, 2005), but putting in this effort is essential to expand understanding of plant diversity (Figure 3). Direct results of these efforts were multifold. First, we now count over 300 extant plants in the wild, three times as many as were known before. Whereas there were previously only 7 plants at one garden, there are now over 120 in protective cultivation at MBC, GHBC, and Belize Botanic Gardens. In-depth field study revealed that the Sinkhole Cycad was in fact a new species, *Zamia decumbens* (Calonje *et al.*, 2009b), separate and distinct from *Zamia prasina* (Calonje and Meerman, 2009).

Analysis

This project shows clear use of modern decision making and evaluation contexts. A conservation challenge was noted, a limited population under harvesting pressure; a collaborative opportunity was developed; multiple institutions invested in the fieldwork; and publications, living *ex situ* collections, and greater understanding were the outcomes. A report on the MBC website provides further information.

Third Example: The Caribbean *Zamia* Project

Caribbean *Zamia* species have been extensively studied, yet remain poorly understood. Variability within and amoung populations plays a role here, as well as the physiographic nature of the Caribbean; barely distinguishable populations on different islands are sometimes given different names. This complex of species and populations is distributed over seven countries, so even political boundaries may have added to the taxonomic complexity. Dr. Alan Meerow of the USDA has studied these plants extensively. One recent breakthrough was his development of microsatellite markers for the Caribbean *Zamia* (Meerow and Nakamura, 2007). This advancement enables detailed assessment from the molecular genetic perspective.

Analysis

Examining this ongoing project in the modern contexts shows an exemplary model for collections development. Multiple challenges here are scale, scope, complexity, and capacity. By partitioning the project and working closely with collaborators, opportunities for fieldwork have been maximized. Field projects in Jamaica (2008), Dominican Republic (2009) and The Bahamas (2009-2010) involved the USDA, MBC, Fairchild Tropical Botanic Garden (FTBG), Jardín Botánico Nacional Dr. Rafael Moscoso de Santo Domingo (JBSD), The Bahamas National Trust, and the Plant Conservation Centre of Kingston. Including labwork and herbarium research, NYBG and Florida International University would be added to the list. Immediate plans for further fieldwork will bring Instituto Ecología y Sistemática into the project – making this an exceptionally broad collaboration throughout the Caribbean (Figure 4). Thus, investments have been broad and multi-institutional. Outcomes are even broader than investments. Research papers are forthcoming, and new living collections are cultivated at each participating garden, as well as distributed to colleagues in Xalapa, Mexico (Instituto de Ecología), Shenzen, China (Fairylake Botanic Garden), and Kirstenbosch, South Africa (SANBI). An unprecedentedly high level of integration of genetic, phytogeographic and morphological data with the living collections distinguishes this project.

The synthesis

Cycad collections exemplify the best aspects of a botanic garden living collection, and especially so when the modern contexts are considered. Cycads present many conservation *challenges*; there are tremendous research *opportunities* for these fascinating treasures; *investments* in colleagues, collections, and research is essential; and the *outcomes* of this work are important, tangible, and set the stage for further advancement of botany.

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Figure 1: *Cycas micronesica*, an Endangered cycad of the western Pacific. Prior to 2003, this was the most common canopy tree on Guam.

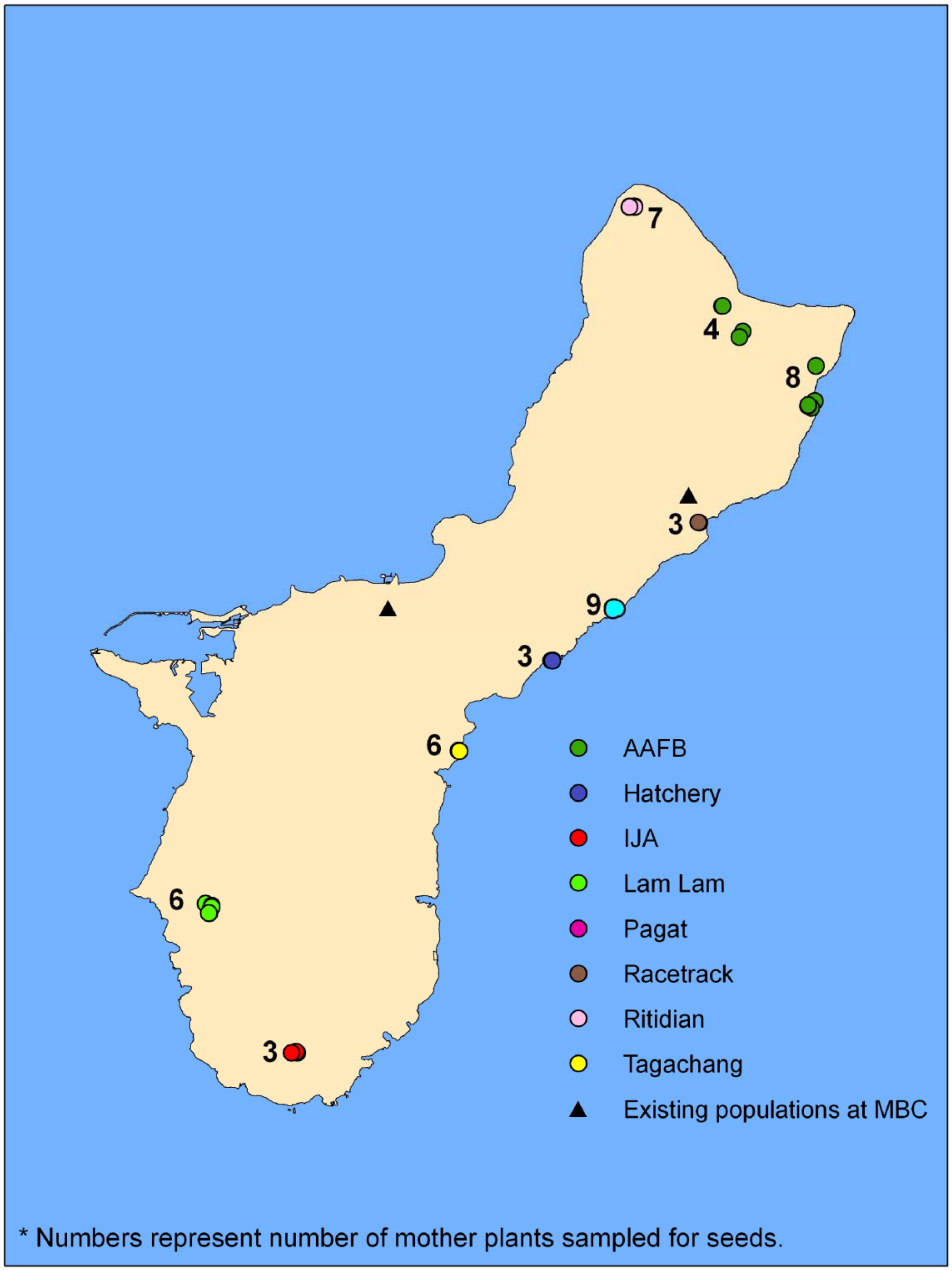

Figure 2: Accessions of *Cycas micronesica* collected in Guam during fieldwork in 2007. Phytogeographic and genetic diversity are important parameters in current collections development, especially for *ex situ* conservation purposes.

Figure 3. *Zamia decumbens* at the type locality, a sinkhole in southwestern Belize.

Figure 4. *Zamia pumila* at JBSD with Alberto Veloz, Javier Francisco-Ortega, Michael Calonje, and Francisco Jiménez Rodríguez.

Table 1.

MBC Cycad Collections, 2010.

Taxa (total)	227
Taxa: (wild collected)	202
Accessions: (total)	1,484
Accessions (wild-collected)	1,265
Plants (total)	3,756
Plants (wild-collected)	3,255
Valid taxa of Cycads:	339
% of taxa at MBC:	66%
% of taxa with data at MBC:	60%
% of accessions with data	85%
% of plants with data:	86%

Data are from the most recent inventory, January 2010. The taxonomic authority is Osborne *et al.* (in press).

Testing bioclimatic hypotheses with botanic garden collections - curatorial considerations

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Abstract

Hardy plant accessions for botanic garden collections can be chosen with the help of bioclimatic vegetation maps. If plants grown in the collections are of known provenance one can study their survival in relation to source zone. This offers a framework for testing the validity of vegetation maps. We used such plant accessions to test the validity of the vegetation zoning for the northern hemisphere developed by Finnish scientists. We estimated the probability of survival of accessions in relation to their source zone in order to see if plants moved to the target location from a putatively corresponding vegetation zone have a higher probability of survival than plants moved from milder or harsher zones. The actual results are reported elsewhere; the focus of this paper is on the suitability of botanic garden collections for this kind of a study. Due to various horticultural and curational problems we were only able to utilize ⅓ of the available accessions. This resulted in parts of the realized analyses becoming unreliable. We found the deterioration of the collection data to be a waste of the original acquisition effort. We therefore conclude that for botanic gardens to ensure the scientific value of their collections, it is better to have fewer accessions with well-maintained data represented by many individuals than to grow large numbers of accessions with single individuals and poor data. If this principle is adhered to, we see good potential for botanic garden collections also in research on plants and climate change.

Key words

Bioclimatic zone system, boreal, curation, hardiness, phytogeography, provenance, vegetation zone, zonation

Introduction

A substantial part of the work of botanic gardens (henceforth BGs) deals with growing exotic plants. Especially in harsh climates, selecting the right provenances of plants to be grown is crucial for their success. The selection can be guided by vegetation maps, since climate is among the decisive factors governing the occurrence of plants and, therefore, the vegetation they form. Many practices for dividing the world's vegetation into smaller entities have been presented (Holdridge, 1947; Walter, 1976). One approach is to delimit climatically defined vegetation zones and regions whereby so-called bioclimatic vegetation maps can be drawn (e.g. Thornthwaite, 1948; Krajina, 1959; Küchler 1964; Hare & Richie, 1972; Walter, 1979; Box, 1981; Rivas-Martinez & Rivas-Saenz, 1996-2009). These can be applied to choose plant accessions from other parts of the world with the expectation that plants transferred between bioclimatically corresponding areas should succeed in the target location. This principle is routinely applied in forestry and horticulture but actual tests of the validity of bioclimatic vegetation maps seem to be scanty.

If plants grown in BG collections are of known provenance one can study their survival in relation to source zone. This offers a framework for testing bioclimatic theories. Therefore, BG collections can improve our understanding of plant survival in relation to climate and the range of climatic conditions that plants tolerate. This in turn can offer important information on plants in a changing climate.

We used BG plant accessions of known provenance to study the validity of a bioclimatic vegetation scheme. We tested if plants moved to the target location from a putatively corresponding vegetation zone have a higher probability of survival than plants moved from milder or harsher zones. The actual results of the study are thoroughly reported elsewhere (Hällfors *et al.*, submitted manuscript). The focus of this paper is on the quality and suitability of BG collections as a basis for this kind of a study, and on implications for the curational practices of the collections. We conclude with some recommendations for BG horticulture and collection curation.

Material and methods

We used Helsinki University Botanic Garden's (HUBG) collection in Kumpula to test the vegetation zoning developed by Finnish scientists during the mid and latter part of the 20th century (Kalela, 1961; Ahti *et al*., 1968; Hämet-Ahti *et al.,* 1974; Ahti, 1980; Tuhkanen, 1980, 1984; Hämet-Ahti, 1981). This so-called bioclimatic zone system (BZS; Goward & Ahti, 1992) divides the northern parts of the northern hemisphere into phytogeographically and climatically corresponding regions (Hämet-Ahti, 1981). According to the BZS, Helsinki is situated in the northernmost part of the hemiboreal zone (Fig. 1). The studied plant material consisted of accessions of known wild origin collected in the 1990's. Four expeditions were carried out and yielded accessions as follows: Japan 1993 (402 accessions), China -94 (336), Canada -95 (250), Japan -99 (55); the total number of accessions was 1,043.

HUBG's database T-puska (Lipponen & Schulman, 2005) was used as the primary source of data. The aim was to define, for each accession, the number of plants originally planted and the number still alive in the years 2007-2009, when the data were collated. From these numbers we calculated the proportion of surviving individuals in each accession. These accession-wise proportions were then pooled within each of the source zones, resulting in a single survival probability characterizing the zone. To test the BSZ hypothesis, the survival proportion of each of the zones was compared to that of the hemiboreal zone, the one where HUBG is situated. The comparison of proportions was done using logit models (Collett, 2002). The results of the comparison of the survival proportions are represented as Odds Ratios (OR), which can be used to describe proportions and to compare probabilities (Komonen & Rita, 2008).

Simultaneously with the collation of the data, the usefulness and quality of the information on each of the original accessions were evaluated. This resulted in the following step-wise reduction of accessions to be included in the final analyses:

1. For 92 accessions there were no follow-up data. These accessions had been collected and entered into the database but since then information about them has, for some reason, never been updated. Removing these left 951 accessions to be treated further.
2. The number of accessions that never germinated, died as seedlings or were removed from the collections before leaving the nursery was 198. Thus, 753 accessions remained.
3. For enabling statistical analyses we had to discard all accessions with fewer than five planted individuals. This meant removing a further 138 accessions from the data, leaving 615.
4. A total of 120 accessions had to be abandoned for one of the following reasons: the accession had not been collected in the wild but from e.g. another garden during the expedition; there was no mentioning of collection zone; parts of or whole accessions were planted in the other collection area of HUBG where local climate and gardening practices differ somewhat from those in Kumpula; the curational data were too deficient to be included in the study (there were either obvious errors in the original or later counts or the up-dating had been too infrequent leading to plants having disappeared in between counts without an obvious reason or, in some cases, we suspected that plants had reproduced in between counts). After these exclusions we were left with 495 accessions.
5. During the process of qualifying accessions presented above, we became aware that there still existed some problematic cases. The information concerning some accessions was

difficult to interpret. We decided to discard accessions of species in which the individuals are difficult to define and, therefore, to count accurately. We also decided to discard species that we suspected are naturally short-lived whereby deaths of individuals possibly were not caused by external factors. We were also more skeptical to questionable entries in the database and decided to discard an accession if the recorded data about it were somehow dubious. Because we wanted to divide species into life forms we also discarded some large woody species that could not be readily defined as either a tree or a shrub. In order to avoid extra noise due to these problems we decided to discard from the dataset a further 116 accessions.

In the end the study material consisted of 379 accessions, which is about 36% of the 1,043 accessions originally available.

Results

According to our hypothesis, the survival probability characterizing the hemiboreal zone should be the highest, and the zone-specific probabilities should decay progressively when moving to zones further away from the hemiboreal one. However, the results show a somewhat different picture (Fig. 2). The survival probabilities increase from the temperate zone towards hemiboreal, as expected, but the highest survival probability is exhibited by plants from the middle boreal zone.
This could have been interpreted as a reason to refute the hypothesis. However, we continued by dividing the accessions into life forms (e.g. woody species and herbaceous) to single out possibly differing responses caused by differences in life history traits.

The woody accessions, when analysed separately, showed a more similar signal to what we expected (Fig 3). There are no unexpected deviations in the curve. Also, the survival probability within the different subzones of the boreal region are similar to each other, while there is a substantial drop in the probability of survival in the temperate and hemiarctic accessions. The results for the herbs, however, show no clear or logical signal and the overall picture is completely different from the expected (Fig. 4).

Discussion

The prerequisites for this study were good considering the large collection of accessions of known wild origin. Unfortunately, though, problems with the data left us with only c. ⅓ of the original number of accessions in the database for the actual analyses. This, we believe, affected the results of the study. For example, of the more than 170 original herbaceous accessions, we could analyse only 72. The numbers of herbaceous accessions originating from the more northern bioclimatic zones hence became very low (middle boreal zone: n=2; northern boreal zone: n=2; hemiarctic zone: n=4). Our conclusion, therefore, is that the results on the herbs are not at all reliable.

The difference in the clarity of the results between woody and herbaceous accessions may also be attributed to the fact that woody species are easier to count and handle. Many woody species do not spread vegetatively and their sexual reproduction does not go unnoticed. The data on woody accessions are therefore more reliable. Thus, by separating species with different life forms and curational needs we were able to outline sources of error and possible explanations for the results. While it is probably unavoidable that part of the potential data are lost with seeds failing to germinate, and with human mistakes involved in collection management, it is of the utmost importance to be meticulous with curation and up-dates to prevent unnecessary loss of accessions and deterioration of the quality of the collection. Notwithstanding the good preconditions in Kumpula BG considering the high number of wild-collected plants with exact information on provenance zone, the quality of the data had been allowed to deteriorate. This was an unfortunate waste of the effort put into the gathering of the plant collection, since much more understanding could have been gained on the plants' relationships to climate, had this not occurred. The obvious explanation for the imperfect collection curation is variation in management resources over the years. The collection simply was too large for the available staff to perfectly curate constantly. For the BG community, we therefore recommend to only keep as many accessions as one is able to properly manage. Furthermore, within accessions it would be important to have several individuals instead of building 'stamp collections' with plenty of taxa represented by single accessions consisting of only one or two individuals. This is important not only for the value of the collections in conservation, but also for studies demanding a large volume of raw data.

In summary, we recommend to value quality before quantity to ensure the scientific value of BG collections. If these recommendations are adhered to, we see good potential for BG collections also in research on plants and climate change.

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Figures

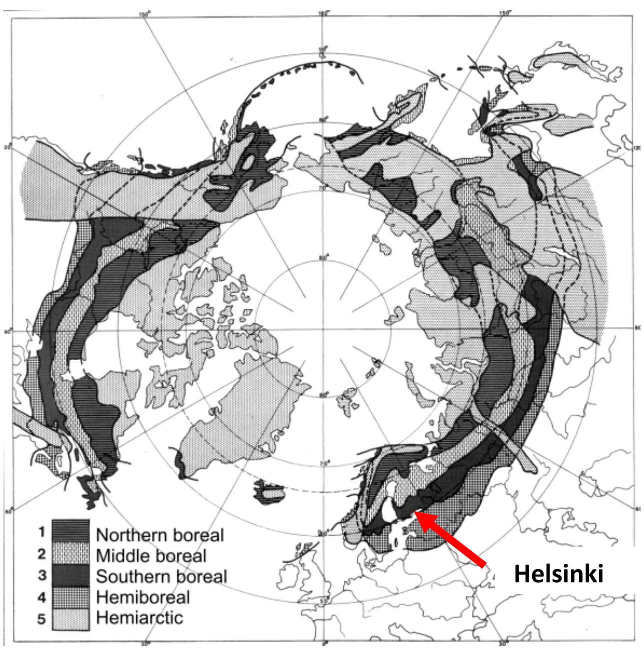

Fig. 1 The circumboreal zone and its transcontinental subzones according Hämet-Ahti (1981). Reproduced with kind permission from the Finnish Geographical Society. The position of Helsinki added.

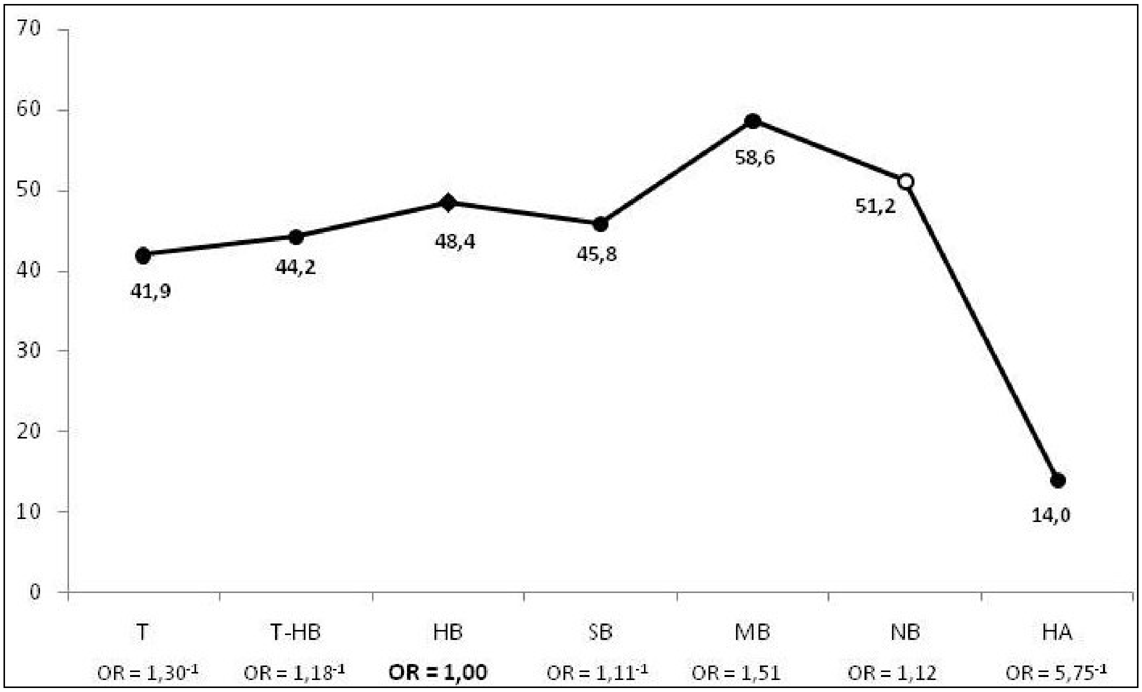

Fig. 2 Comparison of survival proportions (expressed as odds ratios; OR) in the dataset (total N=379) of accessions collected from different source zones to that of accessions collected from the hemiboreal zone. ORs below one (amount of decrease) and above one (increase) marked as suggested by Rita & Komonen (2008) to allow for comparison. n(T)= 119; n(T-HB)= 33; n(HB)= 95; n(SB)= 66; n(MB)= 45; n(NB)= 13; n(HA)= 8. Closed circle= significantly different from reference class, open circle= not significantly different from reference class (Wald's test, $p<0.05$ and $p>0.05$ respectively); rhomb= reference class.

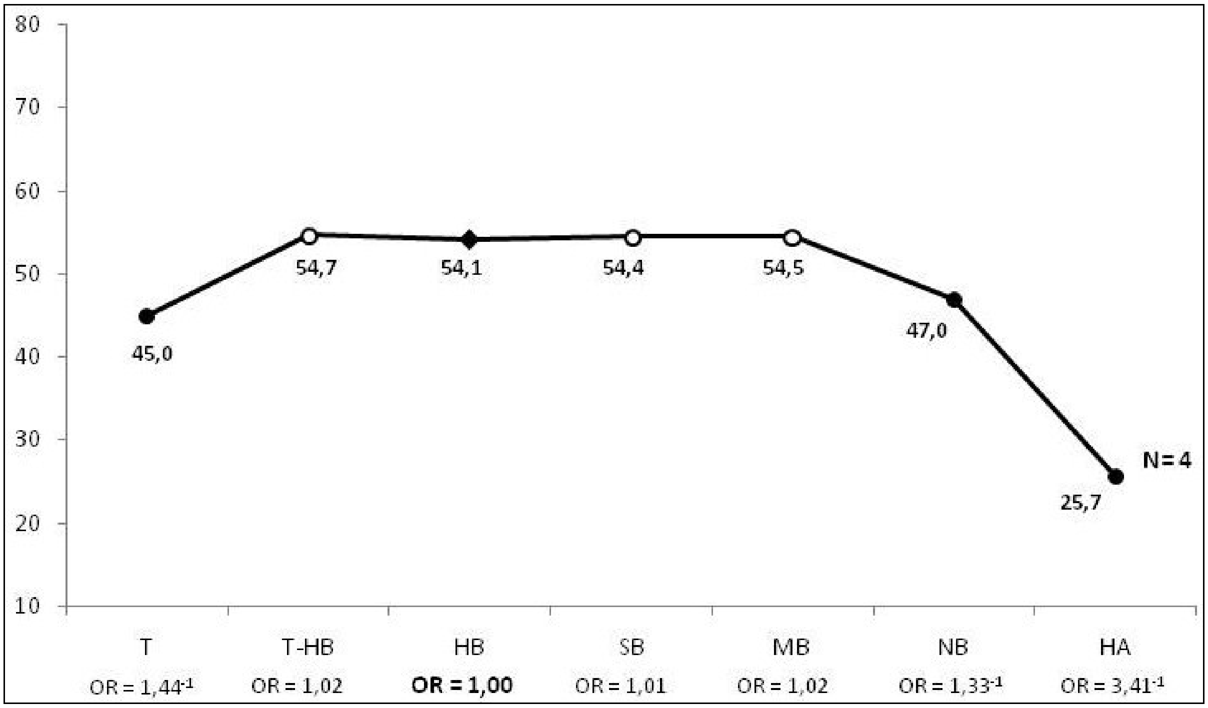

Fig. 3 Comparison of survival proportions (expressed as odds ratios; OR) in the dataset of **woody** accessions (total N=307) collected from different source zones to that of accessions collected from the hemiboreal zone. ORs below one (amount of decrease) and above one (increase) marked as suggested by Rita & Komonen (2008) to allow for comparison. n(T)= 90; n(T-HB)= 26; n(HB)= 81; n(SB)= 52; n(MB)= 43; n(NB)= 11; n(HA)= 4. Closed circle= significantly different from reference class, open circle= not significantly different from reference class (Wald's test, p<0.05 and p>0.05 respectively); rhomb= reference class. Cases where n<5 marked.

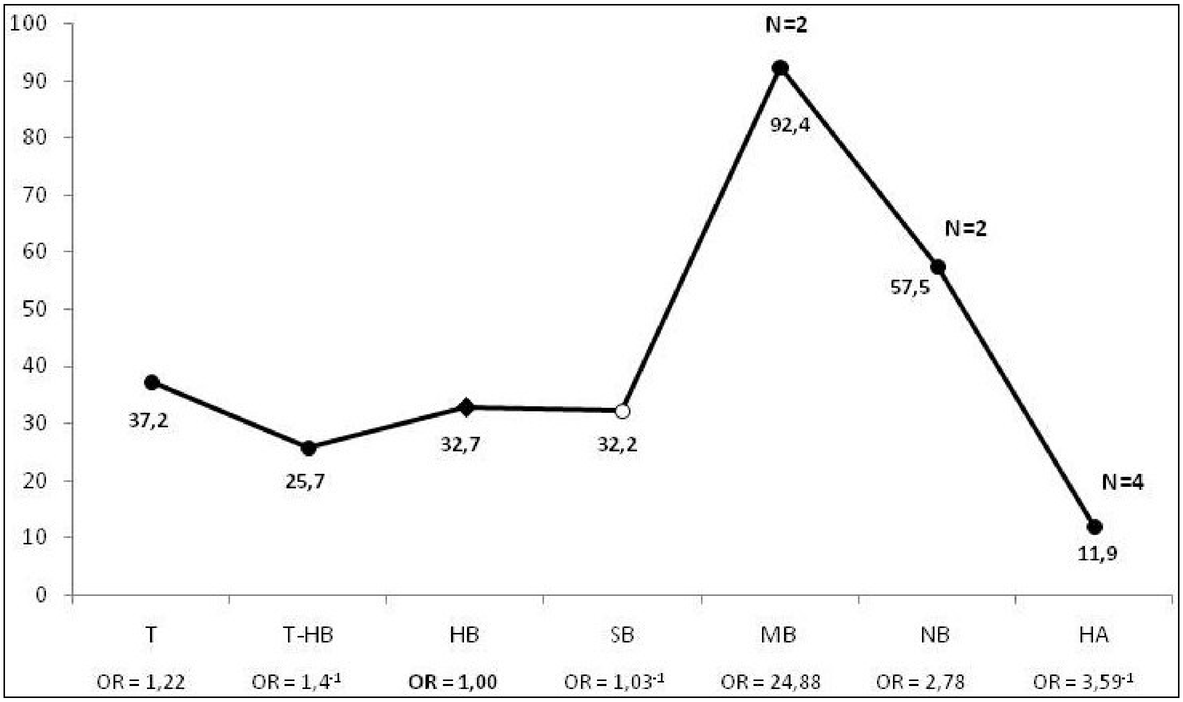

Fig. 4 Comparison of survival proportions (expressed as odds ratios; OR) in the dataset of **herbaceous** accessions (total N=72 collected from different source zones to that of accessions collected from the hemiboreal zone. ORs below one (amount of decrease) and above one (increase) marked as suggested by Rita & Komonen (2008) to allow for comparison. n(T)= 29; n(T-HB)= 7; n(HB)= 14; n(SB)= 14; n(MB)= 2; n(NB)= 2; n(HA)= 4. Closed circle= significantly different from reference class, open circle= not significantly different from reference class (Wald's test, $p<0.05$ and $p>0.05$ respectively); rhomb= reference class. Cases where n<5 marked.

Plants in the spotlight. A botanic garden display of Red List species supporting the 2010 International Year of Biodiversity.

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Abstract

The historic Hortus Botanicus Amsterdam boasts an exhibit of fifty threatened plants during the International Year of Biodiversity 2010. A stunning 144 page catalogue called ‘Plants in the Spotlight’ includes habitat pictures, stories, maps and conservation facts on each imperilled plant. Approaching each species as a ‘personality’ with its very own ‘life story’ gives visitors an excellent view into the world of threatened plants that often remain overlooked. When looking at fifty individual species from across the globe, a variety of conservation issues become apparent. The catalogue serves is both an attractive must-have for visitors and for educators it is a toolbox filled with examples for environmental education.

Introduction

The Earth is currently facing an extinction crisis of unparalleled extent. To give clarity to the pace and nature of these extinctions, the International Union for the Conservation of Nature (IUCN) annually composes and publishes the IUCN Red List of Threatened Species. This list presents an educated estimate of the extinction risk for each evaluated species. Against the current extinction crisis, the United Nations have declared 2010 the International Year of Biodiversity. This resulted in several international, national and local initiatives to create momentum for public awareness and action to save biodiversity.

As the diversity of plants, the green sustainers of our food chain and climate, is the core activity for botanic gardens, these institutions are due to play an obvious role in safeguarding and showing the value of biodiversity. The role of botanic gardens in this context has been proposed in detail by Botanic Gardens Conservation International (BGCI) through a number of reports and guidelines - like the Gran Canaria Declaration, The International Agenda for Botanic Gardens in Conservation and the Global Strategy for Plant Conservation (GSPC).

The Amsterdam Botanic Garden has been devoted to the study of plants since 1638. During those 370-odd years it has built up an impressive history in tandem with many important geopolitical events related to the activities of the once great trading city of Amsterdam. This eventful, international history is captured on a three acre site which sits like a jewel in the city centre, delighting thousands of visitors monthly, and entrusted to an independent foundation funded by ticket sales and municipal contribution. In 2010 the garden's main strength lies in converting the rich history and high visitor numbers into outreach for plant conservation. It is a story-telling garden, best equipped to meet the GSPC Target 14 on communication, educational and public-awareness programmes illustrating the importance of plant diversity and the need for its conservation.

What is biodiversity?

Biodiversity may seem easy to define: the extent of variation within life on earth. However, the first challenge appears when one attempts to express or measure this variation. Are we losing a number of species, genera, or families, or is the amount of variation lost below the species level:

varieties, (sub-) populations or gene pools? Closely related to this conundrum is the question as to why biodiversity is worth the conservation effort. What is the value of different plant families, genera, species, subspecies or populations? The sheer complexity of global biodiversity makes it difficult to explain the importance of each thread in the web of life. The value of biodiversity as a whole, however, is strongly defined by the fact that it presents an inestimable number of possible benefits. Grouping these benefits into three distinct types, the following 'definitions through appreciation' for the variation of life on earth were formulated:

Beauty
Appreciating beauty is a very subjective way to appreciate biodiversity. Our planet is decorated with an incredible number of organisms, from colourful flowers to towering trees. Considering the unique beauty of each species fills the fascinated observer with awe, and an urgency to act, knowing that extinction means lost forever. Already we grieve the loss of the dodo, quagga and the St. Helena olive – all gone forever. Biodiversity has an intrinsic value and may be defined as the glory of creation.

Use
The myriad of species on earth, especially plants, still hold huge undiscovered promises for pharmacology. With their host of secondary metabolites, plants from all parts of the world still provide scientists with new ideas for the development of life-saving medicine. Simply, the loss of species reduces the choice of as yet undiscovered biochemical agents useful for future medicines. Of course, many plant and animal species are responsible for our health and well-being through providing food, building material, fibres and more. Biodiversity is a pool of opportunities.

Ecology
One of the most important aspects of biodiversity is possibly the most difficult to grasp: ecosystem services. A species-rich ecosystem is more resilient and provides many vital services. For instance, many of our crop plants are dependent on wild bees for their pollination. These bees live in proximity of agricultural fields, if their habitat has been preserved. Another example is drinking water, often produced in well-functioning ecosystems like the Catskill mountains above New York, or the coastal dune seepages that feed the water-works of Amsterdam. A loss of species can cause a sudden collapse of an ecosystem or its service. Biodiversity is resilience.

Concept development

From this backdrop of global extinctions, the Amsterdam Botanic Garden wished to play a role to present the case for conservation.

The most obvious approach in this garden would be that of looking at the individual plant species. A list of all IUCN Red List species found in our garden was composed using the very practical plant upload tool on the BGCI website. From some 200 Red Listed garden plants we made a selection of 35 individuals to form our exhibition, supplemented with 15 species that were not endangered internationally, but listed as threatened in the Netherlands. The selection was based on location in the garden, look of the plant, taxonomic group, native region and conservation issues. It was attempted to distribute all factors evenly within the final selection of species, resulting in an exhibition with a variety of plants from around the world, including cycads, conifers and angiosperms, annuals, succulents and hardwood trees; fifty species hidden throughout garden and greenhouses. Each plant was marked with a numbered, 10x11cm Red List sign attached to the conventional plant label.

Exhibit catalogue

Showing a variety of conservation issues was important to the exhibition: addressing the relevant threats to biodiversity, ranging from habitat loss, to climate change to invasive species. But before a visitor is ready to hear the story of how badly a given species is doing in the wild and care, they first have to appreciate the unique character of that species.

To make the experience up-close and personal, the exhibition was designed to introduce plants as personalities. The fifty exhibit plants are described in a 144 page, bilingual (Dutch and English) catalogue, with two pages devoted to each species. An introductory paragraph gives each species a profile. Just as we judge a person in a first glance, a reader immediately decides if the plant is worth further attention or not. Just as an individual can strike us as charismatic, pretty, or extraordinary, so too can a plant. Perhaps it is utilitarian, has medicinal uses, plays a role in history, or encapsulates a strange beauty. Introducing plants as characters raises our curiosity motivating us toward conservation. A more traditional approach might dryly describe the number of anthers, or size of the corolla tube, for instance, followed by a scrap of information about ecology and plant use as an afterthought.

Next, the text leaps into ecology and habitat, allowing a visitor to discover more about where and how the plant lives. Specific conditions and background information help foster an understanding of the third paragraph dealing with threats and outlook. Here you will find the reasons for a plant being placed on the Red List, and whether the future situation may improve or deteriorate. This is also where various conservation issues are addressed.

Finally, an attractive picture of the species in its habitat is included, plus a distribution map of the native range and an IUCN Red List symbol with the status. As scientific names are difficult to remember, a colloquial name is always given in Dutch and English. If such a name did not exist, we inventively made one up, based on either an existing scientific or local name.

Personalities

These plants ooze character. For example, the Wood's cycads (*Encephalartos woodii* Sander, Extinct in the Wild) are presented as the cloned sons of a lonely bachelor, who survive 'only in gardens and greenhouses' since their poor father was dug out from the wild. This story is followed by a poignant black-and-white picture from 1907 of the last wild specimen.

The Angels' Trumpet (*Brugmansia aurea* Lagerh., Vulnerable) has an ethereal face, sharing the clouds with the angels. The species is native to the Andean cloud forests in Ecuador.

The Parana pine (*Araucaria angustifolia* (Bertol.) Kuntze, Critically Endangered) too, has an interesting story to tell: the native inhabitants of the southern Brazil used to shoot arrows into her crown to dislodge her nutritious cones. A sustainer of life.

Education tools

Seeing fifty distinct, yet interrelated stories of threatened plants yields a good overview of conservation issues. A few examples are given below.

Possible effects of climate change are explained by the dove tree (*Davidia involucrata* Baill., Vulnerable), reminiscent of the lush vegetation during the late Tertiary. Before the onset of the Pleistocene, the last great global climate change, this tree and a number of relatives were widespread throughout Eurasia and North America. Of all *Davidia*'s only the dove tree remains, endemic to central China, witness of past extinctions due to climate change.

On a barren rock off Ibiza in the Mediterranean, the endemic Margalides spurge (*Euphorbia margalidiana* (Kuhbier & Lewej), Critically Endangered) clings to the edge: the rock is prone to erosion and the plant is specifically adapted to the present climatic conditions. Changing rainfall patterns or temperatures could be fatal.

Overharvesting of plants for medicinal purposes continues to be a problem, as can be seen in Arnica (*Arnica montana* L., endangered in the Netherlands) Although still common in the mountains of Western Europe, its trade has already been restricted by CITES appendix D.

For other, more vulnerable species like Lignum Vitae (*Guaiacum officinale* L., Endangered) it is already too late. Renowned for its resin used to treat syphilis, the unsustainable harvesting of the trees since 1492 has led to near-disappearance of this Caribbean species from the wild.

The danger of invasive plants and animals to existing ecosystems becomes ever more evident. Invasive species can penetrate ecosystems through and through, obliterating their food species or the less vigorous native counterparts. Since the introduction of rabbits on Round Island near Mauritius, the bottle palm (*Hyophorbe lagenicaulis* (L.H.Bailey) H.E.Moore, Critically Endangered) has almost become extinct as seeds and seedlings were systematically devoured by the introduced aliens. Now, after successful eradication of the Round Island bunny squad, the palms are returning to the landscape!

Also invasive plants can have a deleterious effect on the natural species composition. The white-topped pitcher plant (*Sarracenia leucophylla* Raf., Vulnerable) in the south eastern United States is suffocated by expanding mats of Chinese kudzu vine (*Pueraria lobata*).

Conclusion

The exhibit ‘plants in the spotlight’ offers both an alluring glance into the world of plants, whilst also providing educators and tour guides with a practical toolbox full of examples to explain the main triggers of current biodiversity loss. Examples of plant species, alive and kicking in the Botanic Garden of Amsterdam.

Acknowledgements

Many thanks to Chloe Wolsey who improved style and English language.

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Weed risk assessment for botanic garden decision making

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Abstract

The purpose of this study was to investigate a potentially powerful tool, the Weed Risk Assessment, to help guide responsible development of botanical garden collections. Increasing concerns over invasive plant introductions have led to development of risk assessment measures. These measures can be applied to botanic garden practice to help mitigate the risks of plant introductions. The Weed Risk Assessment (WRA) originally developed for use in Australia has been modified for use in other parts of the world, such as South Florida. Active botanic garden research, utilizing plant records going back more than 70 years, compares WRAs in two categories: 1) conservation collections and 2) horticultural introduction/distribution plants. This assessment seeks to determine whether different kinds of plant collections pose different risks of naturalization.

Keywords

Native, alien, invasive, WRA, *ex situ*, *in situ*, *inter situ*, plant conservation

Changing foci of botanical gardens

Botanical gardens have a wealth of experience with exotic plant introductions, going back many centuries. Historically, most of these introductions have been for purposes of food, medicine and ornament (Foster, 1999). Intensive collection of food and ornamental plants was especially intense in the late 19th and early 20th centuries (Stoner and Hummer, 2007). Major botanical gardens in South Florida, especially Montgomery Botanical Center and Fairchild Tropical Botanic Garden, were born of this era and have long experience with exotic plant introductions. Concomitant to the collection of a large diversity of plants, gardens became centres for the study of this diversity through plant systematics research, as witnessed by the important herbarium collections often associated with gardens.

However, the past two decades have witnessed a shift in botanical garden focus and increasing interest in plant conservation (Heywood, 1990), and in a broader scope for scientific research, such as monitoring effects of climate change (Donaldson, 2009).

Making choices regarding *in situ*, *ex situ* and *inter situ* approaches:

Traditionally, plant conservation efforts have been classified as either *ex situ* or *in situ*, with *in situ* efforts focusing on preserving a species where it was first encountered and documented during historic times. Efforts to cultivate and preserve plants outside this criterion have been classified as *ex situ*. Many factors weigh on decisions regarding which conservation strategies to pursue for a given set of circumstances. Sometimes these decisions are made on largely *a priori* philosophical grounds, such as the view that only *in situ* conservation has merit because preservation of a species outside its historic context does not allow a full appreciation of the “wild value” of the species in its natural state (Rolston, 2004). *Ex situ* conservation in botanical gardens is also often questioned on genetic grounds (Aplin, 2008), but recent research has demonstrated that population based collecting efforts can adequately capture well documented genetic diversity in a botanical garden collection (Namoff *et al*., 2010). Furthermore, many plant species can be successfully propagated by vegetative means, enabling *ex situ* preservation and duplication of wild origin genotypes indefinitely.

For a growing number of species, *in situ* conservation is no longer a practical option. Some species have lost their entire habitat to human activity, or to natural disasters, and a steadily increasing number of species owe their continued existence to cultivation. The plant conservation situation is becoming increasingly desperate in biodiversity hotspots such as New Caledonia (Bouchet *et al*., 1995). In Hawaii, deficiencies in both *in situ* and *ex situ* approaches have led to a third approach, *inter situ* conservation, that recognizes the value of restoring populations of critically endangered species to prehistoric and early historic sites once inhabited by a given plant species, but not part of its traditionally recognized habitat (Burney and Burney, 2007). Another approach, Quasi *in situ*, involves cultivating *ex situ* collections in a semi-natural environment (Volis and Blecher, 2010)

If mainstream climate change projections prove correct (IPPC, 2007), then the concepts of *in situ*, *ex situ* and *inter situ* may carry far less meaning as the Earth’s climate shifts and the historical ranges of plant species become less habitable or uninhabitable, and new areas become more habitable. To come to terms with this challenge will require a deeper paleoecological perspective that sheds light on variability and change in natural systems to large changes in environmental conditions (Froyd and Willis, 2008).

Thus, the key question before the conservation community at large and before gardens is not “is *in situ* or *ex situ* conservation to be preferred?”, but rather “are plant species worth preserving even outside their historical context?” We suggest that the latter question be answered in the affirmative, and suggest that biodiversity has great value even when circumstances prevent it from being appreciated in its historic natural setting. This opens up the possibility of gardens utilizing a very practical non-*a priori* approach to conservation that treats each challenge on its own terms with a mix of *in situ*, *ex situ* and/or *inter situ* approaches that best serves the needs of the plant species in question and takes into account the relevant biological, environmental, political and financial factors. Thus, we advocate a data driven, rather than philosophy driven, approach to *in situ* vs. *ex situ* questions.

How do we approach the natives and aliens?

Given the increasingly urgent conservation needs of many rare plants, there is growing motivation to bringing the full suite of practical conservation options to bear on conservation planning. However, as more gardens pursue *ex situ* conservation and assisted migration projects, necessitating cultivation of rare plants outside their native ranges, questions are beginning to arise regarding the risks associated with this approach (Ricciardi and Simberloff, 2009). In a few instances, a rare or endangered plant has become invasive outside its native range. A classic case is *Pinus radiata*, which is under considerable conservation threat in its handful of distinct native habitats

(Rogers *et al*., 2006), yet is becoming invasive through escape from mass forestry plantations in many countries (Richardson *et al*., 1994).

Problems caused by invasive non-native plants are very well documented in a variety of contexts. However, as is the case with questions of *in situ* and *ex situ* conservation, a temptation exists to oversimplify the issues and rely on broad *a priori* generalizations - such as considering non-native plants inherently “bad” and native plants as inherently “good” (Slobodkin, 2001). Yet this approach overlooks the many complexities that exist in questions of nativity and invasion (Warren, 2007). Such an approach would portray all *ex situ* efforts as “too risky” based on the precautionary principle that one can never be 100% sure that a plant species will not become a problem outside its native habitat one day under some circumstances (Ricciardi and Simberloff, 2009). The use of *a priori* generalizations becomes especially questionable when definitions of nativity depend more on political boundaries than on ecological considerations. For example, many species from other parts of Australia have become invasive in the Australian state of Victoria, yet are often not considered as such due to their being “Australian natives”. In addition, some indigenous species in Victoria have begun to behave invasively in some contexts, forming thick stands that crowd out other native vegetation (Carr, 2001). The drive to develop generalized scientific laws (such as those that characterize physics), often where they may not exist, has been suggested as an impediment to progress in ecology (Weiner, 1995), whereas a focus on understanding the inherent variability of species and natural systems has been suggested as a remedy (Hansson, 2003). Local variability and contingencies appear to predominate in cases of invasiveness as well (Simberloff, 2009). Thus, we suggest that issues of invasiveness are best handled by considering the specific ecological context and the specific species involved, rather than resorting to *a priori* generalizations.

Botanical garden introductions and invasion risk

A small portion of plants introduced into cultivation through botanic gardens have become naturalized or invasive and the potential exists for further problematic introductions if proper precautions are not taken (Reichard and White, 2001). A recent example in South Florida involves exotic mangrove introductions by the Fairchild Tropical Botanic Garden (FTBG). Of 14 species introduced from the 1940’s to the 1980s, five have survived in cultivation and one has escaped and shown invasive tendencies (Forqueran *et al*. 2009), another species has persisted for 70 years and produced some seedlings, due to horticultural intervention to control native vegetation, but has shown no tendency to spread beyond the original planting area. These results are not surprising given that the overwhelming majority of introductions are not invasive (Gordon and Gantz, 2008), and many garden introductions prove to be challenging to maintain in cultivation over the long term. The question thus arises: Can we reliably predict the small portion of plant introductions that are likely to become invasive?

Weed Risk Assessment

The Australian Weed Risk Assessment (WRA) was developed to attempt to screen plant introductions (Pheloung *et al*., 1999). This assessment evaluates each potential plant introduction using 49 questions that encompass a wide range of factors such as the biological characteristics of the plant, its environmental tolerances, any characteristics that may render it directly harmful to humans or agriculture, and its introduction history in other areas. The result of the assessment is a numerical score that classifies the weed risk of the potential introduction as either low (<1), requiring further evaluation (1-6), or unacceptably high (>6). This assessment has subsequently been modified and evaluated for effectiveness in other countries (Gordon *et al*., 2008a). The Australian WRA has been adapted for use in Florida, USA and evaluated by Gordon *et al.* (2008b). The Florida WRA detected 92% of known invasives and correctly did not reject 73% of known non-invasive species.

Do *ex situ* conservation plants have a lower risk of invasiveness than horticultural distribution plants?

Botanic gardens frequently acquire non-native plants for different purposes. Some are introduced primarily for their ornamental horticulture purposes, others are primarily for education, research or conservation. To evaluate the effectiveness of the Florida WRA for different types of botanical garden collections, we compiled records of 24 non-native plants introduced to FTBG and the Montgomery Botanical Center (MBC) for purposes of conservation, with 20 species distributed to the gardening public by FTBG from 1955 to 1979, before species were being evaluated for weedy tendencies. Although the samples were originally of equal size, two of the distribution species were found to have IUCN assessments of “Vulnerable” and were thus included with the conservation species.

Raw scores of the conservation species were significantly lower than those of the horticultural introduction species and also varied significantly less (Figure 1). Scores of both groups were low overall. When examined categorically 92% of the conservation species, and 57% of the horticultural species were accepted, and one horticultural species, the known Florida invasive *Sesbania punicea*, was rejected (Figure 2). Another species that is known to be naturalizing in South Florida, *Diospyros maritima*, fell into the “evaluate further” category. Thus, the WRA proved to be accurate when assessing these 44 garden introductions and distinguished lower invasiveness risks associated with conservation introductions than horticultural introductions. Reichard, Liu and Husby (2010 in press) discuss this study in more detail.

Conclusions

In conclusion, we recommend use of the WRA as an important tool for evaluating potential invasiveness risk of *ex situ* garden introductions. This data-driven approach can correctly predict invasiveness potential distinctly, whereas *a priori* nativity criteria often do not. Thus, the WRA method can facilitate implementation of a full suite of conservation options to save rare plants from extinction: *in situ*, *ex situ* and intermediate approaches. The alternative *a priori* approach does not take into account the great complexity of the living world and the resulting complexity of conservation challenges, making assessment by nativity criteria alone arbitrary at best and, in a future of increasing habitat destruction and global climate change, irrelevant at worst.

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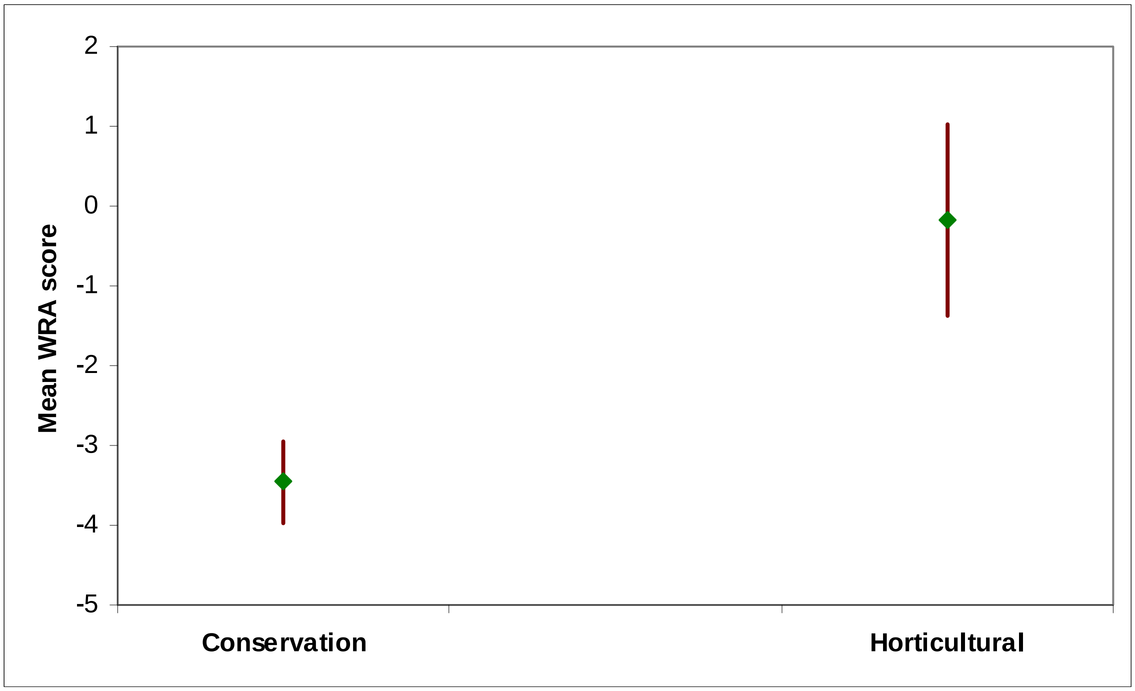

Figure 1. Weed Risk Assessment scores for plants introduced by Fairchild Tropical Botanic Garden for conservation and horticultural distribution purposes. Vertical bars are standard errors of the means. Adapted from Reichard, Liu and Husby (2010 in press).

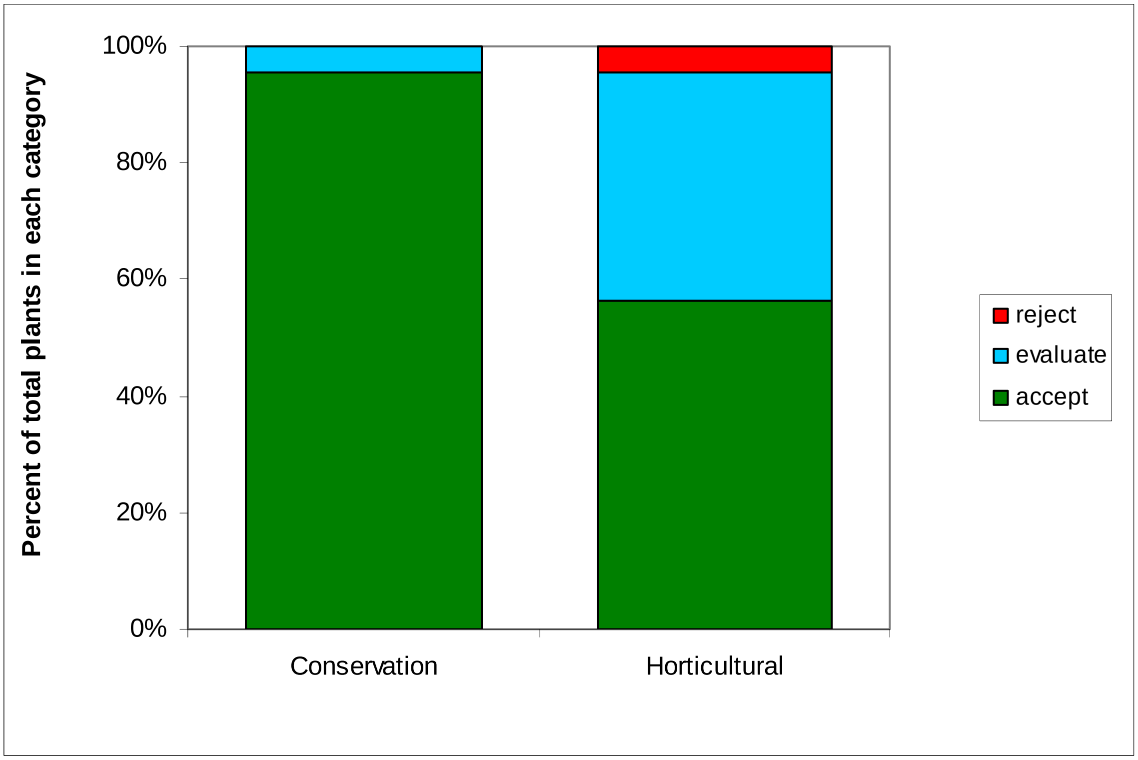

Figure 2. Weed Risk Assessment outcomes by category (accept < 1, evaluate further 1-6, reject >6) for conservation and horticultural introduction plants at Fairchild Tropical Botanic Garden. Adapted from Reichard, Liu and Husby (2010 in press).

Flower Fairies™ by Cicely Mary Barker, a significant experience in education for plant diversity

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Abstract

In May 2008 the Botanic Garden of the University of Salento organized an educational event based on the theme of the Flower Fairies™ by Cicely Mary Barker, as part of the activities of the Project "CERATONIA" (Programme Interreg IIIA Italy - Albania, Axis II, Measure 2.1, Action 3). It had the aim of raising awareness of the interested parties in the conservation status and prospects of exploitation of plant species from Italy, Albania and other Mediterranean countries. This initiative was targeted mainly at primary school children, in order to increase their knowledge and respect of plant diversity in the Mediterranean area; in addition strengthening the conservation of plant species typical to the area. This was achieved by using an artistic approach, which had a great impact on both children and adults, at the same time maintaining its scientific credibility. The event consisted of an exhibition of graphic panels, located at the Fine Arts Academy of Lecce, with the pictorial representations of about sixty fairies and related sonnets representing a set of Mediterranean plant species. Each panel had a framework with botanical information. Participants also took part in a theatrical adaptation of Barker's most well known work which took place in a nearby wildlife park.

Keywords

Awareness, biodiversity, domination, education, fairies, innovation, magic, struggle

The initiative for the activity described in this case study was foreseen in the CERATONIA project (Interreg II cccc), which included in its aims training and awareness programmes in both schools and the local community. This initiative had to overcome both cultural and bureaucratic obstacles in a land which is no stranger both to struggle and domination, literally and metaphorically.

In order to clarify these claims it is necessary to have some background information about the area, geographically, historically and culturally. Salento lies in the deep, south east of Italy. It is quite literally on the heel of the boot which defines Italy. Deriving from the Italian word "sale" meaning salt and "vento" meaning wind, two things that any native of the area are experts in. The name and the direction of the wind can influence the day's activities, whether you spend the day on the Adriatic coast or on the Ionian one. Salento is geographically unique, a peninsula which lies between two seas, an area which for many years was known as the "Terra d'Otranto". Although part of the region of Apulia it is very different linguistically and is very rich in both folklore and traditions (De Martino, 2002), an excellent reason for linking fairies to the botanic aspect of this initiative.

For centuries Salento has been a place where there has been a constant struggle to dominate the land and its natural habitat. It was an area which was entirely covered by forests (native oaks for example, *Quercus ilex* L., *Quercus coccifera* L., *Quercus pubescens* Willd. subsp. *pubescens*) and so in the 15th century a programme of deforestation by the farmers began. The land also had to be cleared of rocks in order to make it usable and this need to keep the land in check continues even today. Fields are neatly and almost obsessively divided and surrounded by dry stone walls. Each field is maniacally cultivated with almost military precision. Today's farmer keeps his land in check by the use of fire, during the long hot summer months it is not unusual to see fires in order to prevent the "natural vegetation" (in this case we are in danger of losing rare species found only in scrubland) taking over the cultivated areas, it is in fact another way of dominating the land (Marchiori *et al.*, 1998). In addition to struggling with the natural vegetation the farmer also has to struggle with natural elements, Salento has long very hot summers, and while it is fertile it can be the victim of freak weather conditions, summer storms and sometimes tornadoes. The winters are often wet and damp and as there are no rivers or lakes fields can easily become waterlogged.

Until the late 18th century Salento was continuously invaded due to it being the last outpost between the West and the East. It was therefore the stepping stone for the following: the Greeks, the Turks, the French the Spanish etc. In fact remnants of these many invasions can be seen along the coast line, lookouts/fortified towers and almost scattered everywhere around the countryside fortified houses/castles known as masserie. The whole of the countryside is marked by human settlements and dwellings, so despite its isolation from the rest of Italy it is surprisingly densely populated.

Despite the continuous invasions everyone left their mark on the area especially from the botanic point of view. From the East came the principal growing techniques and the know-how on organizing gardens. From the Phoenician merchants came the foundation of commercial enterprise with the buying and selling of fruit trees. From the Far East came the most important species of trees cultivated in the Mediterranean area: the fig tree, the pear tree, the apricot tree, the plum, and the walnut tree. All of these were brought by merchants coming and going from East to West, bringing with them species such as black mulberry, but most importantly the citrus trees, that in later years became the predominant inhabitants of our gardens.

From the economic point of view another very important import was that of the vine, probably brought by the Greeks who colonised the area in the VIII-VII centuries BC. Salento has an emerging wine industry which in the last ten years has produced some excellent and prestigious wines.

As mentioned earlier, the original landscape was covered by huge areas of evergreen oaks, Mediterranean xeric grasslands and marshes. Salento again is quite unique in the fact that there is no surface water, no rivers or real lakes; there are only small areas of coastal lagoons. This is another problem, especially when it rains, as there are no rivers or streams to absorb the excess water and so there is a large amount of underground water.

In addition, Salento is a highly interesting area from the bio-geographical point of view. Its geological history and geographical position mark it as a meeting point between the flora of the Eastern Mediterranean Basin and that of the rest of Italy. This explains the presence of Eastern Mediterranean species such as *Ephedra foemina* Forssk., *Erica manipuliflora* L., *Quercus ithaburiensis* Decne. subsp. *macrolepis* (Kotschy) Hedge & Yalt. and *Aegialophila pumilio* (L.) Boiss. The flora of the Salento is made up of 1,033 specific taxa and 307 sub specific taxa organised into 21 ferns and allied groups, 6 gymnosperms, 992 dicots and 321 monocots, for a total of 115 families and 560 genera. The considerable incidence of therophytes highlights a clear Mediterranean imprint of the investigated area. The endemic species of the Salento represent 3.21% of the total flora: there are 7 endemic species exclusive to Salento and 4 endemic of Apulia, while the others are endemic of Southern Italy and the Balkan Peninsula (Mele *et al.*, 2006).

Over the centuries Mediterranean Man has struggled to tame the wild and savage beauty of the countryside. In taming his environment he eliminated all of Nature's creativity by enclosing it in a walled garden and filling it with fruit trees which were necessary to help him in his survival. This concept is true even today: most gardens are created not for their natural beauty, but to keep the countryside tidy and useful. Perhaps one of the first things a stranger to the area notices is that it is completely lacking in public gardens and open spaces, children have no green areas in which to play. This was another important reason to promote this kind of project, that today's generation are completely ignorant of the great wealth of natural beauty that surrounds them.

It was fortunate for us that one of the main aims of project CERATONIA was the promotion of biodiversity conservation and awareness in the local area. But as always the main thread of this case study was the struggle to overcome opposition to anything new and innovative. The school system is very traditional, children sit in rows, and the teacher is situated at the front of the class. Group work and a sense of group identity is viewed with fear and scepticism. It is not unusual to stay seated at the same desk for six hours at a time, playtime is usually spent in the classroom and any open areas are ignored and left overgrown. There are no Parent Teacher associations who work together for the promotion of extracurricular activities, in fact "Voluntary" and "Volunteer" are unknown concepts in our society. Everything extra is usually paid for, so a project like ours was initially viewed with suspicion. So from the beginning we really had our work cut out. In addition to this we also had to convince a system which views innovation as a form of anarchy, in fact there was always the risk that our project would become lost in our complicated bureaucratic system. It was therefore very important that we did not lose sight of our aims.

The question now to be asked is why we chose Cicely Mary Barker. The main reason was that most children today are more disconnected from nature than previous generations (Louv, 2005). Also society is developing in such a way that children are having no contact with nature or their own natural environment, preferring to interact with virtual dimensions. The results being, that not only do fewer and fewer children know about wild flora, but they also don't know or recognise the most common species of cultivated flora. Our children are victims of "over structured" time, their every waking moment is filled and their lives are stressful, parents are over protective and have a sense of "stranger danger". However, all children are fascinated by fairies and a sense of magic in general. Cicely Mary Barker has fascinated generations of children and her magic never fails to attract them. Different to today's generation of fairies which are virtually generated and isolated from the sense of nature, Cicely Mary Barker's fairies were painstakingly drawn and painted by hand, connecting them to both wild and cultivated flowers. So along with Barker's message "the need to believe", we had found a combination which would meet our aims and would be a sure success.

Armed with the necessary permission from Barker's publishing house our project began to take shape, panels were created using, where possible Barker's original illustrations (Barker, 2010), and in other cases they were adapted to fit our needs. A local theatre group was contacted and venues were chosen. It was decided to house the panels in the local "Accademia delle Belle Arti" (our Fine Arts Academy), a fitting place with its beautiful Baroque cloister to hold such an exhibition. Local schools were contacted and visitors included children and adults alike. The event coincided with another local event, "Cortili aperti", when private residents living in the historical centre open their gardens to the public. Although a highly successful event, it is another example of the lack of access to gardens and the strong sense of the private owner. Throughout the week two local botanists explained to the children the importance of plant diversity.

Our theatre group worked their magic in the natural park known as "Rauccio", allowing our young participants to really be in touch with nature (Barker, 2006). The idea for this aspect of the project came from the necessity to create a more hands on activity and to bring our children closer to the immense natural wealth found in the area. The costs of the entire project can be found in table 1.
The project was repeated again in 2009 when we were invited to take part in a local book festival, this time we used only the exhibition panels but it proved to be equally popular and successful.

Conclusion

All in all, our project was a success. However, there are things that could be changed. One would be to take our work into the schools and try to make it more hands on, involving the children in actually growing plants and protecting the areas around them. Contact has also been made with the organizers of an International Ecological Film Festival, who have as part of their competition a schools section.

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Fig. 1 – Typical woody vegetation of Salento (*Quercus ilex L.*)

Fig. 2 – Typical dry stone shelter (*pajara*)

Fig. 3 – Rural landscape (*Olea europaea* L. var. *sativa*)

Fig. 4 – Enclosed "orchard-garden"

Fig. 5 – Flower Fairies^{TM} botanical panels

Fig. 7 – Flower Fairies™ Book Festival exhibition

Table 1 – Costs of the project

		costs
• Panels including all graphics,printing and production	€	3.550,00
• Educational support, games and entertainment	€	750,00
• Theatre group	€	2.750,00
• Additional costs, audio, lighting	€	2.950,00
• **TOTAL**	**€**	**10.000,00**

Botanic gardens and the implementation of the Global Strategy for Plant Conservation in Austria

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Abstract

Austrian botanic gardens have been actively involved in the implementation of the Global Strategy for Plant Conservation since the GSPC was adopted at CBD CoP 6 in The Hague (The Netherlands) in 2002. This paper gives a brief survey of the GSPC-related activities of the Austrian botanic gardens, indicates the relevance of selected BG-projects to achieve certain GSPC-targets, and shows effects for the botanic gardens as a result of their involvement in GSPC issues.

Key words

Austria, Botanical Gardens, GSPC-implementation

GSPC-implementation in Austria

In 2003, a GSPC kick-off-meeting was organised by the Austrian CBD-Focal Point (which also acts as GSPC Focal Point) at the Ministry of Agriculture, Forestry, Environment and Water Management. At this meeting, the author of this paper (as representative of the Austrian botanic gardens) was invited to present and explain the GSPC targets and objectives to potential stakeholders.

In 2004, the Austrian Biodiversity Strategy was developed by the Austrian Biodiversity Commission which includes BG representatives. GSPC targets were incorporated into this strategy.

Between 2004 and 2007, the Austrian botanic gardens mainly focussed their work on two GSPC targets, target 8 (ex-situ conservation) and target 10 (alien invasive species).

In 2007, the first (of three) Austrian GSPC-expert workshop took place. It was initiated by the Austrian botanical gardens and the GSPC Focal Point and organised by the Botanical Garden, University of Vienna. This workshop provided, for the first time, an overview of current GSPC-related activities in Austria, and, at the same time, established a dialogue between the stakeholders on individual and organisational levels. The workshop identified options, impediments and gaps in implementing the GSPC in Austria and resulted in a "GSPC-roadmap to 2010" including proposals for actions.

In line with the roadmap, a number of GSPC-related projects were carried out between 2008 and 2010, several of them at Austrian botanical gardens. These projects were coordinated by the Botanical Garden, University of Vienna and co-financed by the Austrian GSPC Focal Point. The results of the projects were reported at the workshops in 2008 and 2009 where they were discussed and their outcomes were used to adjust actions for the follow-up activities.

A summarizing GSPC workshop is planned for November 2010 to evaluate the achievements in the first phase of the GSPC and to set the frame for the activities required by the second GSPC proposed for adoption at CBD CoP 7 in Nagoya (Japan) in October, 2010.

Austrian botanical gardens and their contributions to selected GSPC-targets

Austrian botanical gardens and their staff have been involved in the implementation of all 16 GSPC targets. Some targets, however, were subject to more intensive work in the botanical garden community. The following chapter summarizes the activities of Austrian botanical gardens related to those targets during the last 8 years.

- Target 1 (A widely accessible working list of known plant species, as a step towards a complete world flora)

An important step to reach this target for Austria was the publication of the third edition of the "Exkursionsflora von Österreich, Liechtenstein und Südtirol" (Fischer *et al.* 2008). Several scientists based at Austrian botanical gardens participated in the preparation of this work. As part of the GSPC implementation efforts in Austria and financially supported by the GSPC Focal Point, an online version of the "flora" has been started in 2007 (Fischer *et al.*, 2007). It includes contributions from botanical gardens´ staff members. Besides these Austrian based checklist activities, researchers from the Botanic Garden, University of Vienna, have compiled a database of all names of *Bulbophyllum,* the largest genus in the orchid family, and recently published a CITES checklist of this genus based on the database (Sieder *et al.*, 2009).

- Target 3 (Development of models with protocols for plant conservation and sustainable use, based on research and practical experience) and
- Target 8 (60% of threatened plant species in accessible *ex situ* collections, preferably in the country of origin and 10% of them included in recovery and restoration programmes)

Several botanic gardens in Austria (i.e., of the University of Applied Life Sciences Vienna, the City of Linz, the Carinthian Centre of Botany Klagenfurt, the Karl-Franzens-University of Graz, and the University of Vienna) have, since 2002, established programmes for integrated *ex situ*/*in situ* conservation of Austrian endangered species. These programmes include seed collection activities according to established protocols (like the seed collecting manual of ENSCONET: ENSCONET, 2009), germination tests and cultivation at botanical gardens and planting programmes *ex situ*. They, finally, aim at replanting the corresponding species at sites of their original occurrence, as part of *in situ* habitat restoration activities (e.g., in connection with LIFE-Nature-projects like "Pannonic Steppes and Dry Grasslands", 2004-2008, Wiesbauer, 2009). One example of a target species for such activities is *Dracocephalum austriacum* (Lamiaceae), today restricted to two localities in Austria.

In 2003, the Austrian BGs have started a documentation of their *ex situ* collections of rare and endangered plant species of Austria in order to establish a coordinated approach to secure all threatened species in Austria *ex situ* in botanical gardens (in living collections as well as in seed banks). The following gardens actively participate in this project, which is co-financed by the Austrian GSPC Focal Point and coordinated by the Botanical Garden, University of Vienna: Alpine Garden Villacher Alpe; Arche Noah; Botanical Garden City of Linz; Botanical Garden Karl-Franzens-University Graz; Botanical Garden Carinthian Center of Botany Klagenfurt; Botanical Garden University of Applied Life Sciences Vienna; Botanical Garden University of Innsbruck; Botanical Garden University of Salzburg; Botanical Garden University. of Vienna; Flower Gardens Hirschstetten, City of Vienna. The basis for this project is the "Red List of endangered *Pteridophyta* und *Spermatophyta* of Austria" (Niklfeld 1999), which lists 1,798 species as endangered in Austria (incl. subspecies, microspecies and regionally endangered species). According to the recent survey in the Austrian botanical gardens (Fuchshuber & Kiehn, unpubl.) 779 of the 1,798 endangered species are actually present in *ex situ* collections, 406 of those with documentation of their origin. Of the 520 species considered to be critically endangered in the "Red List", 191 are found in *ex situ* collections, 100 of them with documentation of origin. 382 of the 779 cultivated endangered species are present in only one *ex situ* collection. 106 of those are critically endangered and 7 extinct in the wild. Of these 113 taxa, only 55 have documentation of their origin. As a consequence of this evaluation, the Austrian botanical gardens will not only strengthen their cooperative effort to include additional species into *ex situ* collections, especially of the 520 taxa considered to be critically endangered. They will also look at the accessions already present in the collections without documentation of origin, and, if necessary, replace them with material from a known origin. This evaluation might, especially in the case of species considered to be rare on a worldwide scale, require the use of molecular markers (e.g., fingerprint methods like AFLPs): one pilot study has clearly indicated that plants of the Lamiaceae *Phlomis tuberosa* of unknown origin cultivated at the Botanical Garden, Univervsity of Vienna, cluster together with other Austrian populations of this species (and are genetically different from populations occurring further East). Thus the material in cultivation is likely to have come from an Austrian source (Schönswetter & Kiehn, unpubl.), and, therefore, at least for the time being, will not be replaced.

Besides being cultivated in living *ex situ* collections, the rare and endangered Austrian plant species are also the subject of an Austrian-wide seedbanking project. Initiated in the context of the EU-project ENSCONET and coordinated by the Botanical Garden, University of Vienna, three local seed banks have been established (at the Botanical Garden, Karl-Franzens-University of Graz; the Botanical Garden, University of Applied Life Sciences Vienna, and the Botanical Garden, Carinthian Centre of Botany Klagenfurt (Kiehn *et al.*, 2009). This collaborative approach aims at collecting as many of the rare and endangered species of Austria as possible as well as more common species from endangered habitats. The project is linked with seed bank projects on the European level (especially the ENSCRI-project proposal for the 7th EU framework programme), which, for example, provides the facilities for backup storage of seed material, or gives the background for prioritising species for collecting efforts.

An additional aspect of both living collections and seed banks relates to the potential effects of global warming. In order to proactively adjust collection policies in this context, the Austrian botanical gardens have established links with monitoring programmes like Gloria (GLobal Observation Research Initiative in Alpine environments; http://www.gloria.ac.at/).

- Target 10 (Management plans in place of at least 100 major alien species that threaten plants, plant communicates and associated habitats and ecosystems)

At their annual meeting in Graz in 2007, the Austrian botanical gardens agreed to install a neophytes-related information homesite on the network homepage (Berg 2007). The instalment and the maintenance of this homesite (http://www.botanik.univie.ac.at/hbv/index.php?nav=83b) are financed by the Botanical Garden, University of Vienna, with support from the Austrian GSPC Focal Point in 2008 and 2009.

Several representatives of Austrian botanical gardens have participated in the development of an action plan for the botanical gardens of German speaking countries related to invasive and potentially invasive neophytes. These guidelines were adopted by the Austrian botanical gardens in 2008 (Kiehn *et al.* 2007; english version: Kiehn *et al.*, 2008). One activity in the context of this action plan was the eradication of *Toxicodendron radicans* (Poison Ivy) at the Botanical Garden, University of Vienna, and an information campaign related to the serious health problems caused by this species. Actually, data for the species are collected on the European level (please communicate reports for this species to the author of this paper: michael.kiehn@univie.ac.at).

Scientists from botanical gardens of the University of Salzburg, the Karl-Franzens-University Graz, the Carinthian Centre of Botany Klagenfurt, and the Universty of Vienna have started a series of publications on little documented, potentially invasive species observed in botanic gardens in Austria/Europa (Eberwein *et al.*, 2010, Eberwein & Berg, 2010); an evaluation of a selection of such taxa is the subject of a current diploma thesis project at the Botanical Garden, University of Vienna (Lechner & Kiehn, 2010).

Summary

Botanic gardens are intensively involved in the implementation of the GSPC targets in Austria. They coordinate and participate in relevant scientific and conservation projects. This involvement not only considerably contributes to reach the goals of the GSPC targets, it also helps to raise the socio-economic and political profile and recognition of the Austrian botanic gardens community. Thus, GSPC-activities are likely to improve options for securing employment of competent staff and mid-term financial support. The Austrian botanic gardens will continue their commitment towards reaching GSPC targets in 2010. They will also work on visions for useful activities beyond 2010.

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Using BGCI's databases to connect plant collections and expertise to support the development of an international Sentinel Plant Network

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Abstract

There are over 2,600 botanic gardens in operation today, located in nearly every country and ecosystem around the world. It is estimated that 30-40% of the world's known plant species are grown in the living collections of these botanic gardens, often not in the country or even on the continent in which they are native. This presents a significant opportunity to understand and predict when and where species may become pests, or when and where they may be susceptible to other introduced pests (particularly fungus and insects). The Sentinel Plant Network is a proposed formal structure under which individual gardens would be able to act collectively to increase the predictive power of their collections. However, without an understanding of which species are held where, and what resources are currently resident within botanic gardens around the world, the activities of a Sentinel Plant Network will be hindered. There is an opportunity to increase the scope, content, and utility of BGCI's two global, publicly accessible databases in order to support key components of a Sentinel Plant Network to help predict and prevent new pest incursions around the world.

Keywords

Early warning system; Insect pest; Invasive plant; Monitoring; Plant collections database; Plant pathogen; Sentinel Plant Network;

Article

The concept of a Sentinel Plant Network

Botanic gardens that maintain living plant collections from around the world could work together to form the basis for an international Sentinel Plant Network, where living plant collections are connected and capable of serving as early warning systems to help predict and prevent the incursion of new pests (insects, pathogens, or invasive plants). The idea of a sentinel network is not new, and in a few cases model programmes (such as New Zealand's expatriate plant pilot programme) have been implemented on a national or regional scale (Fagan, Bithell, and Dick, 2008; Fagan, 2008; Miller, Beed, and Harmon, 2009; Britton et al., 2010). There is a demonstrated need for more effective early warning systems for new pests, which if implemented could eliminate significant environmental and economic costs of future invasive insects, pathogens, and plants.

A clear example of why a Sentinel Plant Network could help mitigate environmental and economic costs via early detection and prevention of new pests comes from the 2002 discovery of the Emerald Ash Borer in Michigan, USA. The infestation of this beetle (native to Asia) was not identified in time to eradicate it and prevent its spread, so its range is rapidly increasing throughout the United States and Canada. After only 5 years, over 53 million native ash trees (*Fraxinus* spp.) were killed by the beetle, and in the next ten years the infestation is predicted to cost an estimated $10.7 billion to treat, remove, and replace the more than 17 million planted ash trees likely to be killed in urban areas alone (Kovacs et al., 2010). If a Sentinel Plant Network had been in place allowing botanic gardens in Asia growing ash trees native to North America to monitor and report any unusual insect damage, the extreme susceptibility of North

American ash trees to the Emerald Ash Borer could have been predicted and measures put in place to monitor and eradicate any occurrences before they became too large to control.

While the need is greater than ever, a number of components are required for the development of a truly international Sentinel Plant Network of botanic gardens. In this article we address four key components that are needed to help form the basis of such a Network, which include: 1) connecting plant collections to identify which plants are growing where, 2) locating reliable information on the native distribution of plants growing in collections around the world, 3) identifying which gardens have the capacity or partners in place to be able to monitor for potentially new and invasive pests/pathogens/plants, and 4) establishing a network (formal or informal) of botanic gardens and partners that is based on collections information and expertise, and provides a specific means of communication, collaboration and information sharing.

Which plants are growing where?

An increasing number of online databases exist that are connecting accession-level information about the living collections at botanic gardens and arboreta around the world, which will only grow in content and functionality in the coming years. However, the only database that connects living collections (at the taxa-level) around the world is BGCI's PlantSearch database (see www.bgci.org/plant_search.php). This database is powerful because it allows free participation by any institution able to provide an electronic list of the taxa found in their living collections. In March 2010, this database contained 611,000 records representing 181,000 taxa growing in 700 botanic garden collections in 112 countries around the world. This included collections information for 73 botanic gardens in the United States, 34 in China, and 18 in Russia.

The information in PlantSearch is searchable on-line, but the identity of gardens holding specific collections is not revealed. Instead, researchers interested in contacting specific gardens regarding a taxon in their collection can submit a request through BGCI's online system, and collection holders have the option of responding to requests or not. Expanded off-line searching capabilities currently allow BGCI staff to perform more specific searches, for example the database currently contains nearly 2,000 records of Ash trees (*Fraxinus* spp.) growing in botanic gardens located in 33 countries.

BGCI is working to increase the content and quality of data in the PlantSearch database, as well as its utility to botanic garden contributors and other end-users such as researchers and conservation planners. BGCI encourages all gardens, regardless of collections size or focus, to upload taxa lists to PlantSearch to gain useful information on the taxa in their collection and to ensure their collections are globally connected through this database tool. BGCI is also assessing the potential to expand on-line querying capabilities for garden contributors, which could facilitate more direct communication amongst botanic gardens taking part in an international sentinel plant network than is currently possible.

What is the native distribution of plants found in botanic garden collections?

The PlantSearch database currently allows queries against different lists which help BGCI or contributing botanic gardens identify taxa in their collections that are known to be threatened, possess medicinal properties, or are crop wild relatives. This functionality of the database has recently been expanded, allowing BGCI and contributing gardens to identify taxa native to the United States and Canada, following information on global ranks provided by NatureServe (NatureServe, 2010). While this is an useful expansion which could facilitate monitoring at individual gardens as well as communication amongst gardens, expanding PlantSearch's capability to include distribution data for other continents and countries will be an important future addition to guide the establishment and work of a Sentinel Plant Network.

Where are resources and expertise located?

Knowing where plants are being grown is only one piece of the puzzle in laying the groundwork for a Sentinel Plant Network. An additional component is the need to know which gardens have the capacity to monitor, identify, and report potentially invasive pests, pathogens, and plants. For this, we believe GardenSearch, the only global database of botanical expertise and capacity in the world's botanic gardens (see www.bgci.org/garden_search.php), has the potential to fill this role. However, targeted upgrades in database structure and content will be necessary before this database will be fully useful. Currently, by searching on keyword, the online interface of this database can be used to locate gardens in different countries with expertise in botanical research, conservation and education. Yet none of the current fields contain information on the specific resources and expertise that may help connect and inform a Sentinel Plant Network. In addition, the database's online search functionality is very limited, although expanded off-line searching capabilities currently allow BGCI staff to perform more specific searches, for example to identify gardens with research programmes on invasive species biology and control in the United States.

To support the Sentinel Plant Network, the GardenSearch database could be updated to include new fields which easily identify gardens who maintain plant pathology programmes, provide pest/pathogen identification services to visitors, or who already monitor their collections for new pests, pathogens, or potentially invasive plant species. This year, BGCI will be carrying out an online survey that allows the global botanic garden community to identify where resources, expertise, and interest exist that could help form the foundation of a Sentinel Plant Network (BGCI, 2010).

Establishing a network for information gathering, sharing, and communication

Connecting plant collections as well as resources and expertise through comprehensive global databases is an important step in forming the foundation of a Sentinel Plant Network, but communication pathways will need to be enhanced in other ways as well to make the network as efficient and valuable as possible. This includes communication between gardens holding plants, between garden staff and outside organizations that can help identify new pests or pathogens, between gardens and the general public (which could have an important role to play in expanding monitoring efforts – the American Public Gardens Association will be working on this in 2010-2011), and between gardens and organizations working to predict and prevent new pests. For this, will be critical to engage not only a broad array of botanic garden staff, including those involved in pest management, plant records, entomology, and pathology, but also organizations in other sectors, including researchers at academic institutions as well as individuals at government agencies.

We believe that it is important for the global botanic garden community to begin taking the steps necessary to build a Sentinel Plant Network. This network has the potential to not only increase predictive and preventative measures available to stop the next insect pest, plant pathogen, or invasive plant incursion, but also the power to demonstrate the value of living collections, and the opportunity to educate and engage botanic garden visitors on a relevant and timely topic where they can help make an impact.

For more information, visit www.bgci.org/usa/sentinel.

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Assessing invasive potentials of plant species cultivated in botanic gardens in Central Europe

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Abstract

Botanic gardens can be potential hotbeds for future plant invasions, but they are also well suited as observation areas for potential invasiveness of cultivated, non-native species. This paper presents a diploma work actually carried out at the University of Vienna as part of the activities of the Austrian Botanic Gardens Working Group to mitigate negative influences of invasive plant species originating from botanic gardens. The work aims to assess invasive potentials of plant species in botanical garden collections and look at the establishment of an early warning system and an identification tool for such species.

Key words

Assessment of invasiveness, botanical Gardens, Central Europe, early warning system, identification tools, invasive alien plant species

Background of the project

Invasive alien species are known to cause great economic, health and ecological problems all around the globe.

Numerous invasive plant species (like *Impatiens parviflora* or *Heracleum mantegazzianum*) have started from botanical collections. Thus botanic gardens have a high responsibility to monitor their holdings carefully for potential invasives.

The Austrian Botanic Gardens Working Group has already been working for several years on best practice strategies to mitigate potential negative influences of invasive neophytes in botanic gardens. As part of these activities, voluntary guidelines for botanic gardens related to potentially invasive neophytes were adopted and published in collaboration with the Association of Botanic Gardens of the German speaking countries (Kiehn *& al*., 2007).

Data collection and first results

Last year, the Austrian Botanic Gardens Working Group started to collect data on potentially invasive plant species cultivated in its member gardens with the aim to provide this information on standardized information sheets to other botanic gardens, (ornamental) plant traders, market-gardens, amateur gardeners and all interested parties. As part of these activities, data collection about observed invasiveness of plant species in cultivated botanic gardens is performed by a questionnaire in the context of a diploma thesis (M. Lechner).

These investigations are focused on non-native species that have shown obvious colonization and expansion patterns during the past decade. That way, the collected data allows the detection of species at the threshold of invasiveness – the narrow time window between an (eventually) long-term steady-state situation and an exponential population growth.

The questionnaire was distributed via e-mail to botanic gardens in Austria, Germany and Switzerland. It contained questions about species with tendencies to spread uncontrolled in a botanic garden, their occurrence, their spreading pattern, and, if applicable, their management. This way, a network of relevant information was set up.

For 75 non-native species, the questionnaire and additional contact work revealed a potential to become invasive in at least one botanic garden in Austria or Germany.

Amongst those, the investigation revealed several species of concern. Some of them are intensively spreading, but are already worked on or documented by other research groups. Others lack essential features for "long distance" invasiveness, but are aggressively expanding on a local scale and therefore should not be planted in botanic gardens in their own interest. Examples for such taxa are *Aster novi-belgii*, *Duchesnea indica*, *Eschscholtzia californica, Geranium sibiricum, Lysimachia vulgaris*, *Solidago flexicaulis*, *Solidago graminea* and *Stachys affinis*.

Actual and further steps

Several other species have been selected to be published in the form of information sheets. A publication introducing the aim of these sheets (Eberwein *& al*., 2010), as well as a first information sheet (on *Pinellia ternata*, Araceae; Eberwein & Berg 2010) have meanwhile been published. Additional six taxa hitherto not considered to be invasive in Austria or Germany were selected for the next series of information sheets: *Campsis radicans, Echinops exaltatus*, *Impatiens flemingii*, *Inula magnifica*, *Oxalis corniculata* (and other *Oxalis* ssp.) and *Verbena bonariensis*. Data collection on cultivated taxa is also continued (e.g., for *Toxicodendron radicans*, a species with invasive potential causing health problems – please report observations for this species to michael.kiehn@univie.ac.at).

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Meeting Target Eight: *Rhododendron subgenus Vireya* in New Zealand as an example of *ex situ* conservation.

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Abstract

Target Eight of the Global Strategy for Plant Conservation requires knowledge and management of Red List species in cultivation, but what are the practical issues and difficulties associated with such *ex situ* management? Rhododendron is not native to New Zealand, but preliminary data indicates species are present in large numbers in collections and botanic gardens, and many of these accessions are of known wild-source. Following the Red List workshop in Singapore in 2008 it became apparent that New Zealand holds a considerable number of Red List species, particularly *Vireya* species, some not otherwise known in cultivation, and many of wild origin. This resource appears to have potential for *ex situ* conservation, and we are investigating this issue with a three part study. A survey of collections reinforces the role of the Pukeiti Rhododendron Trust collection as the major collection of *Vireya* species (about 160), but also highlights issues around nomenclature, recording and labelling. A DNA fingerprinting study is showing the extent of variation among different accessions, and therefore the usefulness of the collections in conservation. At the same time this study will inform some of the taxonomic issues within the Vireya group, which in turn influence conservation action and priorities. The data from these two studies will then be used to propose conservation action and priorities. This paper will outline our investigation into the potential of New Zealand collections of *Rhododendron subgenus Vireya* for *ex situ* conservation.

Keywords: Rhododendron, Vireya, Conservation

Introduction

The principles and theory of *ex situ* conservation have been recognised for many years (Given, 1987) and the use of this form of conservation is now accepted as part of an overall approach (Geurrant et al., 2004; CBD, 2002). In recent times Targets 2 and 8 of the Global Strategy for Plant Conservation have brought *ex situ* methods in to focus as those targets generate Red Lists (Target 2) and then search for those species in cultivation (Target 8), so that the germplasm may be used in conservation plans. Plant conservation remains an urgent problem (CBD, 2006) and every revision of the Red List increases the number of species at risk and, at the same time, we know that botanic gardens and plant collections around the world contain thousands of plant accessions. How applicable are those accessions to the conservation problem and do they have any useful role in *ex situ* conservation? In this paper we explore *ex situ* conservation in relation to collections of *Rhododendron* subgenus *Vireya* in New Zealand and relate this to the recently conducted Red List assessment for that genus (BGCI, 2008).

Principles of *ex situ* conservation

In 1987 Given (1987) considered *ex situ* conservation as a component of an overall conservation approach and suggested that it had several functions:

- Insurance against loss in the wild.
- Preservation of genetic diversity and genetically different forms.
- Provision of material for research and assessment.
- Educating public and community about the importance of conservation.
- Provide plants for exchange and re-introduction.

He also recognised the difficulties and suggested that the value of *ex situ* collections for conservation was negated by inadequate genetic variability in collections, pest and disease problems, poor commitment to conservation, lack of coordination between gardens, and inadequate record keeping and documentation. He outlined what he saw as institutional and structural barriers to *ex situ* conservation such as poorly defined mission, poorly formed collections policies, and lack of coordination between institutions. He believed a framework for *ex situ* conservation was needed that could address the size of the problem, the balance between *in situ* and *ex situ* methods, the necessary understanding of plant populations, and a process for areas where the flora had not been studied.

Many of these difficulties remain today and debate continues about genetic representation, pest and disease problems, invasive species, and sampling and documentation (Anon, 2010; Anon, 2007; Dosman, 2006; Ennos et al., 2005; Guerrant et al., 2004; Given, 1987; Heywood, 2010; Maunder and Byers, 2005). Maunder et al. (2001) highlighted *ex situ* problems in their study of threatened European flora in botanic gardens in Europe, where they found the majority of taxa concentrated in a small number of collections, very few wild-source accessions, and poor documentation of those collections. Do these problems occur in other countries and with other plant groups? How do we overcome such limitations to improve the usefulness of such collections?

In other aspects of *ex situ* conservation, significant progress has been made through the framework of the Global Strategy for Plant Conservation (CBD, 2002) and its forthcoming update (Anon, 2010), and through international associations like the Species Survival Commissions and Botanic Gardens Conservation International (BGCI) who facilitate documentation, research, and collective effort through their networks (Wyse-Jackson and Sutherland, 2000). BGCI is running a programme of Red List assessments under Target 2 of the Global Strategy (Gibbs and Chen, 2009; Cicuzza et al., 2007; Oldfield and Eastwood, 2007) and is also developing an extensive database to facilitate Target 8.

New Zealand plant collections and international Red List species

It has been estimated that New Zealand contains around 40,000 taxa of exotic plants in cultivation (Carver et al., 2007; Parsons, 2009) – which vastly outweighs our approximately 2800 native taxa. Approximately 2200 naturalised taxa have been recorded (Webb et al., 1988) but the bulk of cultivated flora are inadequately documented in government datasets and national herbaria (Parsons, pers.comm., 2009). The Ministry of Agriculture and Forestry "Biosecurity Index" lists some 27,000 taxa but this is acknowledged as only a partial description of cultivated flora (Parsons, 2009) and comparisons indicate that it covers ½ to $^{2}/_{3}$ of taxa present in collections (MacKay, 2008, 2005). A Plantfinder describes some 30,000 taxa in commercial trade (Gaddum, 2000), but commercial trade does not cover all taxa present in collections (MacKay, 1996). Thus there is no comprehensive description of cultivated flora in this country and there are many unrecorded taxa in collections.

Studies of exotic woody flora in New Zealand reveal about 12,000 taxa in about 120 plant collections and about 80 sources in commercial trade (Cliffin, 2001; MacKay, 2005; MacKay 1996; MacKay, 1995; Smith 1983; Smith 2009). There is a wide diversity of woody taxa in collections, with only partial overlap between collections and trade, and with the most significant collections on private or Trust properties, not in government institutions. The temperate tree collection at Eastwoodhill Arboretum and the conifer collection at Torwood Arboretum are two examples. (New Zealand does not have government-funded botanic gardens, sites such as Christchurch and Dunedin Botanic Gardens are run by local authorities – thus we do not have a 'botanical infrastructure' like most other countries.) Some of the studies considered Red List species, with varying numbers of taxa found, including wild-source material (Brockerhoff et al., 2004; Jamil, 1998; MacKay, 1996). A 2005 study examined 238 genera using the World Conservation Monitoring Centre database and found 952 Red List species in New Zealand collections, concentrated in certain genera (MacKay, 2005), suggesting that New Zealand collections may have some potential for conserving some groups. *Rhododendron* was not included in those studies, nevertheless about 1200 taxa, including about 250 taxa of species or subspecies rank, were picked up in those surveys (MacKay, 2005, 1996, 1995). Major *Rhododendron* collections had not been considered so there were clearly more *Rhododendron* taxa present, and some of those were rare in cultivation (Smith, pers.comm. 2007). It appeared that New Zealand collections may have potential for conservation (MacKay, 2008a) and the draft Red List for vireya provided a framework to examine the resource in New Zealand.

Ex situ **conservation and Vireya Rhododendron**

Rhododendron is a large genus of some 1250 species which is broadly divided into about 900 temperate species, largely found in mainland Asia, and about 350 subtropical species of the *vireya* subgenus which are found in various countries throughout the Malesian archipelago and into northern Australia. Most of the *vireya* group are shrubs, many epiphytic and from high altitude regions. A high level of endemism coincides with occurrence in countries where habitat loss and deforestation are problems, yet only three species had previously been Red Listed (BGCI, 2008).

Conservation of *Rhododendron* is being addressed by BGCI, initially with a Red List assessment of the genus, as part of their programme of assessments under Target 2 of the Global Strategy for Plant Conservation. The draft Red List (BGCI, 2008) suggests that of the 373 species in subgenus *Vireya*, 187 are likely to be Red Listed in some form. This assessment prioritises species and focuses studies for Target 8; to find those species in cultivation and use that data in conservation planning.

Conservation of this genus, however, is confounded by taxonomic complexity. If species A is Red Listed, but is not clearly distinguished from species B, should species B also be subject to conservation action? Or, can species A be omitted from conservation action because it is not distinguishable from the more common B, and the larger population of B does not need conserving? *Rhododendron subgenus Vireya* is taxonomically complex with division into 11 series, and frequent groups of subspecies. Many species fit neatly into a series, but others do not, and there are many queries over the relationship between species, and sometimes between series (Argent, 2006). Ennos et al. (2005) argue that the conservation approach should be different (broader) with taxonomically complex groups – potentially having a huge effect on conservation action for Vireya Rhododendron.

Fortunately taxonomy of *Vireya* is comprehensively covered in recent monographs (Argent, 2006; Argent et.al., 2007) where each species is described and taxonomic issues and queries are outlined; giving a taxonomic framework for further research. Molecular studies provide some insights, for example, a proposed relationship between *R. loranthiflorum* and *R.luralense* (Argent, 2006) was supported by molecular work (Brown et al., 2006). Other molecular work suggests that some series should be amalgamated (Brown 2006, 2006a), or that some *vireya* series may be more closely related to mainland temperate species (Craven, 2008). These molecular studies suggest some likely revision of relationships, but those studies do not cover all the taxonomic queries raised by the classical studies. Thus we have a subgenus of about 370 species with many unresolved taxonomic complexities that may, or may not, impact on conservation action.

When resources are scarce conservation action must be focussed on the most important species and with the best possible germplasm. The draft Red List establishes an initial priority for *Vireya Rhododendron*, but to which accessions of which taxa in which collections should this be applied? New Zealand collections appear to have some potential, but do they contain species and accessions that are useful? How will plans be altered by the taxonomic complexity of the group? Our study of New Zealand collections will illustrate some of these issues.

Method

To examine the potential role of New Zealand collections of *Vireya Rhododendron* in conservation we propose five steps:

- Examination of the Red List and establishment of initial priorities indicated by that data.
- Determination of the range and distribution of species in New Zealand collections.
- Examine the taxonomic issues and queries associated with Red List species, to establish a priority set of species for testing.
- Molecular testing of those species, using samples from New Zealand collections.
- Interpretation of data and proposal for conservation action.

The draft Red List sorts taxa into greater and lesser priority, but other issues may be evident from examination of the list. How many species were Red Listed? What level of conservation problem does this represent? Did species from a certain region dominate? The draft Red List was examined for geographic or taxonomic patterns and compared to other recent Red Lists. For this analysis some modifications were made to the list to take account of species that had been omitted from the list, so BGCI's base list of 345 taxa was increased to 373 taxa. The Singapore workshop did not complete the assessment of the entire list, so for this analysis the principal author has made an estimate of which of the remaining species are likely to be Red Listed.

The second step was to characterise the *Vireya* resource in New Zealand. Previous studies had not focussed on *Rhododendron* in either collections or commercial trade, so additional data was needed. Over 2008-2009 Smith completed a database of the collection at Pukeiti Rhododendron Trust (Smith, 2009). In 2009 data was gathered on other *vireya* collections – of about 12 relevant collections we were able to gather information from five of them. The others were inaccessible for various reasons, but it is likely that most of the species they contain are in the Pukeiti collection (Smith, pers.comm.). Next, five additional commercial trade sources were added to existing data. From these data the range and distribution of *Vireya Rhododendron* in New Zealand could be described.

Next we addressed the interplay between conservation and taxonomic complexity. Consider the example of Red Listed species in the *Phaeovireya* series. If we conserve *R. bryophilum* (Red Listed) should we also conserve *R.dielsianum* which was not Red Listed but which is difficult to separate from *R.bryophilum?* If we conserve *R.superbum ssp. ibele* should we also conserve *R.gardenia*, which was found in the same location but then never found again, but similar plants key to *R.superbum*. And what of *R.helwigii* which hybridises with *R.superbum* and may have some relationship to it, or *R.inundatum* which also hybridises with *R.superbum*, but *R.inundatum* is in another series. Perhaps all four are more closely related than previously thought, perhaps not, but the best conservation plan will come from being sure about those relationships (Table 1).

Relationships and queries of this nature occur throughout the *vireya* subgenus (Argent, 2006), so diagrams and tables were created in which these factors for each series and Red List species were shown. Those diagrams were reduced to the subset of species that are in New Zealand, thus focussing the selection of species for further testing (Fayaz, 2010). Molecular methods are being used to examine those species (Fayaz, 2010). 132 tissue samples were collected from four collection sites and DNA extracted used a modified Kobayashi method (Kobayashi, et al., 1998). A further 18 samples were obtained from the Rhododendron Species Foundation in United States of America. RAPD analysis (Random Amplified Polymorphic DNA) was used for preliminary tests of DNA quality and this method was used to form a benchmark set of *R.jasminiflorum* samples which were used as comparison in later analysis (Fayaz, 2009). The samples are now being tested with 27 SSR (Simple Sequence Repeat) or microsatellite markers, which have been kindly contributed by Ben Hall (University of Washington) and Frank Dunemann (Bundesforschungsinstitut für Kulturpflanzen, Dresden, Germany). This work is still in progress (Fayaz, undated) but some preliminary results are presented.

Results: the draft Red List

Of 373 taxa of vireya Rhododendron, 187 (50.1%) were Red Listed in some form (BGCI, 2008). Of the 187 rated species, 99, or 52.9%, were given a Data Deficient rating indicating that additional study is needed to clarify the status of these species. About two thirds of rated species come from the islands of New Guinea (86 species) and Borneo (33 species) with the rest from other locations in Malesia (Table 2). The largest number of Data Deficient species came from New Guinea (61 species) whereas Borneo had only 4 species with that rating. Sulawesi (Indonesia) has fewer species, but 69% were Red Listed, as were 69% of mainland species.

Next, given the taxonomic complexity issue, do Red List species occur evenly among the 11 series of the subgenus? (Table 3). The greatest number of rated species were in *Euvireya: euvireya, Euvireya: malesia*, and *Phaeovireya*, but by percentage the worst problem is in *Euvireya: linnaeopsis* with 60% rated - which highlights a geographic issue as this series is solely from New Guinea. *Siphonovireya* (45% listed) is also solely from that island and *Phaeovireya* (46% listed) has all but two species from there, so a geographical issue potentially threatens a whole taxonomic group. *Pseudovireya* at 60% listed also indicates a problem, but most of these are Data Deficient due to inadequate knowledge of mainland species. *Discovireya* was 'best' with only 35% listed, and this series has a wide geographic spread so the conservation issue is less in this group than some others.

These figures appear to indicate an enormous conservation problem but how does this relate to other recently assessed groups? Both *Acer* (Gibbs and Chen, 2009) and *Quercus* (Oldfield and Eastwood, 2007) are comparable to *Vireya Rhododendron* with about half the taxa Red Listed (Table 4), but Magnoliaceae is worse with 87% of taxa Red Listed (Cicuzza et al., 2007). *Acer* and *Quercus* had about a third of rated taxa designated Data Deficient, indicating the need for additional research. In contrast, Magnoliaceae had only 7.6% of taxa rated Data Deficient; so while that group has a conservation problem it is a relatively well-understood problem. *Vireya Rhododendron* stands out from these other groups with the high percentage of Data Deficient rating.

Some geographic trends were also evident in the other assessments. In *Acer* 87% of listed species were from China and other countries in Asia. In Magnoliaceae the split was about 50:50 between Asia and South America, while in *Quercus* about half the listed species came from Mexico and South America, and another third from Asia. These patterns do not equate with the geographic origins of the genera – both *Acer* and *Quercus* are found in Asia, Europe and the Americas but the Red List species were concentrated in Asia and South America. By contrast, in *Vireya Rhododendron* both geographic origin and the conservation issue are focussed on one region, Malesia. When this is combined with the number of species Red Listed and given Data Deficient, *Vireya Rhododendron* appears to have a conservation problem more acute than other recently assessed groups.

Results: *Vireya Rhododendron* species in New Zealand

In total we found 158 taxa of species or subspecies rank of which 63 are of known wild source, and 44 are likely to be Red Listed. The largest collection was that of Pukeiti Rhododendron Trust which contains about 155 taxa of species or subspecies rank, plus three natural hybrids. Using the BGCI database as a measure of international frequency, 128 of the 158 taxa were found in three-or-less collections (noting that this database does not cover the Pukeiti collection), indicating that there are few other collections of *vireya* world-wide.

Geographically, our collections reflect the distribution of the subgenus, with the majority of taxa coming from the island of New Guinea (67 taxa) and then the island of Borneo (39 taxa). The better representation is Borneo with 56% of those taxa present in our collections (Table 5).

When considered by series the greatest number of taxa found in New Zealand are from *Euvireya:euvireya, Phaoevireya, Euvireya:solenovireya*, and *Euvireya:malesia* (Table 6). When species not in cultivation (Argent, 2006) are removed from the list, our collections contain about 65% of taxa in cultivation, but this varies with different series. We have 80% and 79% of *Albovireya* and *Phaeovireya* respectively, down to 45% of *Discovireya* and 37% of *Malayeovireya*.

When the data are reduced to just the Red List species, our collections contain 44 taxa or about 24% of Red Listed *Vireyas*. While there are 63 species of known wild source, only 12 are both Red Listed and wild sourced. The greatest number of Red List species in New Zealand are from *Euvireya:euvireya*, followed by the *Euvireya:solenovireya*, *Euvireya:malesia* and *Phaeovireya* groups. By percentage the *Albovireya* group is noted as we have 37.5% of Red Listed species from that group (Table 7).

Geographically our collections have the greatest number of species from New Guinea, Borneo and then Sulawesi. By percentage Borneo is followed by Philippines and then Sulawesi (Table 7). These data must be read with caution though as species have been assigned to one geographic location when some come from more than one place, which would vary these figures.

With respect to Red List species the taxa in our collections follow the patterns of the subgenus with greatest representation from *Euvireya:euvireya, Phaeovireya, Euvireya:solenovireya, Euvireya:malesia*, and geographically on the islands of New Guinea and Borneo.

Results: molecular studies

The segment of the study is still in progress and only preliminary results are available at this stage. Samples have been tested with about 20 of the 27 available microsatellite markers and these data are presently being processed. Some preliminary findings (Fayaz, 2010, undated) are as follows:

- RAPD analysis indicates that *R .jasminiflorum* and *R. jasminiflorum ssp. oblongiflorum* are distinct entities rather one continuum. If the *R. jasminiflorum* subspecies are distinct this may have conservation implications for *R. jasminiflorum ssp. copelandii,* which was Red Listed, but we were unable to test this species as we do not have it in New Zealand.

- Analysis of data from 6 microsatellite markers supports a close relationship between *R. loranthiflorum* and *R. luraluense*. This is potentially important as *R.luraluense* was Red Listed and *R .loranthiflorum* was not.
- Microsatellite data suggests that *R. lochiae* (syn. *R. notiale*) is distinct from the closely related *R. viriosum*, but at the same time there appears to be a gradation of types within the *R.viriosum* samples. Again this may be important as *R.lochiae* was Red Listed and *R.viriosum* was not.
- Microsatellite data suggests a relationship between *R.archboldianum* and *R.herzogii* (which is in different series), supporting Argent's proposition that there is a relationship between them. *R.archboldianum* was Red Listed while *R.herzogii* was not.

The conservation implications of the molecular data are yet to be fully understood as the data is not yet complete. When these data are fully processed relevant results will be reported.

Discussion

This work shows that New Zealand, and more particularly Pukeiti Rhododendron Trust, contains a significant collection of *vireya rhododendron*. There are 158 taxa, including 44 Red List taxa and 63 taxa of known wild-source, although there are few accessions of some of those taxa. Variability among the accessions is yet to be finalised through molecular testing. There were no other collections of any comparable size in New Zealand, thus important collections are concentrated on few sites with limited accessions. This problem of limited accessions has long been recognised (Given, 1987; Maunder et al., 2001), and Target 8 stresses the need for genetic representation (Anon, 2010), but what are the solutions? Gathering more accessions from native habitat is unlikely to be feasible for most species, so the answer must lie in greater international integration between collections. In this example exchanging material between Pukeiti Rhododendron Trust and other international collections would improve representation in all collections – unfortunately plant importation into New Zealand is very difficult under current legislation (Douglas, 2005), but exportation to other sites is possible.

Although our data shows limited accessions, this problem can be restated as limited accessions in the recorded collections. Of the approximately 12 *vireya* collections in this country another four may contain different material, but we could not access these: one was dispersed without documentation, in another the owner passed away and the new owner has no documentation, in another the owner has also passed away, and in a fourth we could not access the collection. There may not be additional species in those collections, but it is highly likely that there are different accessions present.

In turn this highlights a key issue in advancing the cause of *ex situ* conservation – detailed field work is needed to discover and verify the accessions on which a conservation plan might be based. In other countries such field work might be focussed on botanic gardens and science institutions with formal databases, but in New Zealand that is not where significant collections are found (MacKay, 1995). In this study only two collections are in formal institutions and only one has a database, the rest are on private sites where plant identification and records must be generated from field work. This highlights the next issue, that field work is not a simple task. A high level of taxonomic skill is needed to identify and separate conservation species, which are usually more difficult to identify than common species, and there are limited personnel with this level of skill. In addition, field work must be supported by a comprehensive taxonomy, and this may not always be available.

In combination it is clear that for an *ex situ* investigation to be successful, five elements are needed:

- A comprehensive baseline taxonomy of the group, to provide an understanding of the classification and relationships of the genus and therefore the queries that should be posed about Red List species. In this case provided by the Argent monographs.
- A Red List assessment, to prioritise further examination of the genus and any potential action.
- An integration of the Red List with the taxonomic issues of the group, such that a 'Red List plus associates' group of species can be examined for ex-situ plans.
- Field assessment work to determine where the priority species exist in cultivation, the extent to which they are wild source, and the range of accessions.
- Some form of testing to clarify the taxonomy and identity of accessions and to assess the level of variation among the samples.

After these steps conservation potential can be examined and a conservation approach determined. From this study we propose that elements of a conservation plan for *Vireya Rhododendron* might be:

- International cooperation to accumulate the limited number of accessions worldwide into 'world' collections.
- Examination of the 'world' collection to relate its composition to the Red List.
- Further DNA testing to compare international accessions with New Zealand accessions.
- Integration and prioritisation of taxonomic or geographic issues into a conservation plan that:
  - Develops *in situ*, or in country *ex situ*, conservation in priority countries.
  - Focuses *ex situ* conservation on 'world' collection sites.
  - Integrates the above through exchange of knowledge, plant material and personnel.

Each of these elements should be used in an "*ex situ* conservation assessment" method. This method could be applied to other plant groups, for example temperate Rhododendron, of which New Zealand also has a large collection. The method could also be applied to other plant groups.

Conclusion

For more than 25 years the principles and issues of *ex situ* have been known, and while science continually develops greater knowledge, new processes, and better networks, at another level the original problems remain. Local knowledge, robust data and field work, and international cooperation remain both the problems and the solutions – and every project makes a small advance for the cause. In this project we have shown that New Zealand holds collections of *Vireya Rhododendron* that could contribute to an international *ex situ* collection for that group, and we believe our approach could be applied to *ex situ* conservation of other plant genera.

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Tables

Table 1

Red Listed Phaeovireya species	**Associated species (Argent, 2006)**
bryophilum	*dielsianum* – no clear distinction from *bryophilum*
dianthosmum	
rhodochroum	*haematophthalmum* – found in the same location.
solitarium	
superbum ssp. ibele	*inundatum* (Siphonovireya) – found in the same location and a hybrid between species was collected. *hellwigii* – hybridises with *superbum* *gardenia* – Originally found in the same location as *superbum ssp. ibele*, not found again although similar plants key to *superbum*

Table 2: Number of Red Listed taxa of Vireya Rhododendron according to geographic origin

Origin	**Number of taxa from that origin**	**Number of taxa Red Listed**	**Percentage of taxa Red Listed**	**Number of taxa rated as DD**	**Number of taxa rated DD as percentage of total number rated**
Island of New Guinea	183	86	45.3 %	61	73.4%
Island of Borneo	69	33	47.8 %	4	12.1%
Philippines	28	14	50 %	5	35.7%
Sulawesi (Indonesia)	26	18	69 %	12	66.6 %
Sumatra (Indonesia)	25	14	56 %	9	64.2%
Mainland Asia	13	9	69.2 %	1	11.1 %
Other islands of Indonesia	16	8	50%	3	37.5%
Malaysian Peninsula	11	4	36 %	4	100%
Australia	2	1	50 %	0	50%
Total	373	187	50.1 %	99	52.9%

Table 3: Number of Red Listed taxa of Vireya Rhododendron according to taxonomic series

Series	Number of taxa in that series	Number of Red Listed taxa in that series	Percentage of taxa Red Listed	Number of taxa rated as DD	Number of taxa rated DD as percentage of total number rated
Albovireya	15	8	53 %	5	62.5%
Discovireya	40	14	35 %	8	57%
Euvireya: Euvireya	108	54	50 %	24	44.4 %
Euvireya: Linnaeopsis	15	9	60 %	6	66.6%
Euvireya: malesia	60	31	52 %	15	48 %
Euvireya:saxifragoides	1	0	0 %	0	0
Euvireya: solenovireya	43	23	53.4 %	16	69.5 %
Malayeovireya	17	8	47 %	3	37.5 %
Phaeovireya	49	25	51 %	16	64 %
Pseudovireya	12	9	60 %	1	11.1 %
Siphonovireya	11	5	45 %	3	60%
Unknown	2	2	100 %	2	100%
Total	373	187		99	

Table 4: Number of Red Listed taxa in recent Red List assessments

Group	Number of taxa assessed	Number of taxa Red Listed	Percentage of taxa Red Listed	Number of taxa rated as Data Deficient	Number of DD taxa as percentage of total number rated
Vireya Rhododendron	373	187	50.1 %	99	52.9 %
Magnoliaceae	151	131	86.7 %	10	7.6 %
Acer	191	83	43.5 %	29	34.9 %
Quercus	208	111	53.4 %	33	29.7 %

Table 5: Number of taxa of Vireya Rhododendron in New Zealand, by geographic origin

Origin	Number of taxa from that origin	Number (and percentage) of taxa from that origin found in New Zealand
Island of New Guinea	183	67 (36.6%)
Island of Borneo	69	39 (56.5%)
Philippines	28	13 (46%)
Sulawesi (Indonesia)	26	11 (42%)
Sumatra (Indonesia)	25	8 (32%)
Mainland Asia	13	4 (25%)
Other islands of Indonesia	16	7 (43.8%)
Malaysian Peninsula	11	6 (54.5%)
Australia	2	2 (100%)

Table 6: Number of Vireya Rhododendron taxa in cultivation, and present in New Zealand, by taxonomic series

Series	Number of taxa in that series	Number of taxa in cultivation	Percentage of taxa in cultivation	Number of taxa in cultivation present in New Zealand	Number of taxa in New Zealand as percentage of those in cultivation
Albovireya	15	10	67%	8	80 %
Discovireya	40	24	60%	11	45.8 %
Euvireya: Euvireya	108	81	75%	59	72.8 %
Euvireya: Linnaeopsis	15	7	46.7%	5	71.4 %
Euvireya: malesia	60	34	56.7%	20	58.8 %
Euvireya: saxifragoides	1	1	100%	1	100%
Euvireya: solenovireya	43	29	67.4%	21	72.4 %
Malayeovireya	17	16	94.1%	6	37.5 %
Phaeovireya	49	24	48.9%	19	79.1 %
Pseudovireya	12	11	91.6%	5	41.6 %
Siphonovireya	11	6	54.5%	3	50 %
Unplaced	2	0		0	
Total	373	243	65.1%	158	65%

Table 7: Number of Red Listed taxa of Vireya Rhododendron present in New Zealand, by taxonomic series

Series	Number of taxa in that series	Number of Red Listed taxa in that series	Number of Red Listed taxa present in New Zealand	Number of Red Listed taxa in New Zealand as % of number Red Listed
Albovireya	15	8	3	37.5 %
Discovireya	40	14	1	7.1
Euvireya: Euvireya	108	54	19	35.2
Euvireya: Linnaeopsis	15	9	1	11.1
Euvireya: malesia	60	30	6	20.0
Euvireya: saxifragoides	1	0	0	0
Euvireya: solenovireya	43	22	6	27.2
Malayeovireya	17	8	1	12.5
Phaeovireya	49	25	5	20.0
Pseudovireya	15	9	2	22.2
Siphonovireya	11	5	0	0
Unplaced	2	2	0	0

Table 8: Number of Red Listed taxa of Vireya Rhododendron in New Zealand, by geographic origin

Origin	Number of taxa from that origin	Number of taxa from that origin that were Red Listed	Number (and percentage) of those Red Listed taxa found in New Zealand
Island of New Guinea	183	83	15 (18%)
Island of Borneo	69	33	12 (36.3%)
Philippines	28	14	5 (35.7%)
Sulawesi (Indonesia)	26	18	5 (27.7%)
Sumatra (Indonesia)	25	14	2 (14.2%)
Mainland Asia	13	11	2 (18.1%)
Other islands of Indonesia	16	8	2 (25.0%)
Malaysian Peninsula	11	4	0 (0%)
Australia	2	1	1 (100%)

Building a comprehensive collection of Ash germplasm

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Abstract

This paper summarizes a presentation from the Congress Symposium, "The Introduction of the Emerald Ash Borer in North America, A Case Study of Invasive Species Epidemiology and Conservation of the Host Species." It briefly discusses the state of *Fraxinus* (ash) taxonomy, ash as a landscape and forest tree, some of its specialized uses, including those by Native Americans, and its role in supporting other organisms. The devastation caused to native, North American ash populations by the introduction of *Agrilus planipennis* (emerald ash borer; EAB) to the Detroit, Michigan area has already led to the loss of tens of millions of trees. Diverse efforts are underway to document and slow EAB's spread and develop appropriate biological controls. Scientific research on ash-EAB interactions, including the study of potential tolerance or resistance mechanisms, breeding and genetic-diversity analyses, and ash systematics, would all benefit from access to well-documented, diverse ash germplasm. To help redress this unfolding biological tragedy, a collaborative, international effort to conserve these important genetic resources has been organized. Fortunately, ash is amenable to *ex situ* conservation through seed storage and cryogenic storage of dormant winter buds. Key partners in this effort are described herein, with a focus on the coordinating organization, the USDA-Agricultural Research Service's National Plant Germplasm System, along with a summary of progress to date and future plans.

Keywords

Agrilus, Emerald ash borer, *Ex situ* conservation, *Fraxinus*, Invasive species, Seed collection

An introduction to Ash, its value, and Emerald Ash Borer

Fraxinus is a member of the Oleaceae with winged fruits, consisting primarily of temperate, deciduous trees and shrubs, including ±60 species native to the Northern Hemisphere. Ash diversity is highest in China (22 species; Wei & Green, 1996) and the United States (16 species; USDA-ARS, 2010a). In the absence of a modern monograph for *Fraxinus*, however, such information can only be gleaned from floras. Fortunately, future efforts to develop a modern monograph should benefit from the recent phylogenetic analyses of Wallander (2008), who used nuclear ribosomal ITS sequences to study 40 *Fraxinus* taxa, and the work of Guy Neson, who is preparing a treatment of *Fraxinus* for Flora of North America.

In eastern North America, there are six native *Fraxinus* species (Fernald, 1950) under threat of functional extinction by the exotic insect pest, *Agrilus planipennis* (emerald ash borer or EAB), introduced from Asia to southeastern Michigan, probably in the 1990s (Siegert *et al.*, 2007). EAB adults feed on ash leaves, with larvae feeding on cambial tissue in ash stems and trunks. Female EABs oviposit on both healthy and stressed ash trees (Poland & McCullough, 2006), and there is no documented resistance among these six ash species to larval feeding, which ultimately leads to the death of the infested trees. Larvae commonly infest and kill both mature trees and juvenile saplings (Hermes *et al.*, 2009a). This phenomenon severely reduces opportunities for the evolution of increased tolerance to EAB and may hasten these species' extinction.

Two native *Fraxinus* species, *F. americana* (white ash) and *F. pennsylvanica* (green ash), are extensively cultivated and widely appreciated as stress-tolerant landscape trees (MacFarlane & Meyer, 2005). Many communities in the north central U.S. have overused green ash along their streets, leading to situations where it forms a significant proportion of the urban forest (Raupp *et al.*, 2006). Green ash also has a long and extensive history of cultivation as one the most commonly used trees for windbreaks in the Great Plains (Hoag, 1965). In garden settings, only a few selected staminate clones of white and green ash have generally been planted, which presents special challenges for the *ex situ* conservation of these species as noted below.

In addition to white ash and green ash, *F. quadrangulata* (blue ash) and *F. profunda* (pumpkin ash) also grow to sufficient size in forests to facilitate commercial harvest for timber and wood products. But beyond ash as a general timber commodity, ash wood has a diverse range of specialized uses. White ash wood exhibits a combination of strength and flexibility that makes it especially well suited for tool handles and as the first choice for professional baseball bats (Gasner & Widmann, 1990). Ash wood is also being crafted into artistic furniture and bowls.

Ash wood has also traditionally been employed by Native American communities in the north central and northeastern U.S. and eastern Canada (Schmidt, 1990). *Fraxinus nigra* (black ash) logs are laboriously pounded, and long thin strips of wood, known as splints, are removed layer-by-layer and trimmed. The splints are then woven to make a wide range of both utilitarian and decorative baskets.

These ash species occupy a wide range of ecological niches in eastern North American forests. Green ash has an especially wide geographic range from the Atlantic Coast west to the foothills of the Rocky Mountains and from the Gulf of Mexico north to the Canadian Prairie Provinces. Its wide distribution is mirrored by its broad ecological amplitude, occurring in seasonally flooded, floodplain and lakeside habitats, all the way to dry upland forests. White ash has nearly as wide a native range, but is generally restricted to fairly well-drained, mesic forests. Black ash is found in northern wet or boggy forests, often associated with *Picea* (spruce) and *Larix* (larch). Blue ash is associated with alkaline or calcareous soils, in a more limited geographic range in the central United States with outliers in Ontario, typically occurring in rocky, limestone woodlands. Pumpkin ash and *F. caroliniana* (Carolina ash) are typically found in or near standing water in the southern United States, growing with *Taxodium* (bald cypress) and *Nyssa* (tupelo).

In addition to the general ecological services that native ash trees contribute by providing food and shelter for wildlife, they also support a suite of at least 70 native specialist arthropods (Gandhi & Herms, 2010). Such species include *Tethidia barda* (brown-headed ash sawfly), *Lignyodes* sp. (ash seed weevil), *Aceria fraxinifolia* (flower gall mite), and 21 species of North American butterflies and moths (Wagner, 2007) affected by EAB's spread and the resulting death of millions of trees.

The spread of Emerald Ash Borer and potential controls

Since its North American introduction, EAB has been expanding via both natural dispersal and human assistance. Of the two, human-mediated dispersal is the more serious, in that it facilitates long-distance movement and the establishment of new infestations beyond the primary detection network (Poland & McCullough, 2006). This initially happened via the transport of nursery stock, wood products, and firewood. Today, firewood movement remains the most serious concern, as it is difficult to control through regulation. The spread of EAB is being diligently tracked by an extensive network of traps and regularly documented through the online publication of maps (Emerald Ash Borer, 2010).

In the wake of EAB, tens of millions of ash trees have already been lost (Smith *et al.*, 2009), with billions of dollars invested in tree removal, disposal (to prevent EAB reproduction), and replanting. But potential future economic losses are even greater, considering that the estimated number of remaining ash trees is as high as 8 billion (USDA-APHIS, 2010). When facing these huge costs, it is clear that investments to slow the spread of EAB serve two functions. First, they limit the annual economic burden to landowners and governmental agencies (Sharov, 2004; Poland & McCullough, 2010). Second, they buy time towards the effective deployment of biological control strategies, new treatments, and the potential development of resistant/tolerant ash trees.

There are many EAB-response strategies being implemented; a detailed enumeration is well beyond this paper's scope. Some of the most important, especially for the near-term, include the refinement of effective EAB trapping (Francese *et al.*, 2009; Marshall *et al.*, 2009) and monitoring systems (Careless *et al.*, 2009), the use of quarantines (USDA-APHIS, 2006) on the movement of ash nursery stock, timber products and firewood, accompanied by extensive public-education campaigns such as Don't Move Firewood (2010), the development of insecticide treatments to protect high-value trees (Herms *et al.*, 2009b), and research to identify, test, and introduce biological control agents (Bauer *et al.*, 2009; Gould *et al.*, 2009; USDA-APHIS, 2010). From a more long-term perspective, studies on the evaluation, mechanisms, and genetic control of host-plant resistance in Asian ash (Eyles *et al.*, 2007; Rebek *et al.*, 2008; Mason *et al.*, 2009), and on the potential tolerance of surviving native ash in highly infested zones (Koch *et al.*, 2010) are critical, as are tests of interspecific ash hybridization (Koch *et al.*, 2009), genetic transformation in ash (Pijut *et al.*, 2010), and investigations of genetic diversity, breeding systems and structure in extant populations (Hausman *et al.*, 2010). These efforts hold the promise of an eventual revival in planting ash as a landscape tree and of the re-introduction of ash populations to native forests.

The need for Ash germplasm

Research is focused on the host plant should advance more quickly with reliable access to well-characterized ash germplasm. *Ex situ* germplasm collections, if well designed, can provide a wealth of genetic diversity for economically and ecologically important traits, and supply known sources of clones and populations to serve as scientific controls or checks. But as we entered this crisis, *ex situ* ash germplasm collections in the U.S. were poorly developed. In 2002, there were no recognized ash collections among North American botanic gardens in the North American Plant Collections Consortium; ash provenance collections previously assembled by foresters were neglected or entirely abandoned (Steiner & Lupo, 2010); and the U.S. National Plant Germplasm System (NPGS) conserved only a few ash collections.

At that time, among other curatorial functions, I served as the NPGS curator for *Fraxinus*. As EAB spread and losses mounted, I began to consult other researchers and agencies concerned about this gap in *ex situ* conservation. At that time, the USDA-Natural Resources Conservation Service's Rose Lake Plant Materials Center began to mobilize volunteers to collect ash seeds in Michigan (USDA-NRCS, 2010). The U.S. Forest Service National Seed Laboratory initiated seed collections within its agency and with numerous partners (USDA Forest Service, 2010). The Canadian Forestry Service expanded efforts to collect native ash seeds for the National Tree Seed Centre (Natural Resources Canada, 2010). And within the NPGS, I began planning a series of domestic seed-collection expeditions and established contacts with the Morton

Arboretum and Beijing Botanic Garden to plan Chinese collection trips, designed to sample potentially EAB-resistant ash populations. In addition to the parties noted above, other botanic gardens, state forestry and natural resource agencies, and Native American communities became involved in the collection effort. It was quickly apparent that clear communications and interagency coordination were needed. At a 2009 meeting of interested parties held in Annapolis, Maryland, I agreed to serve as coordinator. In March 2010, I chaired a second meeting at “The Symposium on Ash in North America” in West Lafayette, Indiana, to prepare for the 2010 field season.

Taking on this role was a logical move in that the NPGS is the lead organization within the U.S. for the *ex situ* conservation of genetic diversity of economically important plants and their wild and weedy relatives (Widrlechner, 2009). It has extensive collections and supports considerable research on germplasm conservation protocols. NPGS collections are freely available for research and educational purposes world-wide, and information about the collections is widely disseminated online through the Germplasm Resources Information Network (GRIN) database (USDA-ARS, 2010a).

Assembling and conserving Ash germplasm collections

Fortunately, ash populations can be effectively conserved as seeds with orthodox storage characteristics (UK Forestry Commission, 2010), and clones cryogenically preserved as dormant buds (Volk *et al.*, 2009). Field plantings can also be maintained, if sufficient land is available and trees can be protected from EAB by geographic isolation and/or the effective use of systemic insecticides. Our initial focus has been on the assembly of comprehensive seed collections. To accomplish this, we must ensure good initial seed quality (embryo development and weevil infestation are important limitations, see seed-collection guidelines by Knight *et al.* (2010)), proper taxonomic identity (supplemented with herbarium vouchers), complete passport data, and effective sampling strategies. Ideally, samples should be diverse enough to allow us to preserve genetic profiles over future generations without inbreeding depression. To maximize overall diversity and the capture of genes conferring local adaptation, it is crucial to avoid areas with significant numbers of cultivated, staminate ash trees that can bias local pollen deposition and focus on sites with established natural populations.

On a broad scale, our sampling strategy is conducted on an individual-species basis, focusing on regions that are being colonized by EAB, stratified by plant-community diversity as reflected in Omernik Level III Ecoregions (Omernik, 1987; US Environmental Protection Agency, 2010). A new website for this conservation project has recently been developed (USDA-ARS, 2010b), which details the sampling strategy and presents current protocols.

Beginning in 2007, the USDA-ARS Plant Exchange Office has supported yearly ash seed-collection trips. Successful trips were conducted in New England in 2007, Missouri and southern Illinois in 2008, and Wisconsin and northern Illinois in 2009. Trips to Minnesota and Wisconsin and to Kansas, southern Missouri, and northern Arkansas are planned for 2010. Because of wide year-to-year fluctuations, summer reconnaissance trips to assess variation in local ash seed production and identify optimal populations for fall collection have proven quite helpful.

These collections and those of many collaborators are being incorporated into the NPGS. All these collections are being conserved at the National Center for Genetic Resources Preservation in Fort Collins, Colorado, with many of the best documented and representative samples being incorporated into the active collection at the North Central Regional Plant

Introduction Station in Ames, Iowa, which I curate. Table 1 lists the number of *Fraxinus* accessions in the active collection by species and continent.

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Table 1. Current *Fraxinus* accessions (by species and continent) conserved at the North Central Regional Plant Introduction Station, Ames, Iowa, USA, as of 1 July 2010.

Species	North America	Asia	Europe	Africa
F. americana	61			
F. angustifolia		1	7	
F. anomala	6			
F. bungeana	1	7		
F. chinensis		23		
F. excelsior			14	
F. "hybrid"	2			
F. insularis		1		
F. latifolia	1			
F. mandshurica		10		
F. nigra	15			
F. ornus	1		10	
F. paxiana		3		
F. pennsylvanica	77			
F. profunda	6			
F. quadrangulata	12			
F. raibocarpa		1		
F. sieboldiana		2		
F. "sp."	6			1
F. stylosa		2		
F. xanthoxyloides		1		
Total	188	51	31	1

Contributions of Rio de Janeiro Botanic Garden, Brazil, to the National GSPC mainstreaming process.

G. Martinelli, T. Messina & M.A. Moraes

Abstract

Even though flora conservation is becoming a more popular subject nowadays, and people are starting to realize its importance, Brazil still needs to advance in such a delicate issue. The maintenance of plant diversity is critical for sustainable development and botanic gardens are playing a key role as centres for conservation actions. The Rio de Janeiro Botanic Garden (JBRJ) has consolidated a long history of contributions to the development of scientific knowledge and plant conservation frameworks, protocols and actions. In order to mainstream national efforts with international initiatives towards plant conservation, the National Centre for Plant Conservation (CNCFlora), was created in December of 2008, under the JBRJ infrastructure. The Centre’s working program was aligned to the framework established by the Global Strategy for Plant Conservation (GSPC), prioritizing the targets that meet national needs and capacities. Therefore, CNCFlora has focused efforts, during its first year, on achieving advances in specific GSPC targets: 1 and 2. in this paper we have gathered all contributions made by Rio de Janeiro Botanic Garden, on the mainstreaming process for both of these goals. Despite CNCFlora’s recent creation, the significant results obtained on the targets mentioned above, evidences the importance of botanic gardens in taking part on the process of flora conservation all over the world, leading the way and working as a model for other scientific institutions and environmental agencies. The contribution of big and important institutions is the first step towards achieving targets, especially in developing countries.

Keywords

Botanic gardens; flora conservation; GSPC targets; listing processes.

Introduction

Botanic gardens all over the world play a key role in conservation by maintaining a wide range of plant specimens in living collections, particularly those considered rare and threatened. According to the 1997 IUCN Red List of threatened plants, 34,000 taxa are considered threatened with extinction. Nowadays, approximately one third, over 10,000 species, are cultivated in botanic gardens. These plants may contribute to species recovery programmes, reintroduction in the wild and provide long-term backup collections. Botanic gardens also protect areas within and outside their property enhancing local biodiversity. Research and education are also important tools for plant conservation and have been widely implemented in such institutions. But, in order to achieve results, networking is mandatory as it provides exchange of expertise and knowledge on the matter.

After 202 years, the Rio de Janeiro Botanic Garden (JBRJ) has a long history of contributions to the development of scientific knowledge and plant conservation frameworks, protocols and actions. Several initiatives can be highlighted, such as the creation of Itatiaia National Park, in 1937, the first Brazilian national conservation unit. Further on, the establishment of an important botanical collection, the RB Herbarium, the DNA bank, the live collection and the institutional seed bank, represent major steps towards effective conservation. For more than two centuries, JBRJ has protected in its boundaries the memory of Brazilian natural landscapes and their transitions, preserving plants introduced during colonial times, since its creation, and at the same time, investing in scientific advances for the challenge of maintaining plant diversity.

In order to mainstream national efforts with international initiatives towards plant conservation, the National Centre for Plant Conservation (CNCFlora) was created in December of 2008, under the JBRJ infrastructure. The Centre's mission is to coordinate national efforts, and to understand, document, and conserve plant diversity in Brazil, in collaboration with research institutions and environmental agencies worldwide. The challenge is being faced according to the framework established by the Global Strategy for Plant Conservation (GSPC), prioritizing the targets that meet national priorities and capacities.

Brazil's extreme plant diversity (Mittermeier *et al.* 1997) and the lack of information on the species constitute a very hard task in establishing conservation priorities. For a long time, the only major work to treat the Brazilian flora in a comprehensive manner was the *Flora Brasiliensis* by Carl von Martius (1846-1906). The list was sponsored by the emperors of Austria and Brazil, and by the King of Bavaria. It was produced in Germany, between 1840 and 1906, by Carl Friedrich Philipp von Martius, and August Wilhelm Eichler e Ignatz Urban, with the contribution of 65 specialists from several countries. The inventory has 19,958 species with confirmed occurrence for Brazil (Urban, 1906), in 15 volumes and 40 parts, with a total of 10,367 pages. It contains taxonomic descriptions in Latin and 3,811 lithographic prints. However, that was done a century ago.

In the following years, many new species and new occurrence records for Brazil were published, but no further inventory was conducted. Recent reviews suggest estimates of described species of plants and fungi, ranging from 63,456 to 73,956 (Lewinsohn, & Prado, 2002). The most recent figures cited for vascular plants are 56,108 species with 12,400 (22%) endemic (Giam, 2010). In this way, an accurate revision of the information on the Brazilian flora needed to be made, in order to guide future conservation efforts.

Any initiative towards assessing plant species extinction risk would rely on the present state of knowledge regarding our flora. Therefore, past attempts were significantly limited by available information on plant species. The first Brazilian Threatened Species List was published in 1968, after the work of the Brazilian Foundation for Nature Conservancy (FBCN). The list was composed by 13 plant species and included extinction risk categories accordingly to IUCN standards. In 1992, the Brazilian Government published the second version of the Official List of Threatened Plant Species. Despite the short number of species included, the list also contained the conservation status accordingly to IUCN and known distribution. The list was composed of 105 plant species.

The present red list of endangered plant species (MMA 2008) considers only two existing categories: a) threatened (*Appendix* 1); b) deficient data (*Appendix* 2). The 471 species included by the Environment Ministry on *Appendix* 1 are those with high risk of extinction from nature in a close future. And, the 1,078 species in *Appendix* 2 are those which available information (geographical distribution, threats/impacts, and others) are still deficient. Nevertheless, the present list generated disagreement between the academy and government sectors.

The aim of this paper is to highlight Brazilian advances in GSPC Targets 1 and 2. We discuss the main challenges faced during the process and point out future steps towards mainstreaming of other GSPC targets in Brazil.

Results

In order to achieve GSPC Target 1, Rio de Janeiro Botanic Garden Research Institute was designated, through the CNCFlora to coordinate the extensive work of consolidating a list of the national Flora. Therefore, in 2008, a technical committee composed by 17 representatives of the Brazilian botanical scientific community was established in order to determine the taxonomic working groups, its coordinators and the information requirements for each plant species mentioned on the list.

The first step was to integrate all existing lists published by taxonomic groups or bioregions. All available data was migrated to a species information system developed specifically for the task. Each specialist group coordinator has received a password for editing the species database, updating the system accordingly to their work group. It was necessary to coordinate c. 400 taxonomists and review c. 94,145 taxa.

The resulting list (Forzza, R.C. *et al.* 2010) is composed of 40,989 plant species, out of which there are 3,608 Fungi, 3,496 Algae, 1,521 Bryophytes, 1,176 Ferns, 26 Gymnosperms and 31,162 Angiosperms. For vascular plants, Brazil is clearly the most diverse country in the world, with documented diversity greater than might have been predicted in comparison with other mega diverse countries. Brazil also has the largest proportion of vascular plant endemism in the Neotropics with 55.9% (18,082) endemic species.

In order to achieve GSPC Target 2, JBRJ was designated, through the CNCFlora to coordinate a preliminary assessment of the conservation status of all known plant species, at national level. A brief overview of the Brazilian threatened species listing historical background makes evident the absence of a particular extinction risk classification system for plant species and of a consistent scientific network capable of supporting strategic decisions regarding biodiversity conservation.

The main challenge is to mainstream national conservation demands with global conservation policies well recognized by the international scientific community, considering specificities of the Brazilian flora and its depletion, demanding new ideas and more up to date tools.

Considering the need to improve conceptual and methodological definitions to address threatened species conservation status assessments in Brazil, CNCFlora has been engaged in the process of diagnosing threatened species listing processes and the present system of threatened species management, identifying globally emerging trends in plant conservation. A technical meeting was organized in June, in order to bring together a formal proposal to be presented to the Environment Ministry, with the specifications of a modern and adequate system of endangered species management, aligned to the GSPC framework. Besides that, 12 recovery plans are being elaborated under the coordination of the Centre. Eight action plans for Orchidaceae, one for Amaryllidaceae and three for Lauraceae species. It is important to note that this represents more than the total number of action plans ever developed in Brazil for threatened plant species, and constitutes an important step in plant conservation policies towards a more proactive approach.

Advances in the target mentioned were possible due to extensive research and discussion on conservation protocols adopted by different countries, its strengths and weaknesses, its adequacy to the Brazilian biodiversity status and its institutional capacities. During the two years of operation, CNCFlora staff have been reviewing all literature on the subject, in order to standardize national efforts for plant conservation.

The present Official List of Brazilian Threatened Plant Species, (MMA, 2008) has 1,547 species. Despite the high percentage of species from the 1992 list, included in the present list, almost 20% of them were maintained without proper documentation. Further on, the number of species considered as endangered by the Brazilian Government does not represent even 5% of the Brazilian flora, which remains a small figure considering the present state of biodiversity depletion. It considers only two existing categories: Threatened (Appendix 1) and Data Deficient (Appendix 2).

The studies have shown that despite controversies regarding advances in the Official List of Brazilian Threatened Plant Species, after the last review conducted in 2008, several improvements were achieved along the way. The first positive aspect is the significant increase in species number. The present list has four times more *taxa* than the last version. But that's not enough. Methodological development is needed in threatened species management policies, reducing the time gap of Government's response actions between information provision and decision-making. Standardization of protocols nationwide is essential to the development of a consistent threatened species database. Defining new conceptual approaches for threatened plant species conservation planning is a matter of extreme urgency and an incredibly difficult task for developing countries.

At the moment the efforts are directed to reviewing the Official List of Threatened Plant Species, in order to publish a new one, well documented and scientifically based. Together with that, the main goal is to be able to develop a Brazilian Threatened Species System Framework and a system enabling a more dynamic process for threatened species listing processes. This will be presented to the scientific community in September at the National Botanic Congress, in Manaus, Brazil.

At the same time, the CNCFlora's team has been working on the production of a National Red Book. Data and photo gathering is a great challenge in such a biodiverse country where the lack of investment in research and the poor networking among institutions and scientists are a reality. It is a time consuming activity but the aim is to be able to put it all together by 2011.

Discussion

To guarantee the long term sustainability of CNCFlora and its actions, investments in capacity building for the conservation of plant diversity has been a priority since the Centre's creation. Therefore, the CNCFlora Grant Programme was established. This already supports 11 professionals, 3 undergraduate, 1 graduate, and 5 post-graduate students. Alignment between the JBRJ and the Brazilian National School of Tropical Botany – ENBT, has been strategic to assure the necessary infrastructure for increasing the number of trained specialists in plant conservation.

However, the most challenging task might be to guarantee proper communication among actors involved in the plant conservation process, avoiding by that, redundant efforts. In this way, CNCFlora has been investing time in establishing working agendas with all government institutions related to biodiversity and plant conservation, in order to consolidate an effective network. Despite people's good will, and existing guidelines for plant conservation, the Brazilian institutions seem to be unsupported in implementing their conservation agendas. This Centre has been playing a key role in articulating actors and focusing efforts in the recommendations of GSPC Target 16, related to building networks.

Despite CNCFlora's recent creation, the significant results obtained on the targets listed above provides evidence of the importance of botanic gardens taking part in the process of flora conservation all over the world, leading the way and working as a model for other scientific institutions and environmental agencies. Mainstreaming national conservation policies with the GSPC framework is of great relevance. Since biodiversity does not respond to political boundaries, the conservation strategies for plants must be transversely and globally implemented, in order to assure effectiveness of actions.

To face the new challenge of plant conservation worldwide, and halt biodiversity loss, new integrative approaches are needed. It is necessary to establish communication among actors involved in this process, and botanic gardens can play a key role. Science itself can not address all related matters. Therefore it is important to consider political, economical and social aspects of the actions undertaken, establishing a permanent communication channel between scientists and decision makers. The Rio de Janeiro Botanic Garden is highly committed to the challenge and has already consolidated important contributions for the National GSPC mainstreaming process.

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Brackenhurst Forest Botanic Garden, Kenya: towards a self-sustaining botanic garden

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Abstract

The Brackenhurst Botanic Garden in the highlands of Kenya was registered in 2004. It was started by planting indigenous trees on land previously used exclusively for exotic species like cypress, eucalyptus, wattle and Australian Blackwood. It now covers 20ha (50 acres) of 'natural' forest plus a small indigenous garden for herbaceous species. The original plan was to develop an arboretum but it was soon realised that biodiversity would be greatly enhanced by a vigorous understorey layer of herbs, ferns, orchids and shrubs (comprising mainly Rubiaceae and Euphorbiaceae). We have just passed our collection target of 1,000 species, mostly from upland East Africa but a few from other East and Central African countries. We have several endangered species growing well and producing viable seed. The botanic garden therefore encompasses indigenous biodiversity conservation (birds, Lepidoptera and mammals), watershed and wetland protection, and environmental education. Funding, or lack of it, has been the greatest obstacle to progress followed by invasive species which consumes 60 percent of our budget. Our 2010 budget to date is $10,500 which has to cover annual salaries of six staff plus all equipment. It is clear that in a developing country, supporting a botanic garden is not a priority. The only way to ensure perpetuity of the project is to make the forest income-generating. This will be achieved through six endeavours: 1) herbal medicines; 2) understorey coffee; 3) locally produced charcoal from energy efficient kilns; 4) indigenous tree seed production; 5) spring water; and 6) ecotourism: we already have numerous visits from bird-watchers and horticulturalists from Nairobi. So after 2012 we hope to be self-sufficient.

Introduction

Brackenhust forest was started as an arboretum in 2000 with the aims of recreation, education, but above all, the conservation of indigenous plants. In 2003, we registered with Botanic Gardens Conservation International (BGCI) as a botanic garden. The garden is situated near Tigoni in Limuru district, 25 km north of Nairobi at an altitude of between 1800 and 2000m. The natural vegetation type is tropical montane forest but 99.9 percent of this in the district has been replaced by agriculture (coffee, tea, flowers and smallholder farming), exotic tree plantations (eucalyptus, wattle, and cypress), and residential land.

Kenya, like all African countries is experiencing rapid population growth. The population in 2010 is over 38m compared to 2.9 million in 1930. This has led to increased land pressure and demand for scarce resources leading to deforestation in both the high potential areas and in the arid and semi-arid lands. Only 30% of Kenya's land area is medium to high potential and only 1.7% of Kenya's land area is forest. Landscapes countrywide are changing fast: the Mau forest complex, the largest water tower in Kenya has lost 150,000 ha (30%) over the last two decades and the remaining forest is all under threat. This results in loss of both ecosystem services and indigenous biodiversity.

As land becomes registered, pastoralists sell land to farmers of different ethnic origins and this leads to loss of woodland and grassland: tension rises as grazing land is lost, especially during droughts.

Meanwhile urbanization is increasing: Nairobi is approaching 3m and the cost of residential land is soaring: the land around Brackenhurst Forest is fetching over US$150,000/ha for residential purposes. Land in the area is even used for illegal dumping of waste.

In this context, a botanic garden of 20ha could be seen as an unnecessary luxury in a country with high poverty, high unemployment and scarcity of good land. Obtaining local financial support for such a venture has been impossible. But with international support,
Brackenhurst Forest had just past its milestone of 1,000 indigenous plant species collected and recorded, and it now has the largest cultivated collection of indigenous species in Kenya. As the forest has grown, so has the number of recorded species of birds, small animal and Lepidoptera. By the start of 2011, signage will be in place with support from Missouri Botanical Garden.

The project started with the removal of exotic plantations. We started planting seedlings and wildings from 'uplands' (1500m-3500m with between 500 and 1500 mm annual rainfall), collecting from ecosystems under threat especially from areas of high endemism such as the Eastern Arc mountains. The collection includes trees, lianas, lianes, shrubs, scramblers (often ignored in formal arboreta) as well as >25 species of orchids (e.g. *Disa sp*. and *Vanilla polylepis*), plus ferns and hemi-parasites (e.g. *Phragmanthera sp*. and *Tapianthus sp*.).
We also grow vulnerable and endangered species on the IUCN Red Lists such as *Euphorbia cussonoides* and *Embelia keniensis*, a climber with only five adult specimens known (we now have propagated >50 young plants). More recently we have collected understory shrub species from the Rubiaceae & Euphorbiaceae plus shade tolerant herbs such as *Gladiolus watsoniodes* and *Delphinium macrocentron, Achyrospermum parviflorum* (Lamiaceae), 6 upland species of *Jasminum* and many lianas and lianes overlooked by arboreta such as *Urera hypselodendron & U. trinervis* (Urticaceae) and woody-based herbs from forest edges such as Pycnostachys spp.

After 10 years we now have a closed canopy in the original plantings. We started with bare ground and after 10 years, we find that many of the species we started with have been shaded out (e.g. *Hibiscus cannabinus, Acanthus sennii* and *Scadoxus multiflorus*) so we started a small indigenous flower garden for (woody-based) and non-woody herbs.
The issue in 2010 is how to protect the botanic garden in perpetuity. Funding is always a challenge: we tend to get small grants on an annual basis because most funding agencies only fund for short durations (1 year). No sooner have we got the funds but it is time to re-apply. The control of invasive species/weeds currently takes 60-75% of the budget.

How can we make the forest pay for itself? We are following seven avenues for income generation, so that in three years time we will generate enough funds to pay for the small staff.

1. Ecotourism through biodiversity: in addition to the >1,000 plant species, our bird count has risen from 35 species in 2001 to over 160 species in 2010.

2. Herbal medicines: *Urtica massaica* is mixed with *Prunus africana* for the effective prevention and treatment of benign prostatic hyperplasia. *Centella asiatica* (Gotu kola) grows in abundance and will be dried and sold locally. It has a huge potential and a large market in India.
3. Seed supply: as trees and plants become mature, our seed supply will become regular and we can sell this locally for other reforestation projects.
4. Cultivated indigenous timber is almost totally unknown in Kenya. Most timber is either illegally or unsustainably harvested or imported illegally from the DR Congo. Meru Oak (*Vitex keniensis*) can yield $1m^3$ after 20 years and is a valuable timber.
5. Energy-efficient charcoal. Charcoal fetches US$1 for 1kg. This is mainly because of transport and the traders' profits. We can supply a limited amount of charcoal from forest trimmings at one-fifth of that price providing about US$1,200 per year, equivalent to the annual salary of a forest worker.
6. Spring water is now reappearing from the forest and this can be bottled locally for the conference centre.
7. PLI is being contracted by European plant growers for ornamental plant cultivation of indigenous *Impatiens* and *Streptocarpus* spp.

There is little doubt that that the 20ha botanic garden and forest will be self-supporting within four years with the above ideas.

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Plant conservation, botanic gardens and the International Agenda

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Abstract

The *International Agenda for Botanic Gardens in Conservation* was published by Botanic Gardens Conservation International (BGCI) in 2000 following widespread consultation within the botanic garden community. Over 450 botanic gardens have signed the *International Agenda*, using it to guide their conservation action. The *International Agenda* was also a key document taken into account in developing the Global Strategy for Plant Conservation (GSPC) of the CBD. The GSPC has 16 targets to be met by 2010. The role of botanic gardens in working towards these targets is highlighted in this paper. The BGCI PlantSearch and GardenSearch databases are useful for monitoring conservation action in line with the GSPC and the *International Agenda*. With support from BGCI, the GSPC has been revised for the next decade. BGCI also proposes to update the *International Agenda*, retaining its essential features and updating it in line with the GSPC.

Introduction

Botanic gardens around the world individually and collectively provide important resources for conservation of plant diversity and opportunities for increasing resilience to global climate change. As often quoted, botanic gardens contain documented specimens of 80,000 - 100,000 living plant species, providing material for display, research, education, *ex situ* conservation and ecological restoration. With at least 200 million visitors per year, they provide an important 'interface' between botanical science, horticulture and the public in an increasingly urbanised world. Botanic gardens collectively provide a respected voice in biodiversity conservation – acting as champions for plants.

Since its adoption in 2000, the *International Agenda for Botanic Gardens in Conservation* (Wyse Jackson & Sutherland, 2000) has proved to be an important document for the botanic garden community guiding individual and collective conservation actions. The *International Agenda* provides a framework for botanic garden contributions to plant conservation, environmental education and sustainable development. The development of the *International Agenda* involved widespread consultation with numerous contributions from individuals, and organisations around the world helping to define the content and terms of the document. Subsequently the *International Agenda* has provided a model for the development of regional and national botanic garden strategies. Registration to the *International Agenda* indicates a commitment to take action and work with the botanic gardens worldwide to secure plant diversity for the well being of people and the planet.

The need for botanic gardens to implement the objectives of the *International Agenda* has become increasingly important since its publication in 2000 as the threats to plant diversity intensify. Ten years on, in the International Year of Biodiversity, it is a good time to reflect on the impact of the *International Agenda.*

Measuring success

The *International Agenda* suggested four broad targets and success measures for the botanic garden community as well as more detailed targets for individual gardens. Progress towards the four broad targets has been good over the past ten years but the work is far from over. Table 1 below indicates progress against the four targets based largely on information contained within BGCI's GardenSearch and PlantSearch databases. The GardenSearch database contains records for 2,677 botanic gardens of which 573 are BGCI members. Contact details are provided for each institution together with information on the date of establishment, location, collections, and activities undertaken. The PlantSearch database contains plant records from 705 botanic gardens (26 percent of all institutions included in GardenSearch with records from 57% of BGCI members). The plant records represent 185,000 taxa from 93,000 species. PlantSearch also contains conservation assessment data in the form of IUCN lists of threatened plants (Walter & Gillett, 1998) and CITES Appendices listings together with partial lists of medicinal plant names and genera of Crop Wild Relatives.

Table 1 Progress towards the four International Agenda targets

Target	Success Measure	Progress by 2010
Global adoption of the *International Agenda*	Number of gardens who have registered adoption	453: 17% of all botanic gardens and 45% of BGCI institutional members
Each known threatened plant & ecosystem included in conservation programmes	Number of species recovery & ecosystem conservation programmes	9,500 globally threatened plant species in *ex situ* collections as recorded in PlantSearch Database; 17% of BGCI members record species re-introduction programmes. 19% of BGCI members involved in ecosystem conservation
Capacity of botanic gardens developed for biodiversity conservation particularly in regions of high diversity. Resources identified & accessed to support their biodiversity conservation activities.	Number of botanic gardens; % that have research, conservation and education programmes.	8% of all botanic gardens known to have conservation programmes; 9% education programmes, 13% research programmes. Equivalent figures for BGCI member gardens: 26%; 24%; and 42% respectively
Current information on the activities, collections & facilities of botanic gardens worldwide available to support biodiversity conservation	Number of botanic gardens linked to the Internet, number with comprehensive & accessible electronic data systems on their collections	Approximately 25% have provided data to BGCI

The *International Agenda* states that botanic gardens cannot work alone: *"they must work in partnership with a wide range of bodies to achieve their targets including governments, organisations, institutions, corporations, communities and individuals".*

The development of the *International Agenda* also recognised the need for global targets for plant conservation which go beyond the work of botanic gardens to be established urgently, specifically to address:

- Halting the worldwide loss of plant species and their genetic diversity in the wild.
- Raising awareness of the importance of plants and the maintenance of biodiversity for the planet and human survival.
- Conservation needs and priorities within national, regional and local strategies on biodiversity conservation, the environment, sustainable development, economic and social policies, land use management and public education.

The overall impact of the *International Agenda* can perhaps be best assessed by the major influence it has had on global biodiversity policy. The *International Agenda* is specifically acknowledged as a key background document and delivery mechanism for the Global Strategy for Plant Conservation (GSPC) of the Convention on Biological Diversity (CBD). The GSPC was adopted unanimously by all countries that are signatories to the CBD in 2002.

The Global Strategy for Plant Conservation

The scope of the GSPC is broad with five inter-related themes:

- Understanding and documenting plant diversity
- Conserving plant diversity
- Using plant diversity sustainably
- Promoting education & awareness about plant diversity
- Capacity building for plant diversity

These in turn are linked to 16 outcome-orientated targets.

Botanic gardens and BGCI have been closely involved in the GSPC since its inception and have strongly supported implementation of the Strategy. The 16 GSPC targets have provided the basis for BGCI's own programmes and activities, for example in the BGCI Five Year Plan 2007-2012. A BGCI member of staff is seconded to the CBD Secretariat to act as GSPC Programme Officer and has been able to support national implementation of the Strategy in a wide range of countries including China, Japan, Mexico and the Seychelles.

Although primary responsibility for GSPC implementation is at the national level, most of the 16 Targets of the GSPC (except for several that are cross-cutting) have an international organisation designated to help facilitate implementation and monitor progress. BGCI acts as the lead facilitating agency for GSPC Target 8 on *ex situ* plant conservation and also GSPC Target 14 on education and public awareness. These two targets are clearly key to the work of botanic gardens around the world and their associated networks at national and regional levels. Linking botanic gardens with other major actors in plant conservation, BGCI provides the Secretariat for the Global Partnership for Plant Conservation (GPPC).

BGCI's online PlantSearch database was designed to monitor progress towards Target 8 of the GSPC as well as providing a planning tool for *ex situ* plant conservation and a mechanism for sharing information on species in collections. Table 1 above shows that

9,500 globally threatened plants are currently recorded in PlantSearch. As progress in IUCN global Red Listing for plants has been slow (Vie *et al* 2009) more detailed analyses have been undertaken for Europe (Sharrock and Jones, 2009) and North America, using regional threatened plant lists. A global GSPC Target 8 report is planned for the Tenth Conference of the Parties to CBD (CBD COP10) to be held in Nagoya, Japan in October 2010.

The GSPC targets have been widely adopted by the botanic garden community (see for example Leiva, 2005; Martinelli 2010; Huang, 2010; Kramer, 2010) and have been used to develop national and regional botanic garden strategies. *International Agenda* targets aligned to the GSPC were agreed in 2004. Linking work to the GSPC targets helps botanic gardens to be closely aligned with national and international policy through the CBD. The role of botanic gardens in implementing the GSPC was recognised in the mid-term review of the Strategy (Secretariat of the CBD, 2009). More recently BGCI has undertaken a survey of botanic gardens to find out about implementation of the Strategy (Williams & Sharrock, 2010). A total of 252 responses were received by the end of May, 2010 from botanic gardens around the world. The results show that all GSPC targets are being implemented to some extent with a wide range of different activities supporting the Strategy.

Overall the GSPC was hailed as a success at the the fourteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA 14) of the CBD. Based on an earlier CBD Decision, efforts have been underway to develop a revised Strategy and targets, moving beyond 2010 and taking into account the impact of global climate change. BGCI has played a significant role in the revision process, for example organising two stakeholder workshops in Chicago and Durban. The resulting document was discussed at SBSTTA 14 with a recommendation for this to be adopted at CBD COP10 in Nagoya.

International Agenda – next steps

With the GSPC in place the *International Agenda* may seem less important. This is, however, a document uniquely binding the botanic garden community that has scope beyond the GSPC in relating to other broad policy initiatives. As already referred to, its adoption shows a level of commitment by individual gardens. Since 2000, there have been both shifts in global biodiversity policy and a deepening of the biodiversity crisis. It is therefore important to update the *International Agenda* to reflect:

- GSPC – adopted in 2002, revised 2010
- Millennium Development Goals - 2000
- Millennium Ecosystem Assessment - 2005
- Global awareness of climate change

In updating the *International Agenda* it is also important not to lose sight of the need for conservation action. It is intended to link *International Agenda* recommendations to the revised GSPC targets and develop *International Agenda* protocols on methodologies and measuring impact – linking to a GSPC toolkit that is being developed by BGCI. Specific *International Agenda* protocols are being considered on education and public awareness; engaging with local communities in conservation planning and delivery and biodiversity and livelihoods.

Conservation action

The GSPC provides a global framework for plant conservation and the *International Agenda* provides a unique framework for botanic gardens closely related to this. In addition to supporting policy development, BGCI has supported a wide range of conservation projects over the past ten years, demonstrating practical approaches to plant conservation. It is hoped that these experiences and practical examples of the work of individual botanic gardens will increasingly help to shape the policy agenda and show the relevance of botanic gardens to major global issues. BGCI has, for example, drawn attention to the work of botanic gardens in relation to biodiversity and human well being (Waylen, 2006). In a recent project undertaken in Uganda and Madagascar, entitled *Wild plants for food and medicine,* BGCI set out to develop a practical methodology on engaging local communities in plant conservation action to support local livelihoods. Activities involved assessment of species and habitats of conservation importance both at scientific level and with direct community involvement and the development of conservation interventions supported by botanic gardens.

BGCI has also developed a comprehensive conservation programme in China with a specific focus on tree conservation projects working with botanic gardens, again linking as far as possible with local communities. In Cambodia, where a botanic garden has not yet been developed, BGCI has been working with the Department of Nature Conservation and Protection on the sustainable management of natural resources in O Toch village which is affected by dam construction. In this case nurseries for bamboo, rattan (basket making), *Aquilaria* (agar wood) and native timber species have been established; a community protected area created and restoration of degraded land has been undertaken using native species. A discussion document has been developed based on the practical experiences in Uganda, Madagascar, China and Cambodia and will be made available through BGCI's website.

Looking ahead

There is an increasing need for botanic gardens to work together to implement the GSPC, the *International Agenda*, and practical conservation in line with these policy documents. The BGCI PlantSearch database is an important tool supporting *ex situ* plant conservation. The BGCI GardenSearch database can help facilitate skill-sharing and collaboration on a wide range of conservation actions. All botanic gardens are urged to support these databases and input data so that they can provide an accurate reflection of the combined conservation work being undertaken. In this way PlantSearch and GardenSearch will continue to be used to monitor the success of the GSPC and *International Agenda* post 2010 and BGCI will work to upgrade the functionality of the databases. Looking ahead the *International Agenda* will be revised through a consultative process and taking into account the outcomes of the CBD COP 10 in October 2010. All comments and input are warmly welcomed to ensure that the *International Agenda* continues to inform, inspire and link botanic gardens worldwide in a common purpose.

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The role of international cooperation among botanical gardens as a tool for the *Global Strategy for Plant Conservation*

Peter Olin

Abstract

Creating an informal international association between botanical gardens and arboreta and establishing linkages with other environmental organizations can be a crucial tool to help carry out the Global Strategy for Plant Conservation. Support and assistance among partner organizations can multiply the effectiveness of their work to develop strategies for plant conservation. The Minnesota Landscape Arboretum in 2001 initiated a multilateral cooperative partnership with several university botanical gardens in Russia (Tver, Petrozavodsk, and Moscow) and Estonia. Since then joint programmes and activities have been realized. There have been reciprocal visits of teaching and grounds maintenance staff, participation in joint presentations at conferences and seminars, the creation of a format for an international children's programme (underway), and informal but very meaningful on-site discussions while visiting each other's gardens. The programme of cooperation has led to the recognition of the importance of botanic gardens and arboreta for plant conservation in various regions of Russia, Estonia and Minnesota and to international friendships between the partners. This has fostered a sense of mutual responsibility and not just among the staff of the gardens, but also among different population groups in the regions. This experience of cooperation between gardens at the University of Minnesota, the State Universities at Tver, and Moscow and Petrozavodsk, the Tallinn Botanical Garden and the University of Tartu can be used as a model for successful promotion and implementation of the Global Strategy for Plant Conservation.

Key words: International, Cooperation, Garden partnerships, Plant conservation, Minnesota Landscape Arboretum, Russian Botanic Gardens

Introduction

There are many gardens in the world that have barely enough resources to maintain themselves, moreover work to save indigenous flora. At the 1994 Garden Management Course at RBG Kew, then Director, Dr. Ian Prance lectured the class on giving aid to gardens in need, especially those in the Tropics. He was working in the Amazon to help local's plant forest openings with native species of economic value to raise funds for survival. The overarching goal was to save plant species. He encouraged all to do like wise.

The Minnesota Landscape Arboretum (MLA) is a northern garden and we do not work in the tropics. Dr Prance's response was simple (I paraphrase), "No one is working with northern gardens and the MLA should be the leader in working with northern gardens."

Getting Started

If a garden is to help another one that has few resources, how does one find such a garden? Since the University of Minnesota Faculty in Horticulture has been breeding for cold hardiness, we looked at places in which they were collecting germplasm or working with a scientist. We ended up in Estonia, at the Tallinn Botanic Garden, working with the former Director, Dr. Heiki Tamm. To locate a garden, however, one easy way is to contact Botanic Gardens Conservation International (BGCI) for names of gardens meeting your specifications of what you want in a collaborator plus their contact information.

However, what would be your specifications? First, is it a garden doing work to save endangered species and promoting the use of native flora? Again that can probably be determined by BGCI or from conversation with garden personnel, web sites, etc.

Second, visit the garden. One can tell a lot just by looking around. Resources or not, does it look well maintained? Is the grass mowed, are the beds weeded, are the trees protected from machinery gouging, are there people visiting the garden, does anyone care! It's really not hard to tell visually, even if the spoken or written word is something different. You also need to meet the main contact person and perhaps some of the staff to see if they work together and whether or not you can work with them.

Third, make sure it is a garden which has a similar climate or climatic zone in which you have expertise. It really is necessary to understand climatic conditions, those conditions that you know and work with in your own garden. If you don't understand winter or desert, for instance, you can have a misguided idea of the potential struggles a garden will have just to maintain plant life, moreover have it stay healthy and survive over time.

Fourth, who runs the garden or makes the major decisions. It must be someone you can work with on an intellectual level as well as on an emotional level, and someone you can trust. If a garden leader says they will collaborate for XYZ cause, will they indeed do so if you hand over resources. Some discussions, formal or informal are necessary, and that can happen at the garden visit, at national or international meetings, or in bringing the individual to your garden. It might be best to create a written document of agreement.

Fifth, there will be a need to give funds to the garden you select. To ensure that you have continuing funds, it would be wise to have a special account upon which to draw. At the MLA we have the Plant Exploration Fund. This is a fund set up to allow University scientists to go world wide to collect germplasm for plant hardiness breeding. It now also allows the garden director to help northern gardens in tough economic straits. The money comes into the fund through donations made by people going on Arboretum Garden tours.

In a few cases you may need to know whether or not you can actually get the funds to the garden you are working with! Political or bureaucratic red tape may make it difficult to help financially and in some cases there is the possibility of theft along the way.

Sixth, you need to be a believer! If a garden can maintain its facilities and employ adequate staff, it can then work on conserving local flora. You must believe this will happen and that your help, financially or otherwise will bring about a positive outcome.

Ongoing Support

Once one has made the commitment to a garden, one must keep that commitment for at least 5–10 years, or some significant period of time, so the garden can begin to develop its own support system from its own efforts. It should be the supporting gardens role to counsel and help guide the supported garden to self sufficiency. This is not always easy and the MLA has not been as active in this area as it should be. There are, however, certain things beyond funds that the supporting garden should look at for determining success.

Learning from each other: The MLA likes to support the staff of the garden it is working with by sending them to conferences like those sponsored by BGCI. At such meetings we have learned from what our fellow gardens have done, what works and what doesn't. The conference is a setting in which to easily transfer information; how to raise funds successfully; how to market your garden; perhaps research or educational techniques; garden maintenance; children's education; etc.

Don't forget to listen and learn yourself. We often learn more than the gardens we sponsor. If you don't learn something new when visiting a garden, consider it time lost.

The MLA Experience

The MLA staff helped the Tallinn Botanic Garden build a research greenhouse. Dr. Heiki Tamm wanted a research greenhouse and found that he could purchase a greenhouse package from Finland for $5,000 US, hire grad students for $600 US per year and buy a small heater for $500 US. We sent him $6,000 US and he built the greenhouse. We also sent a gardener to Tallinn to learn gardening techniques and share gardening experiences.

We made acquaintance with Dr. Yuri Naumtsev of the Botanic Garden of the State University at Tver, Russia, and Dr. Alexei Prokhorov at the Botanic Garden of the State University at Petrozavodsk, Russia, at a national meeting of the American Public Garden Association. We helped buy equipment for Dr. Prokhorov to help maintain his garden, and a van for Dr. Naumtsev so that his staff could get to their research site, a special calcareous area on the Upper Volga River hosting special vegetation which they are documenting. We continued to support Tver by helping to sponsor a conference in 2004 at their University.

The MLA has sent several Russian garden staff to conferences in Estonia and the U.S. The MLA has since worked with the State University at Moscow, Apothecary Garden and the University of Tartu Botanical Garden, Estonia, where Dr. Tamm is now located.

What did the MLA receive in return?

Supporting a garden that needs help is not a tit-for-tat situation and should not be thought of as such. However, we have received many benefits from our associations. First, is the exchange of research information and plant material, which helps both gardens. Second, is a new view of how another garden produces successful programmes, especially in the area of children's education. We have adopted many ideas. Third, ideas on how a garden's maintenance works where a good idea or two pops up, the landscape of a tropical conservatory, a new conservatory built over the old one, etc. Fourth, there are many small ideas that can be picked up, macro-photography of insects, flower interiors, etc. as desk top wallpaper for youth (it must be wild, humorous or gross) that they can get for free; bird stands behind and higher than garden signs or labels so the birds sit on the stand rather than on the sign. Fifth, and perhaps most important, international good will. We try always to be ambassadors of good will which can often be in short supply. We have the chance to rectify that.

Present work of the Minnesota Landscape Arboretum

At present the MLA is involved with Tver, Moscow Apothecary, and the University of Tartu in a project that involves children and their parents or mentors monitoring trees in their neighborhood. Dr. Naumtsev has taken the lead in this project which involves students in the 10–16 year age group at each garden. The student needs to find out all s/he can about a tree(s) over the period of a year, first assessing its condition, and recording everything about the tree that can be found. The student monitors the tree for a year and then does a report. The reports are submitted to the garden, judged and the student with the best report at each garden gets a prize. A second year will allow the student to continue the monitoring but to also develop plans for improving the tree situation in his/her neighbourhood and presenting it to the proper elected officials.

This kind of project can be a heavy work burden but think of the benefits! Young people learning more about trees and their environment, young people making recommendations about their environment, young people educating their parents and perhaps their city officials, young people involved in good work not bad things, and young people having fun.

Costs

In the 12 years the MLA has been involved with the gardens in Russia and Estonia, it has spent about $60,000 US or about $5,000 US per year. Removing the expenses of bringing 35 Russian Garden Directors to the MLA from Washington, D.C. (about $20,000 US) the average cost per year is more like $3,000 US. We make more than that on one good Arboretum garden tour!

Summary

It is important that gardens in the wealthy nations of the world set up cooperative agreements. It may be difficult or easy, it will cost you some of your own resources, but you will gain exponentially. Remember that funds are not the only help you can give: Russian garden directors visiting the MLA heard about dried flower arranging from our auxiliary. They could do it as a money maker and pay local people some of the profits. They learned about the MLA's cold hardy research, about marketing and PR, and about budgeting. They saw the educational programmes, the collections, the gardens and demonstrations; and they saw the people visiting and learning. They also had a good time! We also learned about their gardens and the creative things that they were doing that we could incorporate into our programmes.

The garden you help will gain confidence, understanding and credibility and therefore generate creativity. Eventually your partner garden will begin to help other gardens. It is an ongoing win-win situation.

Atlantis-BG a standard for comprehensive, web-based collection management.

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Abstract

Atlantis-BG is a state-of-the-art programme that links the plant collection database of a botanical garden to other relevant scientific data, such as literature, authors, collectors and illustrations. It also contains address information of relations such as gardens, contact persons etc. Atlantis is a new development in the information technology supporting scientific collection management. It incorporates the new advantages of the web as well as GIS. An overall-shell has been developed so that the databases of the several gardens can appear as one national database.

Keywords: APG III, collection management botanic garden, database, event, mapping, seed list processing, taxonomic tree

Introduction

The development of standards concerning collection management databases for botanical gardens in The Netherlands started in 1984 (Aleva et al, 1984). Dutch Botanical gardens have been working with collection management databases since 1987. In spite of agreed functional standards, different technical solutions were used by different botanical gardens. All solutions were character oriented and covered only a part of the necessary processes. For example for literature, relation and seed management separate databases were used, all character orientated, or even lists on paper or in books, for example for author abbreviations (Brummitt & Powell, 1992).

At the end of the Nineties, thanks to governmental foundations, as a part of a national project aiming at the disclosure and digitalisation of academic collections in The Netherlands, means were found to obtain a new database for the 5 Universal Botanical Gardens mentioned above. A common database should make exchange of information a lot easier and a uniform presentation of (National) collections on the internet possible. It should also combine all sorts of small databases used into an all-containing one, and should disclose localities of collection elements by means of a GIS-like functionality.

In the process of deciding whether to obtain an existing standardised database (such as BG-base or SysTax, both of which were looked at thoroughly) or to develop a completely new one, the choice was made for a new one. It was agreed that the advantages of a development with the newest technologies such as an object-orientated database (Martin 1993) (Booch et al, 1998) which can include all sorts of multimedia objects and a standard web (and windows)-interface balanced out the disadvantages of starting something new and unknown, while a widely accepted relational database such as BG-base, although older and many times upgraded, is already used (still often in the DOS-version) by many Botanical Gardens in the world.

A combination of technical knowledge, and knowledge of the demands of collection management, and the structure of its database, were found in the co-operation of the curator of the Utrecht Botanical garden (Dr. E.J. Gouda), with a software-house specialising in the development of software for collections and archives in general. It took three years of development and testing to accomplish the first version of the database.

The newly developed application “Atlantis Botanic Garden” is a standard application on the Atlantis platform, which is developed specifically for museums and archives. All applications of this platform have functionality in common, such as an object oriented database for storing images and other multi media information, a reporting option, and a super fast full text search engine with synonym and phonetic search capacity for finding information in the database. However, every Atlantis program is specifically designed for its own particular type of collection.

Description data structure (partly)

The kernel consists of 4 levels: Taxon, Accession, Accession-location and Event (*fig. 1*).

Taxon

On taxon level it is possible to display the whole taxonomic system (Cronquist and/or APG III are available) as a tree (31 ranks are possible, from Regnum to forma and hybrids) and using drag and drop features you can easily make changes in taxonomy, i.e. a genus with all species belonging to it can be hung under a different family in one action. This can be done on all levels. The parent taxon (or taxa, in case of hybrids) of a taxon determines its place in the tree. Correct names are bold, synonyms are not, so they are easily distinguishable. Higher taxonomical levels can be left out of the tree for transparency's sake. The number of living accessions are indicated in the tree.

Each garden can choose its own taxonomy tree, or can choose to follow a standard (such as Cronquist (Cronquist, 1981) or APG (Judd et al, 2007, APG III, 2009, Chase & Reveal, 2009, www.mobot.org/mobot/research/apweb/) or an alternative. The taxonomical tree is on the left side of the screen.

On the right side of the screen information on a specific taxon is displayed in six property sheets (*fig. 2*), one of which contains multimedia objects. A multimedia object can be a picture or a distribution map or a film or an article on that taxon. The first property sheet contains a button to enter the accessions linked to this taxon. Another property sheet gives access to all relevant literature in the database to be attached to the taxon. On the other hand one literature reference has links to all relevant taxa and accessions. A direct link can be made to sites on the internet like IPNI, IUCN, IOPI, USDA, FL_EU etc. for a direct check of the name and an indication of its distribution. Standard taxon use categories can be applied including geographical information.

Accession

An accession is a plant or group of plants of one taxon, originating from the same source (e.g. seeds from one seed list number, plant, cutting, etc.) and obtained at the same time. An accession may be found in the garden at more than one location.

The screen structure is the same as in taxon. On the left side is the accession tree. Branches show the identifications and verifications; information about where the accession is located (the accession location) in the garden and information about derived material, such as seeds and herbarium specimens and seed list information.

The property sheets on the right side of the screen contain all relevant information on an accession, such as source, donor, agreement notes, propagation etc., including a property sheet for multimedia objects for that accession. Standard ITF2 abbreviations (Jackson, 1998) are used for all relevant fields on an accession.

When searching for a certain accession there is an option to run the search criteria over any text in the accession part of the database, or part of the database, or over text within specified fields. This can be done in any specified tree.

For each accession in the tree, there is an indication of its status (current or not). Each verification for an accession, and other relevant information such as the date, the name of the verifier and the level of identification can be recorded. The most recent one will be the accepted name for this accession.

Accession location

On this level specific information of individual plants, or a group of plants, is given including the location in the garden where it can be found. Co-ordinates can be added from GPS-measurements and maps of the garden and with selected accession numbers drawn in it can be processed. In the illustration property sheet, Garden location maps can be added in different formats. Then by means of two reference co-ordinates these maps can be synchronized to the attached co-ordinates of each accession, so that in the mapping report the position of the plant is printed at the right place on the map. One specific report starts and uses Google earth satellite maps to project the place of the plants on the map. One accession location can be linked to more events.

Event

An Event occurs to an accession at a certain location, for example sowing, germinating, flowering and dying. The users are free to define Event types themselves. This feature can be used by the head gardener on location.

Free fields

User-defined fields can be imported in a special screen at the accessions and taxa, for example for horticultural information.

Relations

In the tree ‘Relations’ names and addresses of relations, such as companies, colleague gardens, etc. can be inserted. Atlantis-BG has a mail merge facility for mailing to a number of selected relations.

E-mail addresses and web-sites can be recorded as well, and Atlantis-BG can send e-mails to relations or connect with a web-site.

WGS system

A geographical standard WGS-tree is added (Hollis & Brummitt, 1992).

Processes

Reports

Reports can be made using XML ruler templates producing HTML output. Within these templates different criteria, sorting priorities, fields, etc. can be chosen. Reports can be drawn up for each desired object and can include images, maps, www links etc.

Labels

For the production of labels of relations or plants mail-merge for MS Word is used. Any selection can be made and any field, size and lay-out chosen. It is also possible to use reports instead.

Seed list

A seed list can be generated directly from the database as a report. It can also be exported in ITF2 format. The seed list may be composed in HTML format, allowing the user to publish the seed list via the Internet. In this seed list, illustrations (for example photographs in .jpg) of the accessions or taxa can be inserted.

Available amounts and seed orders from other gardens can be inserted, and at sending time the database can process all the relevant labels (gardens and accessions) in the right order. In this way the whole seed list process is covered.

Import and export

Data can be imported and/or exported in ITF2 and/or XML format, making exchange of data possible.

Thematis

It is possible to connect distributed Atlantis databases in such a way, that to any requests, they appear as one single database. Thematis is an extra tool especially developed to connect different (i.e. not only Atlantis) databases to appear as a single one. (www.thematis.nl/botanicportal/)

Web-interface

A user-friendly web-interface with search-possibilities on various levels is added.

Conclusions

Development of Atlantis-BG is never finished, since new demands and possibilities on collection management in botanical gardens will rise. Atlantis has already proved to be a database with many possibilities. It speeds up the routine-parts of the administration process of collection management, and uses the present communication possibilities very efficiently. It makes it possible to cope with changing ideas in taxonomy. It will be easy to incorporate the APG (III) system, which is available, in Atlantis so that the taxonomic tree of Atlantis will reflect the latest taxonomical insights. The disclosure of botanical collections to the public forces curators to clear any possible backlogs in administration as quickly as possible. This is a great challenge as a result of creating a completely new database.

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Figures

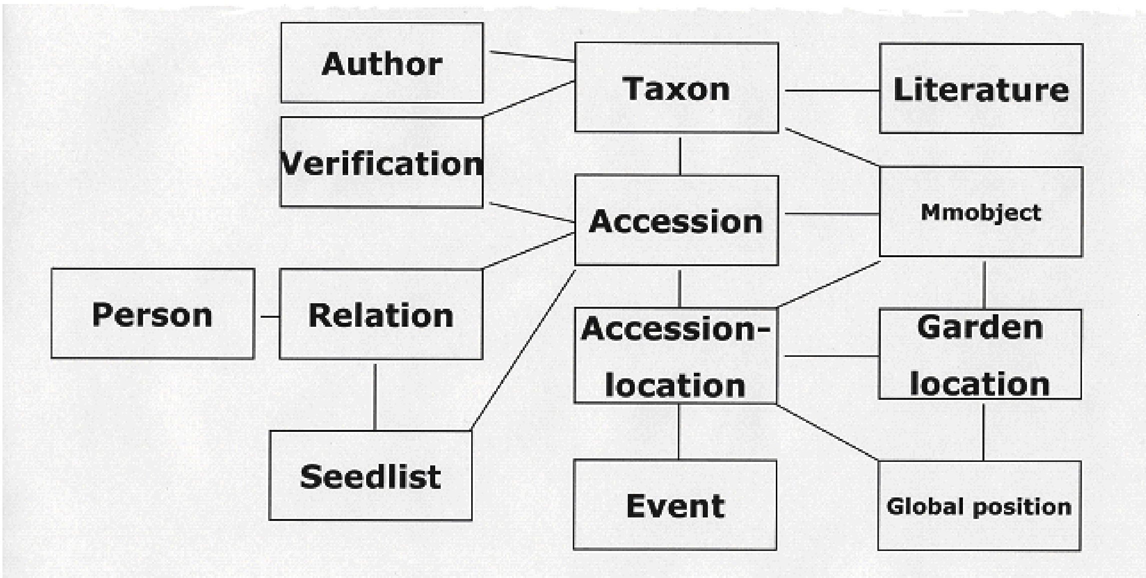

Fig. 1 Simplified database structure

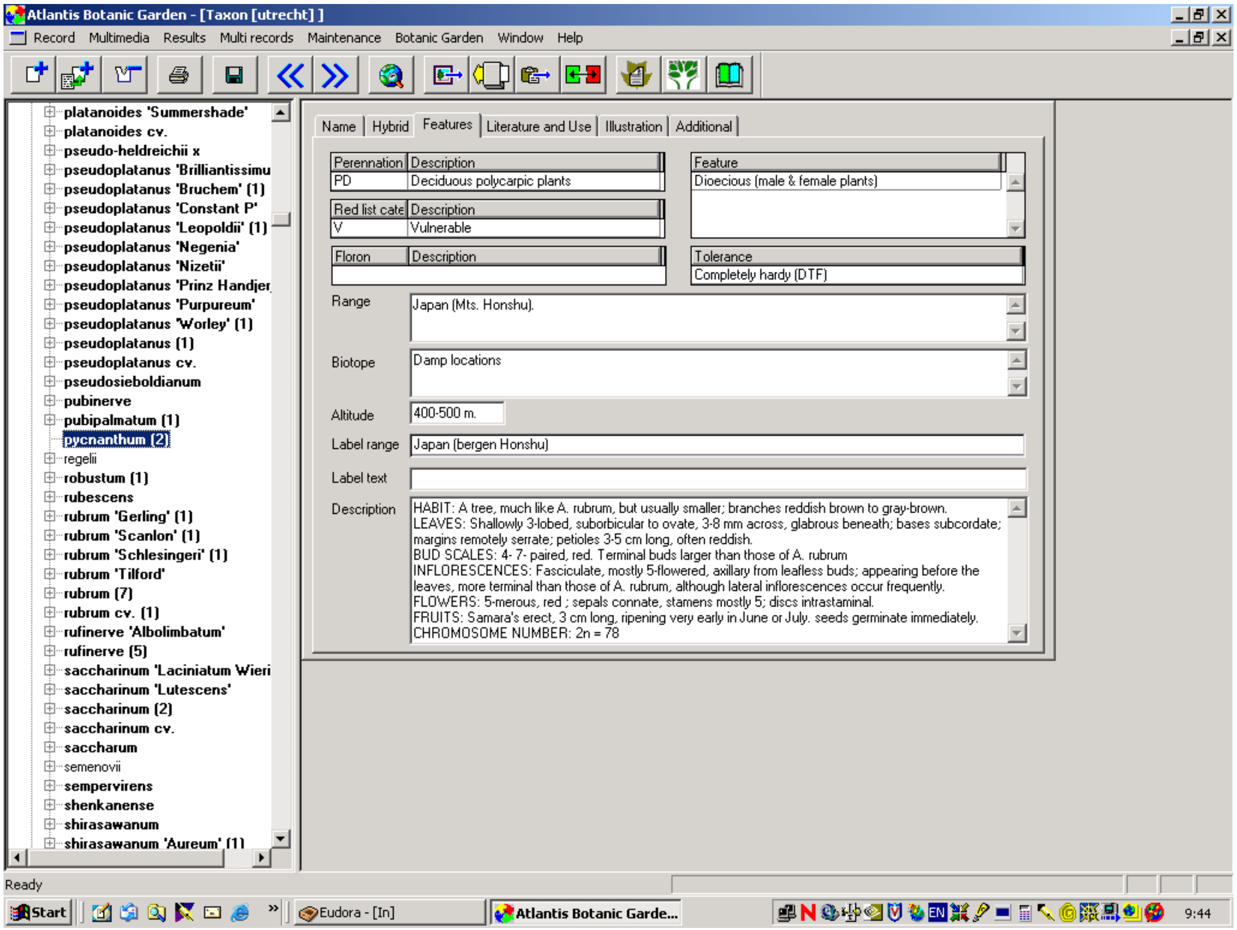

Fig. 2 Third property screen of Taxon including Red List Status.

The challenges and benefits of in-vessel composting our food and catering waste to divert material from landfill and provide Eden Project with a valuable fertiliser

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Abstract

As part of our Waste Neutral Programme, the Eden Project installed an in-vessel food waste composter, the 'Neter 30'. This was developed by Torsten Hultin based on a smaller machine, the 'Big Hannah', many of which are in operation, predominantly in Scandinavia. Hultin promoted these composters to local communities and small businesses to provide food and other biodegradable waste recycling systems, producing a beneficial end product whilst fostering social responsibility towards waste.

Compliance with UK/EU legislation entailed shredding food waste going into the composting vessel. The resulting 'paste', consisting of much cooked waste, gave an acidic low temperature compost when mixed with recommended sawdust pellets. Experimentation under commercial operating conditions increased starting pH and achieved rapid high temperatures using a mixture of finished compost and card fluff as co-feedstocks whilst keeping moisture levels between 40-45%.

'Neter 30' compost can be used unamended as a growing medium or as a mulch. Containing high levels of N and K and reasonable levels of P, its real value is as a high nutrition additive to our green waste compost for use as a spring mulch to reduce our need for high N fertilisers. Work on this is ongoing but early results are very promising.

Key words

Aerobic in-vessel composting, efficacy, food waste, moisture content, pH

Introduction

An aerobic in-vessel food waste composter, the Neter 30, was installed at Eden Project as part of our 'Waste Neutral' programme. We set up our Waste Neutral Programme at Eden Project to minimise the waste of materials in our own operations and to promote the minimisation and recycling of waste to the general public (http://www.edenproject.com/whats-it-all-about/what-we-do/projects-and-programmes/waste-neutral.php). The aims of this programme were encapsulated in a simple slogan: Reduce, Reuse, Recycle and Reinvest. The composting of food waste streamed from our kitchens and catering operations constitutes an important component of the recycling effort at Eden Project and aims to divert a significant amount of organic waste from landfill. The Neter 30 system was selected over a number of composting technologies, including anaerobic digestion, based on its capacity to deal with the expected volumes and seasonal variation in quantities of food waste possible at Eden as well as the compatability of the philosophy of the producer with Eden Project's aims. Built by Susteco AB, the Neter 30 was developed by Torsten Hultin based on a smaller machine, the 'Big Hannah', of which there are over 600 in operation, predominantly in Scandinavia (Wiles, 2006). Hultin promoted the use of these composters to local communities and small businesses to provide systems that could recycle food and other biodegradable waste, to produce a beneficial end product whilst fostering social responsibility towards this waste stream. Making the Neter 30 composter work at Eden is definitely a team effort and this is reflected in the large number of authors on this report! It is one thing to set up and work out the technicalities of operating a composting system, but it is quite another to successfully run such a system at a complex site like Eden Project. For this to happen, the operation of the composter has had to become embedded within the site culture and keeping it there is an ongoing project about support, shared knowledge and shared ownership.

Description of the Neter 30 composter

The Neter 30 in-vessel composter was designed for composting organic wastes, primarily catering waste with added sources of carbon and the optional addition of horticultural waste. It was designed as a single-stage, fully contained, continuous flow-through system, with waste fed *via* an in-auger into one end and compost automatically removed *via* an out-auger at the other. The composter consists of a horizontal stainless steel cylinder approximately 8.5m long, by 2m diameter (volume = *circa* 30m^3), which rotates against fixed end walls. It is housed within a stainless steel outer casing 9.5m long, 2.7m wide and 2.6m high. This outer casing acts as a safety barrier for the moving parts and provides some buffering from external temperature fluctuations. The rotation of the cylinder tumbles the material being composted, mixing and aerating it, whilst moving it along the vessel. The periods of rotation ('run') and standing ('wait') can readily be altered to suit the process. Fixed to the end walls is a spindle that runs through the centre of the vessel. Attached at right-angles to the spindle and spaced at 1.4m intervals, are 5 circular steel plates on each of which 4 temperature sensors and 1 water inlet nozzle (for wetting compost if it becomes too dry) are mounted (Figures 1 & 2).

Operating the composter

The food waste at Eden consists of catering waste from the kitchens and food preparation areas together with scraps from cleared tables and some spent compostable packaging and wooden eating utensils. Until relatively recently this waste contained little raw vegetable material (primarily salad trimmings and scraps) or peelings, as the vast majority of the vegetables cooked on site were delivered ready-prepared (i.e. peeled and washed). This situation is now changing with increasing vegetable preparation (e.g. onions and cabbages) on site (Figure 3).

Members of the catering team in the kitchens and in service areas of the cafeterias (Figure 4) carry out a key role in the running of the composter by source-separating the food waste from other recyclables such as glass, metal, plastics etc. and from general waste. This vital task can be very demanding, especially when the pressure is on during the peak season when Eden can host more than 10 thousand visitors in one day, but without the continuous attention to detail at this stage by the catering team, the quality of the compost produced can be compromised.

The separated food waste is collected by members of the Waste Neutral Operations Team and taken to the recycling compound in 90 litre 'wheelie' bins. When full, these can vary in weight from 25kg (predominantly bread) to 75kg (predominantly wet food waste), with the average full bin weighing approximately 40kg. Food bins are weighed and emptied by bin lift (Figure 5) onto conveyor belts, where the waste is manually inspected (Figure 6) and any contaminants (metal, plastics etc.) missed by the catering team are removed. After inspection, the conveyor delivers the waste to a shredder set to reduce the particle size to 20mm. Once shredded, the food waste is transferred to the composter vessel by the 'in-auger' (Figure 1) and mixed with other feedstocks in the vessel. As the vessel rotates the composting mixture progresses along its length until, after about 70-90 days, it reaches the 'out end' and is removed by the 'out-auger' (Figure 1) as finished compost. The composting process is regularly monitored by members of the Waste Neutral Operations and Science Teams, who collect records of temperatures in the vessel and of the weights of feedstocks put in and of finished compost taken out as well as taking samples from the vessel for measurements of pH, moisture contents and microbiological activity.

Experiences developing the process

Shredding the food waste to 20mm is carried out to comply with the U.K. Animal By-Products Regulations ('ABPR' – HMSO, 2005). The resulting homogenate (Figure 7), is mixed with other feedstocks to reduce its moisture content and adjust its pH and carbon to nitrogen ratio to the optimal ranges of 6-8 and 25:1 - 40:1 respectively (Gilbert *et al.*, 2001). The recommended co-feedstock for use in the Neter 30 was sawdust pellets (Figure 8), which have been successfully used in Scandinavian systems. However, mixing Eden food waste with sawdust pellets resulted in a rapid decline in the pH of the mixture to levels as low as 4.2, leading to very poor composting temperatures. It was suspected that this was in part due to the nature of our food waste, especially its very low raw vegetable material content, and the effect was reduced by the addition of shredded green waste from the Eden Project gardens and finished compost to the mix. The large particles of green waste improved the structure of the compost and both co-feedstocks probably added useful micro-organisms, whilst the alkalinity (pH 8.5 – 9.0) and low moisture content (25-35%) of the finished compost helped to dry the mix and stabilise/increase its initial pH.

Operationally this mix of feedstocks was difficult to put into the composter as a result of the way in which the front end of the vessel was configured and produced mixed results due to the variable nature of the green waste. The addition of co-feedstocks was greatly facilitated by the fitting of a hopper directly over the in-auger (Figure 9), whilst an in-depth investigation of the interaction of physical and chemical factors within the vessel (Orthodoxou, 2008) demonstrated that the moisture content of the compost mix was the main factor affecting the pH and hence the composting temperature (Figure 10). The optimum moisture content was found to be between 35 and 45%, considerably lower than the 50-60% normally considered optimal for composting. Gas analysis in the same study also established that when moisture levels rose, anaerobic conditions did not develop and consequentially were not the cause of the decline in pH associated with such moisture increases (Figure 11). The precise cause of acidic fermentation conditions developing in the composter is not certain, but it was clear that excessively wet (i.e. >50% moisture) and acidic feedstock mixes are to be avoided.

Following on from this study a range of potential co-feedstocks were screened for their ability to adjust the pH to >6 and the moisture content to <45% when mixed with freshly shredded food waste. At this stage 'card fluff', a new material for us, was considered. This waste material consists of fibres and dust collected by cyclone separator from the air in a corrugated board box manufacturing plant (Figure 12) and would normally be disposed of to landfill. It has a pH of 8.5-8.8, probably resulting from sodium hydroxide present in the starch glue used in corrugated board, a moisture content of 7-10%, and a high carbon content, making it a potentially ideal co-feedstock for food waste. Comparisons of different ratios of feedstocks (Figure 13) indicated that the best mix is about 50% food waste to 25% finished compost and 25% 'card fluff'. This gives a pH of 6.5-7.5 and a moisture content of 40-48%. In practice this ratio of feedstocks has produced excellent results, with temperatures rapidly becoming thermophilic (>45^{o}C) within the first metre of the vessel. However it can be difficult to adhere to, especially when large amounts of food waste need to be processed. When this happens, there is the danger of too high a proportion of food waste in the mix giving a reduced pH and increased moisture content, leading to a steady decline in pH and an undesirable drop in composting temperature to 30-40^{o}C. Nevertheless, the temperature of the compost at the first monitoring point gives a good indication of composting efficacy and over the last year this has been >45^{o}C for 80% of the time, and >50^{o}C for more than 60%, leading to temperatures above 60^{o}C in the central portion of the vessel and production of a great compost product that is safe to use.

The finished compost

The Neter 30 enables us to divert approximately 20 tonnes of food waste from landfill and produces about 10 tonnes of compost per year. The compost produced (Figure 14) has passed the PAS 100 quality standard (BSI, 2005) and can be used as a growing medium (Figure 15). However, the majority of the food waste compost produced at Eden is used as an activator co-feedstock in our green waste composting (Figure 16) or as a high nutrition mulch/soil improver (a 25 mm thick mulch will give approximately 40kg N ha^{-1}). Our food waste compost also contains high levels of K and moderate amounts of P, but applying it directly to soil can be unpleasant as it can be dusty and we are now looking at the feasibility of using it as a fertiliser in mulch mixes with our finished green waste compost.

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Figure 1: A) Diagram of the Neter 30 composter showing positions of temperature sensors and access hatches. B) Cross-section showing the central spindle and positions of temperature sensors and water inlet pipes located on plates A – E within the vessel.

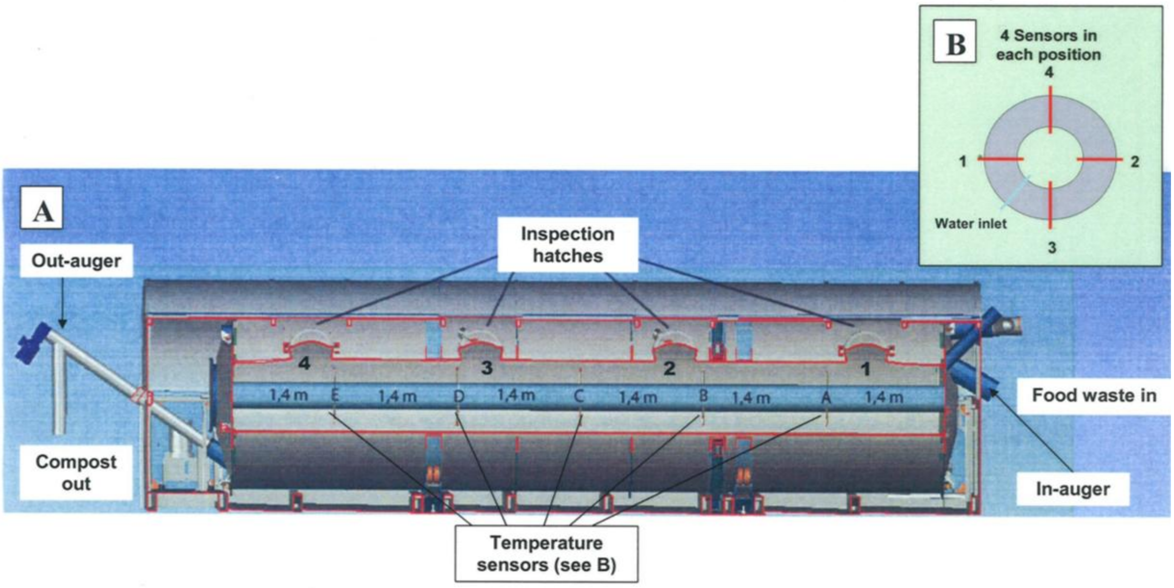


Figure 2: General view of the Neter 30 composter in position in the Recycling Compound at Eden Project.

Figure 3: Photographs of the contents of typical food waste bins at Eden Project.

Figure 4: Louise & Tara from the Eden Catering Team pose for a quick photograph whilst working on the source-separation facility in 'ZZub-ZZub' café.

Figure 5: Bin lift used to weigh and transfer food waste from 'wheelie' bins to the conveyor system for inspection and delivery to the shredder in preparation for composting.

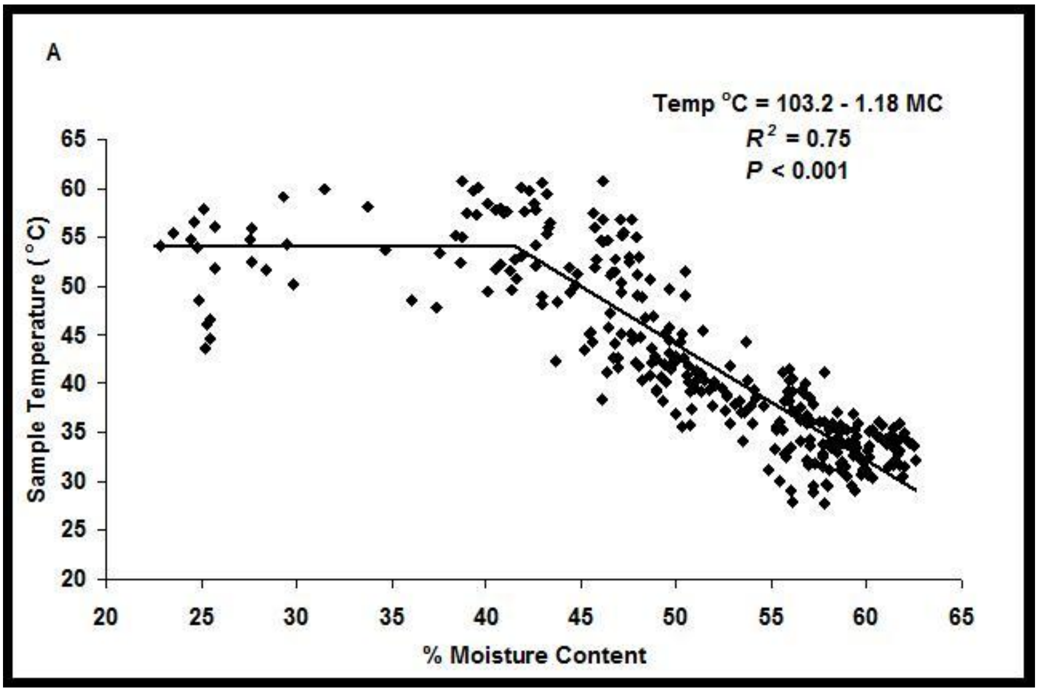
Figure 6: Clare and John from the Waste Neutral Operations Team carrying out final inspection of food waste before shredding and composting.

Figure 7: Macerated food waste entering the composter vessel after passing through the shredder.

Figure 8: Sawdust pellets alone (A) and added to the macerated food waste in the composter vessel (B).

Figure 9: Hopper installed over the 'in-auger' to help adding co-feedstocks to macerated food waste.

Figure 10: Effects of % moisture and the pH of the compost mix on the composting temperature in the Neter 30 composter (Data from Orthodoxou, 2008)



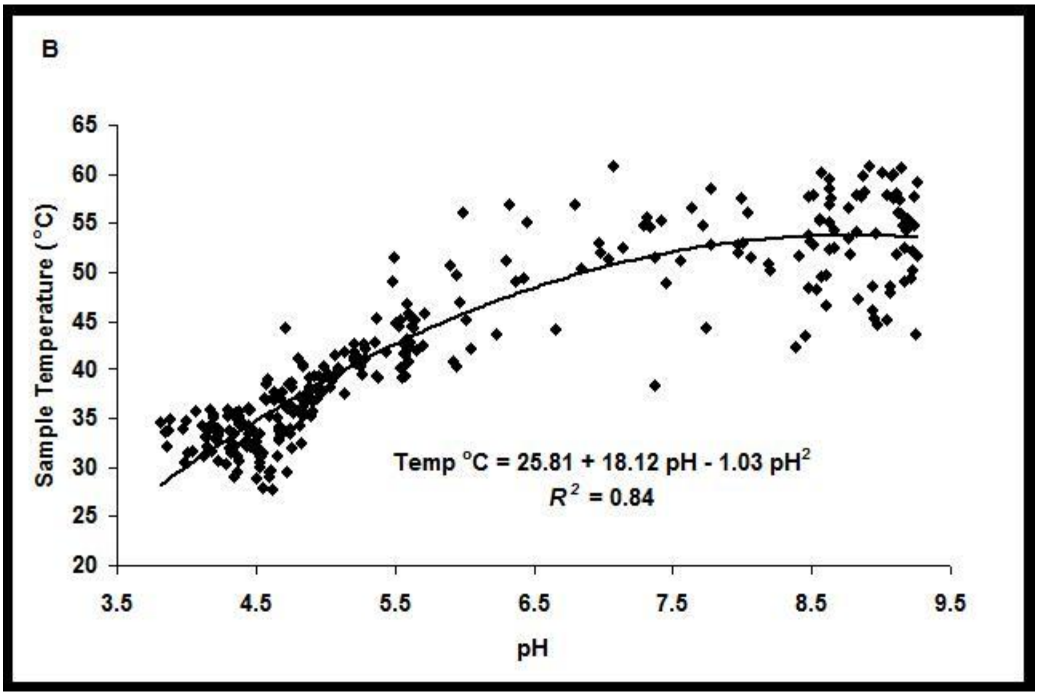


Figure 11: Demetra from Imperial College carrying out gas analysis on the compost mix at the first inspection hatch on the composter vessel.

Figure 12: Photographs of 'card fluff' and the corrugated board plant where it is extracted from the air.

Figure 13: Comparison of the effects of different ratios of co-feedstocks mixed with macerated food waste on the initial pH and moisture content of the compost mix.

Figure 14: The finished Neter 30 food waste compost as it emerges from the composting vessel.

Figure 15: Photograph and bar chart illustrating the effect of the proportion of Neter 30 food waste compost incorporated in a peat-free growing medium (0-100%) on the growth (root and shoot weight) of lettuce plants (*Lactuca sativa* cv. Little Gem).

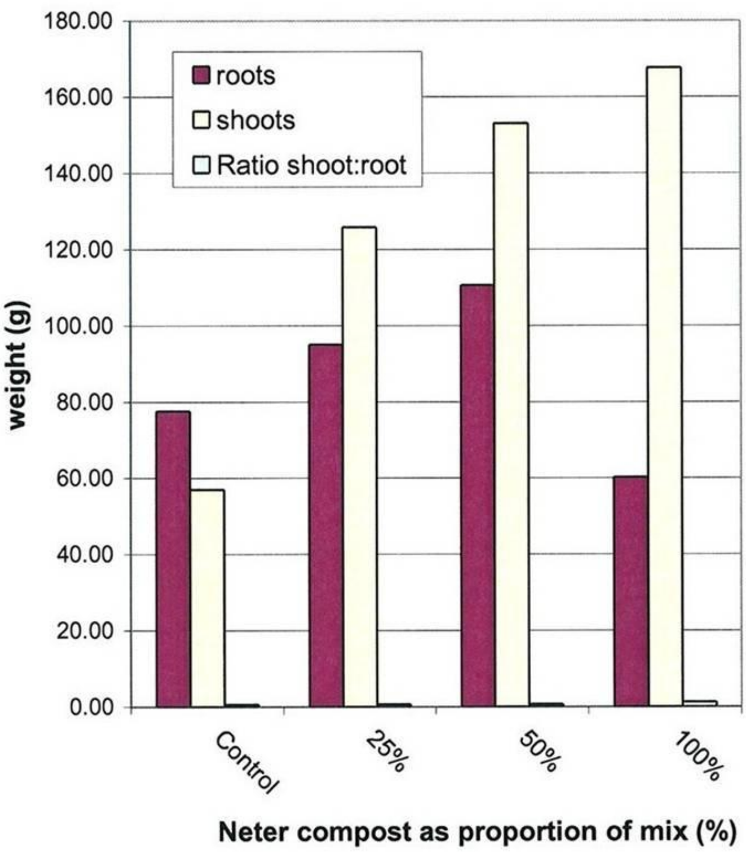


Figure 16: Eden food waste compost is used as an activator feedstock in our green waste composting operation. Here a recently mixed heap is being turned and aerated.

Saving biodiversity: Be the Change

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Abstract
Traditional efforts to preserve biodiversity and address climate change won't succeed until we change the way people interact with the world. Public gardens can play a major role in creating that change. To do this, and be seen with credibility, we must first ensure that our actions reflect our message. When Phipps opened in 1893 people believed there was no limit to the natural resources we used or pollution we produced. 110 years later, by questioning and challenging conventional design and operations, Phipps transformed itself from a relic of the last industrial revolution to one of the worlds greenest gardens. In 2005, Phipps opened the first LEED certified visitor center in a public garden: in 2006 the most energy efficient conservatory in the world: and in 2009 completed designs for a zero net energy and water building to meet the Living Building Challenge and exceed LEED Platinum. Simultaneously, Phipps "greened" its operations and developed extensive new educational programs and collaborations. By demonstrating environmental stewardship and leading by example, Phipps garnered numerous awards, public recognition and funding, and was selected by President Obama to be the G20 Summit host site for the opening reception and leader's dinner in September 2009.

Key Words

Biodiversity, conservatory, environment, green buildings, LEED, Phipps, SITES, sustainability

Introduction

The mitigation of biodiversity loss is a critically important service that public gardens can render to society today. As we look at the strategies public gardens employ to address the loss of biodiversity it is imperative that we emphasize long term solutions over short term solutions. That is not to say that short term solutions are not important and indeed many species have been saved by them. Nevertheless, the most important long term solution to stop the loss of biodiversity is changing the way people interact with the world. Fundamental, pioneering, visible and inspirational changes in the way public gardens operate can lead to long term solutions to the problems leading to the loss of biodiversity.

What are the problems that require long terms solutions? They are the very same man-made problems that are manifest in global climate change. Our relentless pursuit of natural resources and reliance on fossil fuels, our exponential population growth and the vast disparity in social and economic equity that exists throughout most of the world are placing unprecedented pressure on species and the habitats that support them. Our children are growing up in societies that often do not support the development of meaningful connections with the natural world. Another factor that we need to recognize is that this planet cannot support the world's population living the same lifestyle we enjoy in the US. It has been estimated that if everyone in the world were to live the lifestyle we do in the US, we would need seven planets' worth of natural resources to sustain us. We must change the way we live and it is imperative that those of us in the developed world lead that change. We need better solutions for living in harmony with the natural world at a level of shared equitable resource consumption that can be sustained around the world.

Mohandas Gandhi famously said "You must be the change you wish to see in the world". What is so powerful about this statement and the man who made it is that he truly exemplified the change he wanted to see. Are we doing that?

The Phipps Conservatory

It is interesting to look at the history of Phipps Conservatory as a model of how peoples, wants, desires and attitudes have changed, and how we have transformed Phipps to lead by example. Phipps Conservatory was given to the city of Pittsburgh in 1893 by Henry Phipps, a partner of Andrew Carnegie in the steel business. The gift was made at a time when people had a completely different view of the world. At that time, people believed there was no limit to the amount of natural resources we used or the amount of pollution we produced. In fact people believed that we were going to conquer nature. This view was symbolized by the original purpose of the Conservatory, which was to grow and display exotic plants from warm climates in glass houses located in Pittsburgh, where the climate is anything but tropical. In the first 100 years of its history, Phipps gained quite a regional reputation for staging elaborate seasonal flower shows. In 1993, the city of Pittsburgh relinquished operation and control of the conservatory to a non-profit organization. After privatization, we expanded the tradition of spectacular flower shows, and embarked on a three phase master plan to address visitor amenities, add additional exhibit space and replace dilapidated facilities.

Our first project was to replace the main entrance. In the process we learned about Leadership in Energy and Environmental Design (LEED). LEED buildings are energy efficient, water efficient, use local resources and have high indoor environmental quality. We didn't start out to build a green building, but after learning about the program we decided our buildings should reflect our values. When we finished in 2005, we had built the first LEED certified visitor centre in a public garden.

It was during construction of this building that I experienced a revelation. One day, I noticed the contractors were installing floor tiles from a distant country. I was surprised, because I thought LEED buildings were supposed to use local materials. When I questioned the reason for using imported tiles, I was told that "we already got the point for local materials" so it didn't matter anymore. I suddenly realized that we needed to look beyond LEED. That one tile changed the way we looked at our entire operation. We decided not to stop with the building; we decided to look at everything we do to make it as green as possible.

When we looked at operators for our café, we sought out an operator who agreed to focus on local and organic foods. In our gift shop we featured fair trade items and made sure that we were not selling products illegally harvested from tropical forests. It makes no sense to tell people to care about the rainforest and then sell trinkets in your gift shop from people cutting them down. We began to question our use of pesticides and cleaning products, rejecting chemical approaches and adopting innovative and earth-friendly practices in every aspect of our operation. We started to compost all of our preand post-consumer café waste and food waste from events at Phipps. We banned plastic disposables and bottled water and got our café green-restaurant certified. LEED required us to use 10% renewable energy for our welcome centre; we decided to use 100% renewable energy for all of our buildings.

When it was time to build our new conservatory we wanted to make it as efficient as possible. The two major energy demands in conservatories are summer cooling and winter heating. In order to investigate the relationship between energy demands and glasshouse design, we went all the way back to the 1840's when the first conservatories were built in Europe to study their design. We found big glass buildings with small vents at the top to allow the hot air to escape. We looked at many other conservatories all the way up to the present and found that in 160 years very little has changed in conservatory design. Actually, we did find one major change. Starting around the 1980's people began to install giant fans in the glasshouses to introduce outside air and accelerate the escape of hot air through the vents. The fans keep the conservatories cooler in summer, but they use a considerable amount of electricity.

We began to question conservatory design. We asked our engineers to show us how air moves through a conservatory. We modeled air movement through various implementations of the traditional two-vent system. We saw very little change in temperature. We asked our engineers to show us what would happen if instead of a small roof vent, half the roof opened. They objected and stated that we would ruin the chimney effect; we persisted. The result was astonishing. On a 32°C day in a traditionally-designed conservatory, the temperature would be high as 37°C. Using our open-roof design, the temperature was in the low 30's all throughout the conservatory. We immediately had them change the design so that every other row of glass on the roof of our 1,100 m^2 conservatory would open. We then designed our own two-stage shading system to close the shades under the stationary panels of the roof and leave them wide open under the vents to achieve maximum air flow. We learned about earth tubes and installed six concrete pipes a half metre in diameter and 100 metres long, 5 metres underground beneath the new production greenhouses. The ground stays at 13°C year-round at this depth, and by using the draft created by air exiting the roof vents of the conservatory, we could use the ground to passively cool the air. We added a fogging system for evaporative cooling. By the time we finished, we had a conservatory that has no greenhouse effect. It cannot get hotter inside then outside, and it uses virtually no energy to stay cool.

We then looked at heating. Originally our building was designed with single pane glass to allow for the maximum amount of daylight penetration during the winter months when the days are short and the sun is low in the horizon. The building was designed to be wedge shaped with a high south-facing wall so that the new addition would not be visible from the front lawn of the original 1893 conservatory. We requested a sun tracking study and found that all the direct winter sunlight entered through the south-facing wall and none through the roof. This allowed us to make the roof double pane insulated glass, because that is where most heat is lost, and keep the south wall single pane glass to maximize direct winter sunlight penetration. We modified our shading system to function as an energy blanket to conserve heat. We insulated the outside of the northwest and northeast concrete walls for thermal massing. We added a root zone heating system in all of the planting beds so that we could turn the air temperature down on cold winter nights. Our engineers estimated that these changes reduced the heating requirements to 1/7 of a typical conservatory of similar size. We installed an energy-efficient prototype solid oxide fuel cell to make electricity and tempered water for the new conservatory. By the time we finished, we had built the most energy efficient conservatory in a public garden in the world.

Around the same time we heard of the Living Building Challenge to build a building to exceed LEED Platinum (the current highest level of green building) to be net-zero energy and water. We designed our new education, research and administrative building, the Centre for Sustainable Landscapes (CSL), to meet the challenge. The building will rely on a number of strategies to meet the net-zero energy requirements including a robust building envelope, photovoltaics, wind power, daylight, and natural ventilation. Net-zero water strategies include rain gardens, lagoons, cisterns, green roofs, permeable paving, and constructed wetlands to treat and recycle sanitary water. The CSL was also accepted as a pilot project for the new Sustainable Sites Initiative, which is like LEED for landscapes.

The transformation of Phipps has been an extraordinary experience, but it is not just about building green buildings. We see these efforts as a way to inspire the public to explore ways to live a more sustainable lifestyle and we see the CSL in particular as a venue to help us change the way people interact with the world. The CSL provides us with an opportunity to develop pace-setting collaborative research with local universities and institutions. We have great talent in our region focused on green buildings, but research is lacking in how to sensitively incorporate buildings into the landscape. We see our research programmes influencing our education programmes, making the connection between people and plants, making connections between the human and natural worlds where the natural and the built environment intersect.

All of this has resulted in extraordinary publicity and awards for Phipps. In September 2009, after President Barack Obama selected Pittsburgh as the host site for the G20 summit we had an opportunity to put Phipps forward for consideration as one of the host sites. In our presentation on Phipps we highlighted the contrast between the Phipps of 1893, a product of man's quest to conquer nature, and the Phipps of 2009, a model of green buildings and operations. The pitch worked and Phipps was selected as the host site for the official welcome and opening reception for all the delegates and the working dinner for the world leaders.

Have we gone far enough? We don't think so. It is important that all of us continue to look for opportunities to make our institutions more sustainable and influence the public. We need to ensure that our actions support our values. All of us have an incredible opportunity to connect people to nature and an opportunity to change the way people interact with the world. A redefinition of the relationship between people and world resources is necessary to preserve the loss of biodiversity in the long-term. Our actions speak louder than our words; we need to be the change we wish to see in the world.

Can botanic gardens play a role in REDD-plus?

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Abstract

Forests are under threat from deforestation and degradation, posing a real danger to species, human livelihoods and our climate. Reducing Emissions from Deforestation and Forest Degradation (REDD-plus) – is an incentive oriented mechanism proposed to facilitate the largest and fastest reduction in global greenhouse gas emissions. The mechanism may also provide conservation opportunities and the delivery of related ecosystem services. There are clear overlaps in the conservation objectives of many botanic gardens and the aims of REDD-plus. This paper considers the role of botanic gardens in supporting the practical implementation of REDD–plus, should the process be adopted by governments.

Key Words

Botanic garden; capacity building; biodiversity; co-benefits; conservation; partnerships; REDD-plus; species identification.

Introduction

Forests provide livelihoods for 1.2 billion people worldwide (World Bank, 2001) and account for 50% of the world's terrestrial carbon (FAO, 2000, cited in CBD, 2009). Extensive forest loss has made a huge impact on forest carbon stocks. Deforestation is the second largest anthropogenic source of carbon dioxide into the atmosphere (van der Werf *et al*. 2009). It is believed that tropical deforestation alone caused one - two billion tonnes of carbon to be released into the atmosphere every year during the 1990s, which accounted for 15-20% of annual greenhouse gas (GHG) emissions (Gibbs *et al.* 2007).

REDD–plus

In an effort to combat this, Reducing Emissions from Deforestation and Forest Degradation (REDD-plus) may provide financial incentives for reductions in deforestation and forest degradation. The proposed REDD-plus mechanism is a climate change mitigation strategy, where efforts are made to reduce GHG emissions into the atmosphere or to sequester those already emitted (von Scheliha *et al.* 2009). Alongside a reduction in carbon emissions, REDD-plus could provide so called "co-benefits" - for example through the conservation of biodiversity. Considering that forests are amongst the most diverse ecosystems in the world - harbouring an estimated 75% of global terrestrial biodiversity - there is great optimism for the additional benefits offered by REDD-plus (von Scheliha *et al.* 2009).

Negotiations to develop a legally binding mechanism for REDD-plus will take place at the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Mexico, November 2010 (UNFCCC COP16). Some countries have begun to prepare for an international REDD-plus mechanism (UN-REDD, 2009). For example, the UN-REDD Programme in nine pilot countries (UN-REDD, 2009), includes Bolivia, the Democratic Republic of Congo (DRC), Indonesia, Panama, Papua New Guinea, Paraguay, Tanzania, Vietnam and Zambia (UN-REDD, 2010).

Botanic gardens

There are over 2500 botanic gardens around the world (BGCI, 2010). Maintaining more than four million living plant collections from over 80,000 plant species, botanic garden collections contain approximately one third of the worlds known vascular plant species (BGCI, 2010). Botanic gardens are defined as "institutions holding documented collections of living plants for the purposes of scientific research, conservation, display and education" (Wyse Jackson and Sutherland, 2010). Traditionally, many botanic gardens have focused their research activities on taxonomy and biosystematics of plants (Wyse Jackson and Sutherland, 2000). In recent decades, activities have included conservation, education and sustainable development. Most gardens are involved in *ex situ* conservation, for example through the storage of seeds in seed banks and through maintaining living plant collections. Some botanic gardens are also involved in *in situ* conservation. Botanic gardens are therefore repositories of a wide range of skills and expertise related to plant conservation, particularly species identification, biodiversity monitoring, mapping, and habitat restoration, and the collection and storage of specimens (Primack and Miller-Rushing, 2009). Furthermore, many botanic gardens work alongside counterpart institutions in various countries (Primack and Miller-Rushing, 2009). Hence, the far-reaching activity of botanic gardens is easily recognisable (BGCI, 2010).

Botanic gardens are also prominent in international policy. For example, botanic gardens played a leading role in the development of the Global Strategy for Plant Conservation (GSPC) under the Convention on Biological Diversity (CBD) (GSPC, 2002). The Gran Canaria Declaration, drafted by the botanical science community, outlined the importance of a strategy for plant conservation to secure plant diversity for the future. Following the publication of the Gran Canaria Declaration, the GSPC was adopted by the parties to the CBD in 2002. The Strategy consists of 16 targets to be achieved by 2010 and is in the process of being updated for the period 2011-2020. The strategy enables botanic gardens to engage directly with international policy agendas, and puts their work into the context of national conservation strategies. Thus, botanic gardens have the potential to impact high level policy decisions, providing hope that they could mobilise similar initiatives to facilitate their involvement in supporting REDD-plus.

Meeting the technical needs of REDD – plus

In this study, we analysed national REDD-plus pilot project reports and other reviews of REDD–plus to develop an overview of REDD-plus projects and to identify technical barriers to implementation. The reports indicate that priorities and national capacity for implementation of REDD-plus programmes will differ between countries. This paper investigates how the expertise available in botanic gardens around the world can be utilised to address REDD-plus technical capacity gaps. We asked individuals from 11 botanic gardens around the world for information about any existing activities that could relate to the implementation of REDD-plus schemes. An overview of recent or current relevant projects undertaken in eight botanic gardens is outlined in Table 1.

It should be noted that each project overview was developed according to the information provided by each botanic garden at the time that this study was conducted. In addition, case studies in the survey only represent activities from 8 botanic gardens, which is a small proportion of the botanic gardens around the world. Thus, this study does not form a comprehensive summary of all activities within gardens, and how all gardens may be able to support REDD-plus.

Discussion

There are clear areas of strength within botanic gardens that can be used to support the practical implementation of REDD-plus. In the following section, we discuss the ways in which the skills and expertise in botanic gardens may be of direct relevance to address the technical capacity gaps that we have identified as barriers to the implementation of REDD–plus, through our review of pilot project reports.

1. Limited availability of historical carbon and forest area data: most botanic gardens are involved in species identification. Species level information is crucial when measuring forest carbon stock. Botanic gardens can use their expert species identification skills to accurately inform forest carbon stock from both historical and recent data records. Missouri Botanical Garden's carbon mapping project in Gabon for example, provided accurate species knowledge to inform the calculation of forest carbon stocks.

2. Limited human capacity to implement REDD-plus activities: most botanic gardens work extensively through partnerships. The partnerships are currently successful in building capacity for plant conservation worldwide. The skills of staff in botanic gardens could also be useful for addressing the capacity required to implement REDD-plus projects. For example BGT is improving capacity within institutions in Papua New Guinea by training people in tree species identification skills.

3. Poor interpretation or awareness of degradation: extensive species and habitat knowledge within botanic gardens could be used to inform forest degradation assessments. For example, information about plant species found at a site, data about the threat status of plant species, and an understanding of the services that specific plants can deliver, can all be useful in assessing habitat degradation.

4. Limited resource awareness: there is often little consideration for biodiversity in REDD-plus projects (Dooley, 2008). Botanic gardens could help to inform REDD-plus site selection by providing detailed biodiversity data - in order to promote the conservation of biodiversity in REDD-plus schemes and to help ensure that the forest conserved is more stable under environmental stresses.

5. Lack of comprehensive forest assessments: species knowledge can provide information that is vital for forest assessments. Scientists in botanic gardens have advanced fieldwork and research skills that could be highly transferable to REDD-plus related forest assessments. For example, scientists at RBG Kew used a combination of remote sensing techniques and ground truthing to help to inform sites for protected areas in Madagascar. Similar information and skills could be used to help select sites for REDD-plus.

Challenges for botanic gardens in supporting the implementation of REDD - plus projects.

Although there are clear strengths in botanic gardens that could help to deliver successful REDD-plus activities, this study has also identified areas that may hinder the involvement of botanic gardens in such schemes. However, it should be noted, that there may be some activities in botanic gardens that we have not covered in this paper.

1. Awareness of REDD-plus and relevant policy issues: this study finds that there is limited awareness and recognition of the potential role that botanic gardens could play in supporting REDD-plus. Despite this, this study finds that many existing projects in other botanic gardens inadvertently meet REDD-plus objectives.

2. New Partnerships: at present, botanic gardens work in partnership with mainly other botanical institutions. In order to harness the use of knowledge and skills from botanic gardens to deliver co-benefits from REDD-plus, there may be a need for botanic gardens to form more diverse partnerships with other types of agencies.

Many botanic gardens appear to be working in partnership with other organisations nationally. Engaging with REDD-plus may require botanic gardens to share resources and skills through working in partnership with agencies in countries in which REDD-plus projects are active.

3. Limited soil carbon data: This study finds that information about soil carbon is also a technical barrier to the success of REDD-plus at some sites. The strengths of botanic gardens lies in knowledge about plants. Within botanic gardens there is limited capacity to integrate the measurement of soil carbon stocks into projects.

4. Lack of appropriate resources: Some of the work identified in this report is not business as usual for botanic gardens. Engaging in activities to aid implementation of REDD-plus could result in a change in priorities away from classical research, or may require additional resources to supplement this activity.

To help with sharing resources within the botanic garden community, supporting organisations such as Botanic Gardens Conservation International (BGCI) could play a significant role. For example the development of a database of expertise could assist in the development of partnerships and facilitate the communication of botanic gardens REDD-plus strengths. Reviewing the activities of all botanic gardens within their database, BGCI could develop an interactive system for botanic gardens to outline their REDD-plus related expertise, to create and support appropriate partnerships more readily.

Conclusions

The evidence gathered in this study identifies common strengths in botanic gardens to potentially assist in the implementation of REDD-plus. Botanic gardens are home to a vast resource, which as of yet remains untapped by REDD-plus. This paper does not provide a comprehensive overview of the many ways in which botanic gardens could support REDD-plus but could help staff in botanic gardens to consider how their work could support such initiatives.

Despite identified strengths, there are ultimately areas of REDD-plus that cannot be addressed through botanic gardens. This suggests that REDD-plus will likely need to work within a network of institutions and expertise in order for projects to be adequately supported.

There appears to be the variation in awareness of the REDD-plus mechanism amongst the botanic gardens involved in this study, as well as limited resources to support such work, little willingness to engage with REDD-plus as a conservation measure, and limited recognition at the national level as stakeholders in the REDD-plus agenda. This is perhaps unsurprising as REDD-plus is yet to become a legally binding mechanism. The authors of this study hope that this evidence provides an insight for botanic gardens to identify how they could contribute to REDD-plus projects in the future. However, some activities to help implement REDD-plus may require a change in institutional policies and research activities in botanic gardens. If botanic gardens decide to become active in the implementation of REDD-plus, there may be a need to assess their strategic goals and current partnerships to address such global initiatives.

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Table 1: Botanic garden case studies and links to REDD - plus

Botanic Garden	**Recent or Current Projects that could be of relevance to REDD - plus**	**Skills and expertise which could be relevant to REDD - plus**
Botanic Gardens Trust , Sydney (BGT) - Australia	Working partners in Papua New Guinea to provide identification tools to assist with tree identification and documentation.	• expert species knowledge • identification skills • training in the above skills
Rio de Janeiro Botanical Garden - Brazil	Programme Mata Atlantica (PMA) aims to protect 6% of the original Atlantic Forest. The project studies taxonomy, community ecology, ecological anatomy and seed germination to determine species diversity.	• conservation of biodiversity • protection of local livelihoods
South China Botanic Garden – China	Dinghushan Forest Ecosystem Research Station undertakes research into successional processes and area biodiversity to inform forest management.	• forestry research and data provision • forest management skills.
Xishuangbanna Tropical Botanic Garden – China	Scientists at XBG are working to support fellow tropical botanic gardens through capacity development in conservation areas.	• conservation of biodiversity • training in key skills for species identification
Kadoorie Farm Botanic Garden – China	Protecting tropical trtainforest on the Yinggeling nature reserve on the island of Hainan. Comprehensive biodiversity surveys provide an understanding of species diversity within the rainforests.	• training skills in forest monitoring and management

Royal Botanic Garden Edinburgh (RBGE) – United Kingdom	Through the agro-forestry projects in Peru, RBGE scientists taught local communities and organisations working with local communities in small-scale agroforestry projects, to identify and propagate native tree species	• expert species and habitat knowledge • training local stakeholders in the above • local plant identification and research skills.
Royal Botanic Gardens, Kew (RBG Kew) – United Kingdom	Working alongside Malawian partners, the project aims to propagate 50 'useful' tree species that are threatened by over exploitation, and reintroduce species that are valuable to local livelihoods (Sacande, pers. comm. 2010).	• species and habitat level knowledge • conservation of biodiversity • species knowledge to inform forest carbon stock • knowledge about the use of plants to help to protect the livelihoods of local people.
Missouri Botanical Garden (Missouri) – United States of America	With the Gabonese government, mapping the carbon of Gabon's forests. Scientists are ground truthing remotely sensed data by measuring and identifying trees on old transects and in old plots.	• Species knowledge to inform forest carbon stock measurements • species identification • forest monitoring

Sustainable garden is an inspiration for a sustainable city

Elena Pushay
Botanic Garden of Tver State University, Russia

Abstract

This article is devoted to the diversity of cultural activity, education programmes and projects in the Botanic Garden of Tver State University. The Botanic Garden of Tver State University is a famous scientific and educational centre of the Upper Volga Region. In 2000-2010 a number of projects on sustainable development have been fulfilled in the Garden. The outcomes of the projects and new perspectives for collaboration are outlined. New possibilities of interaction for the garden's sake in the form of collaboration with NGO, volunteers, businesses, organizations, and international partners are considered.

Keywords

Biodiversity, Botanic Garden, Cultural activities, Education for Sustainable Development, Environmental Education, Educational programs for visitors.

Introduction

The Botanic Garden of Tver State University was founded in 1879 as a living museum in the open air. The Garden is located in the historical part of the city of Tver and covers a relatively small territory of 2 hectares.

The collections of the Garden consist of 350 species of trees and shrubs, and more than 2,500 herbaceous plant species. There are 19 expositions and 6 conservation collections, for example, a collection of rare and endangered species of plants of the Tver region. Since 2009 the Botanic Garden has been a local scientific and educational centre in the Tver region.

The Mission of the Garden is to open to visitors the diversity of the world of plants in order to contribute to the harmonious and sustainable interaction between people and nature. Environmental education, which is meant to facilitate biodiversity conservation in the region, and public awareness of sustainable development issues, is defined as one of the key functions of the Garden. In 1997 the Botanic Garden of Tver State University became a member of Botanic Gardens Conservation International (BGCI) (Наумцев и др., 2009).

Every season the Garden is visited by more than 15,000 people. The Garden offers a variety of educational activities for its visitors to contribute to spreading the ideas of sustainable development such as guided tours, interactive games and classes, interpretative techniques and cultural activities.

The years 2005-2014 have been declared the UN Decade of Education for Sustainable Development. Education for Sustainable Development provides a perfect platform for working with a range of international collaborations and also provides an opportunity to find the interaction between different groups of people who work with the garden.

We also strive to promote ideas of sustainable development for a wide range of our visitors and to show that anyone can do something to achieve harmony with the environment. The Department of Environmental Education was established in the botanic garden of the Tver State University 5 years ago. Today, we offer educational programmes for visitors of different age categories. We are focusing on outdoor activities. Experiences include a discovery walk, plant and animal observations, sensory exploration of plants, plant works and cultural activity.

We offer visitors traditional gardens educational programmes. Among them Early Childhood Programmes, Secondary School programmes and adult programmes. For adult visitors we are offering a variety of activities: excursions, lectures, landscape design, sustainable gardening, outdoor landscape, volunteer programmes. For Secondary schools we organize diverse programmes, such as Biodiversity 2010, Sustainable Gardening, Red Data Books & Conservation of Plants, Sustainable Development, Interactive Games, and Plant Works.

The year 2010 has been declared as the International Year of Biodiversity. Traditional knowledge is a key to conserving biodiversity. This year, we conducted an environmental camp, dedicated to biodiversity and its conservation. Each day, students studied the various components of biodiversity in the garden: plants, mosses, fungi and ecological activity (establishing of an ecological path).

The International Agenda for BGCI notes that the Botanical Gardens should demonstrate the practice of sustainable development (Wyse Jackson and Sutherland, 2000). In implementing this idea, our Botanical Garden created interactive exhibitions that demonstrate the principles of sustainable land use. Among them “Compost: Step-by-Step”, “Herbs or Wild Kitchen Garden” and “Garden of Native Plants”. The exhibitions included a hands-on organic gardening experience where children do the real work in the Kitchen Garden and make connections between plants and food. Experiences include: gardening such as planting, digging, harvesting, and planting a seed to take home. All exhibitions have interpretative tables and posters advising visitors how to make the same sustainable models in their gardens and yards.

Cultural activities in the Garden are very popular among citizens. An open-air workshop “Garden as it is Seen by Artists: Let’s Draw Plants Together” has been performed in the Garden. A team of teachers and students from the Art College, gave a master class on botanical art and illustration for garden visitors. Primrose Day was held in April and presented spring plants. A Festival of Tulips traditionally attracts visitors and includes master classes: with the artists, crafts, paper and excursions. A master class on batik was lead by volunteers from an NGO.

Our garden now is the result of cooperation at international, Russian and regional level. Since 2001 we have cooperated with the botanic garden of Moscow State University "Apothecaries' garden”. We use different forms of collaboration: joint seminars, workshops, mutual visits to gardens, and staff and student exchanges. Workshops conducted in the Garden of Moscow State University supported by BGCI gave the greatest effect on the promotion of ideas of environmental education.

Over the last 10 years (2000-2010) a number of projects on sustainable development have been fulfilled in the Garden. Among the projects are “Local Agenda 21 for Russia” (Milieukontakt Oost Europa The Neterlands), “Open Your Heart to Nature”: Raising Public Awareness of and Support for Biodiversity Conservation in the Region” (BGCI and HSBC), “Back to the Roots: Sustainable Land-Use and Ethnobotanical Traditions” (supported by British Council DEFRA) etc. In 2002-2004 the Garden in collaboration with NGO Tver Ecological Club successfully fulfilled a pilot project “Environmental Education for the Citizens of Tver” in the framework of the joint Dutch-Russian Project “Local Agenda 21 for Russia” funded by Milieukontakt Oost Europa (The Neterlands). The main goal of the project was to improve the quality of the town dwellers lives by the saving and development of the green zones of the city of Tver. In this project the Garden was chosen as a model of sustainable territory in urban surroundings. Great attention was paid to the process of establishing of informational space in the Garden. The Garden took an active part in the publication of the document “Strategy of Preserving and Development of the Green Zones of the city of Tver for improving the quality of town dwellers life”. As the result of this project the Garden demonstrated its scientific and social capacities for local authorities and the population of the Tver Region.

For the first time this year we are organizing the Plant Conservation Day. The International Project “Adopt the Tree” started last February in collaboration with Minnesota Landscape

Arboretum. The main goal of the project is to complete an inventory of the trees in the city of Tver and to contribute to cognitive interest for plants among the citizens.

We are looking for new possibilities of interaction for the garden's sake in the form of collaboration with NGO, volunteers, businesses, organizations, and international partners. Every garden has a variety of options for interaction of Plants and People. The effectiveness of that cooperation depends on how open and accessible the knowledge will be that we want to share with our visitors.

Over the past 10 years we developed, together with our garden, the way to sustainable development and this is another successful result of our changes. Every employee of the garden contributes to the construction of a garden friendly for local society, and this allowed us to make the transition to a new level of interaction with visitors to the garden and the local community.

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A big change for botanic gardens in Europe: going from the 19th to the 21st century.

Philippe Richard

Abstract

Since the Second World War, botanic gardens have kept the same look according to the basic botanic concept as they had at the end of the 19th century, "the golden age". What could a collection look like today? Let's take into account sustainable development, introduce new medias, and replace the useful (but not very attractive) generic collections by thematic ones. In short, let's become more attractive in order to capture other publics, not only scientists or old gardens lovers, but younger people, not especially interested by nature nor ecology. If conservation is more important than ever, education is taking the lead. For example, to present a plant taken out of its context is probably less efficient considering the fact that it is a living organism, dependant on its environment. Experiences of transformation in the collections are described, such as Bordeaux, but also other places in France and through Western Europe.

Keywords

Plant, ecology, change, collection, environment, use, ethno botany

There is a great diversity in the botanic gardens' world. A rich context which gives the opportunity to talk about botany. During the 20th century, new means to show nature were found in the gardens.

Many themes allow us to understand botany. In Bordeaux, we were able to undertake our project of a new botanical garden in a renovated part of the city. In a Concerted Development Zone (ZAC), on industrial wastelands, we had an opportunity to build an extension of the "old garden", located in the city centre. It is a very nice place, very attractive as an old fashion garden, well-designed at the end of the 19th century. A systematic collection is the main attraction, approximately 2,500 taxa. Considering that it is very important to keep it, as a reference, and also as a good place to teach botany to young -and older- people and to show biodiversity - what could be more efficient than a systematic collection to achieve that?

In the new place, in another district, on the other side of the river, that's where we decided to present things in a different light:

- A systematic collection, or generic collection, cuts the link between the plant and its surrounding context. Then, it becomes more difficult for people to understand that it is **interactive** with the other organisms of its environment.
- It is best to show the plant within its habitat, the ecosystem, in order to restore this link.

We led a program based on:

- the explanation of **biodiversity**, by showing a great number of living organisms in the same habitat,
- showing the evolution of the same landscape during a flexible period of time,
- in order to maintain a high level of biodiversity in the human environment, we used natural resources with more attention to ensure a better renewal of the different organisms.

For example, the fence is made of oak wood, collected after a storm…

In this garden, no flower beds, no systematic collection (such as were maintained in the old garden)

The design was made by the landscape architect *Catherine Mosbach* and organized around four themes:

- Aquatic and hydrophytic plants useful for humans, food or health, to purify water, for ornamental purposes, etc…
- Natural habitats rebuilt from basic elements (sand stone, clay…) At the bottom, geological layers, then soil, and at the top individual species of plants.

Eleven local Natural Habitats to show the interactions between organisms and their habitats: sandy dunes, oak forest, calcareous cliffs, wet or dry heaths…

- Forty four beds showing the relationship between human activities and plants, dedicated to ethnobotany:
  - plants used to make alcohol,
  - used in Chinese medicine,
  - used to make oils, rare vegetables, allergenic plants, flowered prairies,
  - attractive plants for the bees, etc…

- Greenhouses showing Mediterranean habitats, mainly from the southern hemisphere, and other topics. They are equipped with photovoltaic cells included in the glass panels of the roof, and rainwater is collected in $275m^3$ tanks to irrigate the greenhouses and in some other parts of the garden.

Mostly in the non-English-speaking countries, we have to show people how to use properly, if not avoid totally, chemical products or fertilizers. A public garden has to show, in some well chosen parts, the controlled development of weeds. In France, during the year 2009, 63,000 tons of chemicals were used for agricultural purposes, or in horticultural practices. At least for the latter, the use of such chemicals is not necessary. Botanic gardens are good experimental places to show the results of well controlled growth of weeds. They play an important role for the public and especially for children, and they are the best possible example to encourage simple and efficient techniques, such as:

- Irrigation; we have lessons to learn from farmers living in semi-arid countries ;
- No more use of sprinkle watering in warm and windy countries;
- Manual weeding ;
- Using well identified fallow spaces to help people understand the importance of some wild plants, for health or soil restoration;
- Use of recycled materials, such as cardboard boxes to make layers of compost directly usable for the culture of vegetables, use of wood chip, etc…

In conclusion, all this shows how an original garden is a means of success in the understanding of natural processes. We can use Nature, but we must use its resources very rationally in order to let it reconstitute by itself.

Figures

Figure 1: The area of the garden 31 10 06

Figure 2. General view of the garden

Responsibility and cooperation: The educational cooperation policy of the Conservatory and Botanical Garden Of the City of Geneva (CJB), Switzerland, with southern-hemisphere countries

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Abstract

This presentation concerns the responsibility of botanical gardens in the northern hemisphere to cooperate with those in the southern hemisphere in their geographical field of floristic expertise. The objective of these projects is to improve the ability of southern-hemisphere botanical gardens to respond to the wholesale loss of natural and cultural diversity. Through programmes such as those in Paraguay and Senegal that the Botanical Conservatory and Garden of the City of Geneva has been running for more than 10 years, this objective is reached through a policy of education in applied ethnobotany and conservation. These programmes have set up an Environmental Education Centre and a themed ethnobotanical garden and developed an information and educational policy in partnership with the municipalities and the players in the local civil society.

French abstract

La présentation abordera la responsabilité des jardins botaniques du Nord à coopérer avec ceux du Sud dans leur domaine géographique de compétences floristiques. L'objectif de ces projets est d'améliorer la capacité de ces derniers à répondre à la perte massive de diversité naturelle et culturelle. A l'exemple des programmes menés depuis plus de 10 ans par les Conservatoire et Jardin botaniques de la Ville de Genève au Paraguay et au Sénégal, cet objectif est atteint par une politique d'éducation à l'ethnobotanique appliquée et à la conservation. Un Centre d'éducation environnementale, un jardin ethnobotanique thématique sont créés. Une politique informative et pédagogique est développée en partenariat avec les municipalités et les acteurs de la société civile locale.

Introduction

The Conservatory and Botanical Garden of the City of Geneva (CJB) is an institution with a great international reputation, and is also the living museum of the City of Geneva. Like most established botanical gardens, it is in the northern hemisphere, outside the belt of tropical biodiversity that encircles the planet. Unfortunately, there is no correlation between the geographical distribution of botanical gardens around the world and the areas of maximum natural and cultural biodiversities.

This situation stems from the history of botanical gardens and above all the extremely unfavourable economic situation in the countries that are home to the tropical forests, which contain 80% of the world's biodiversity.

One of the crucial missions of botanical gardens at the beginning of the 21st century is to try to check the dramatic loss of plant biodiversity that is occurring. The objectives set by the Global Strategy for Plant Conservation (GSPC) have not been achieved in this International Year of Biodiversity (2010) and are going to have to be postponed for at least ten years. This fact must be realised, despite the considerable sums of money being devoted to the protection and conservation of environments and species. Although it appears that the overall number of species living on Earth has been underestimated, we are continuing to lose numerous species daily, in particular in the intertropical zone.

Even though teams of scientists and botanical gardeners at the CJB in Geneva and many other botanical research institutions around the world are working to record, classify, conserve, reproduce and cultivate these plant species, and even though our specialist educators, writers, botanical editors, and database administrators are informing, educating and publishing papers devoted to this conservation effort, the loss of natural and cultural phytodiversity appears to be rather inexorable.

The CJB's cooperation policy

For more than 10 years the CJB has been attempting in a modest way to provide practical solutions to the very negative state of affairs described above, through a concerted cooperative policy of applied ethnobotany and targeted environmental education. This has taken the form of educational micro-projects set up in those tropical areas where we have floristic expertise (mainly South America and Africa). These projects, based on principles of sustainable development, must fulfil certain conditions and prerequisites if they are to be implemented by us:

- the CJB must have floristic expertise in the geographical area concerned;
- the project must be a local request coming from a municipality, government organisation or local association or club;
- it must be politically and academically approved locally;
- it must involve funding of less than $30,000 per year, if possible shared with a local body or complemented by it;
- it must include the setting up of an environmental education centre (EEC) in the form of some kind of garden open to the public (and if possible frequented) near a large town or city;
- ethnobotanical gardens must be created next to the above EEC;
- the project must be scientifically inspected and approved by a competent local academic authority and/or the CJB;
- a clear timetable must be established for implementation of the three S's (self-determination, self-management and self-sufficiency).

These projects are supported financially through the CJB by the City of Geneva's Solidarity Fund and are encouraged to seek additional funding locally (local municipalities and universities, local associations and clubs, the Swiss Red Cross local office, etc.).

The CJB has developed educational cooperation projects in the following countries:

- in Bolivia, the Kusillo Ethnobotanical Gardens in La Paz, which presented the useful plants and techniques of this Andean country in an interactive museum form in relation to the relevant craft industry and fair trade. This extraordinary educational experiment was unfortunately stopped in its successful tracks by changes in the local political situation;
- in Brazil, the Municipality of Sao Paulo's project for Community Gardens of useful plants on the edge of the Api-Capivari-Monos Nature Reserve, which suffered the same political fate;
- again in Brazil, the Ethnobotanical and Veterinary Gardens at the University of Patos in the state of Paraìba (north-eastern Brazil) are however flourishing. They are part of a project that the CJB continues to support, which aims to promote the traditional knowledge of the veterinary plants of the Caatinga (a type of vegetation typical of north-eastern Brazil). In addition to the gardens, a herbarium and library established by us support the ethno-social element of this conservation project designed to reclaim the local phytoveterinary heritage and its applications;

- in the Ivory Coast, an educational programme about the protection and conservation of Adiopodoumé Forest has been developed, next to the Swiss Centre for Scientific Research. An educational manual of botanical conservation, self-managed by the inhabitants of the villages around the forest in question, has been published. It is very popular in the Ivory Coast and has won prizes in this French-speaking West African country. The manual is applicable to the entire coastal area in this part of Africa;
- in Burkina Faso, in the inner suburbs of Ouagadougou, logistical and methodological support has been given to the Bangr' Weogoo Park Educational Centre, which every day provides several visiting school groups with an introduction to environmental education (EE) in the Sahel.

In addition to these examples, we have been running two "pilot" projects, the development and objectives of which are described below.

The AEPY project in Asunción (Paraguay)

This project, the CJB's longest standing in terms of cooperation with a southern-hemisphere country, is based on the widespread traditional use of medicinal plants in Paraguayan popular culture. Used both for sweetening and flavouring maté and for treating medical complaints, medicinal plants are omnipresent in the markets of this South American country. The trade provides a living for many families of gatherers, peasant farmers, street sellers and market traders. A number of laboratories and dispensaries export these plants, packaged to varying degrees, mainly to Argentina and Brazil. Paraguay is also one of the countries that have seen the highest levels of deforestation in the world in the last fifty years, largely due to forest clearance for timber and coal mining and more recently for growing GM cotton and soya, and pasture.

An ethnobotanical study carried out in the markets of Asunción in 1996 by the first author of this paper showed the richness of the local phytomedicinal heritage, with more than 700 species being used in the country, 70% of which were gathered in the region. In parallel, this ethnobotanical research was used to develop an approach and a methodology for applying ethnobotany to environmental education within the framework of the Asunción Botanical Garden. This programme is governed by an agreement between the municipalities of Geneva and Asunción. It has resulted in:

- the establishment of a Medicinal Garden containing a collection of more than 500 species and varieties used in Paraguay, making it one of the finest medicinal plant collections in South America;
- the publication of numerous works, educational sheets, themed papers, brochures and books;
- themed workshops, tours, classes and courses being offered to the general public;
- the publication of videos, programmes broadcast on local television and radio stations, themed supplements in daily newspapers and exhibitions both in the region (4) and abroad ("Cap au Sud" in 2002 in Geneva);
- the creation of secondary collections (National University of Asunción, Patino Aregua Ethnobotanical Gardens, community gardens, cottage gardens (5), etc.);
- a collaboration, sponsored by the Swiss Red Cross (SRC) with 29 peasant-farmer associations concerning cultivation, domestication and reforestation with Paraguayan medicinal species, including the production of an integrated production manual;
- the creation of *Campotech*, at the request of the peasant-farmer associations and again in collaboration with the SRC. This is a post-school-age technical education establishment that promotes and helps create professional opportunities for adolescents by connecting them with the community and trying to prevent large-scale migration to towns and cities;
- the production in 2009 of a book, the reference work on the medicinal plants used in Paraguay and widely distributed free of charge among groups frequenting the markets (wholesalers, retailers and gatherers) and peasant farmers. This work

contains original taxonomic, ethnobotanical, phytopharmaceutical and horticultural information. It is based on the living collection at the Asunción Botanical Garden and provides a host of information on the toxicity and conservation of the species in question.

This project is currently in the process of becoming self-sufficient through a new independent intermediary association called AEPY (Asociación Ethnobotanica Paraguaya) that has been set up in Paraguay and is championing and promoting the project while seeking funding.

The CEEH project (Hann Environmental Education Centre) in Dakar, Senegal

This Senegalese project is based on the same fundamental principles as the AEPY project in Paraguay.
It is made up of several sections and an extension project:

- the Education Centre itself, which is housed in the restored former Aquarium in Hann Park, the only green space in the entire Dakar conurbation, which is expanding fast. This centre receives numerous school groups and provides an introduction into environmental topics, continuous professional development training for teachers (eco-education) and summer camps;
- the Ethnobotanical Garden, which is home to a very fine collection of Senegalese useful plants, with explanations and classified by use;
- the publication of educational sheets, an environmental education manual for the pre-Sahelian zone (co-published in the CJB's educational series) and various documents published in collaboration with the Ministries concerned (Education and Environment), including a short work for the "Tiny Tots' Hut", a decentralised visitor facility present in the villages;
- the setting up of programmes for the communities in the municipality of Hann (waste management, composting, "family kitchen gardens", environmental music festival, etc.);
- the extension project itself, which involves establishing a second Environmental Education Centre in St. Louis in northern Senegal, at the former INRA (National Agronomic Research Institute) acclimatisation garden.

Responsibility and conservation (Conclusion)

These two examples clearly demonstrate our readiness to work in the southern hemisphere using both our floristic and ethnobotanical expertise and that of our partners to develop together socioeducational micro-projects that meet the requirements of quality sustainable development.

In our opinion, the botanical gardens in the developed countries of Europe, North America and Asia have an obvious – and often post-colonial – responsibility to collaborate and work to restore and use the gardens of the intertropical belt in developing countries. This initial collaboration should be followed by cooperation to establish a concerted ethnobotanical policy applied to environmental education.

The methodology is the same for all our projects:

1. Compilation and validation of ethnobotanical data stemming from traditional learning;
2. Promotion of the heritage value of this popular knowledge and reinforcing the self-esteem of the local populations, in particular in the disadvantaged classes;
3. Raising of awareness of and engendering a process of responsibility with respect to the conservation of plant species;
4. Production of suitable teaching materials, construction of an ad-hoc mediation programme.

In the light of our accumulated experience, projects that are developing positively, the socioeducational impact locally and the impact in terms of environmental policy at regional level, we can surely and definitely encourage and recommend that other botanical gardens form this type of partnership with our colleagues in the southern hemisphere.

The combination of these projects and their promotion by Botanic Gardens Conservation International through the network of their different structures, in addition to providing a form of recognition, would give a clear signal that the federating authority is committed to these north-south collaborations. We sincerely hope so.

Figures

AEPY Medicinal Gardens, Asuncion, PY

Ethnobotanical Gardens, Hann Dakar, Senegal

Veterinary stall, Patos Market, Brazil

Molecular studies on *ex-situ* conservation of rare and endangered Polish plants

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Abstract

Implementing Target 8 of the Global Strategy for Plant Conservation (GSPC) in 24 Polish botanical gardens, 275 taxa out of 446 National Red List threatened plant species (61,7%) are available as living plant collections or seed bank holdings. The effectiveness of genetic diversity conservation in *ex situ* collections should be monitored. We have chosen three endangered species in Poland and endemic or relict species to compare the genetic structure of *ex situ* and *in situ* populations using microsatellite-based DNA markers (ISSR and SAMPL). The particular aims of our studies were to examine the level of genetic variation between an artificial *(ex situ*) and its source *(in situ*) population and to analyze the efficiency of *ex situ* conservation of living plants in addressing issues to conserve genetic variation at the species level. The results of a comparative molecular analysis of investigated species showed significant changes in genetic diversity between populations from botanical gardens and natural localities. It was concluded that the *ex situ* collections just partially represent the primary genetic variation, however more than 70% of total gene pool of each species was captured in *ex situ* populations.

Keywords

Botanical garden, conservation genetics, genetic diversity, ISSR, living collections, SAMPL

Introduction

To achieve the GSPC Targets 8 and 9, the Botanical Garden of the Polish Academy of Sciences in Warsaw has gathered data based on gene-level diversity of *ex situ* conserved collections of three endangered in Poland and endemic or relict species to compare the genetic structure of artificial versus source populations using microsatellite-based DNA markers (ISSR and SAMPL).

Cochlearia polonica (Brassicaceae) is a narrow endemic Polish scurvy-grass extinct in its primary locality known only from one transplanted population in southern Poland (Fig. 1) (Kwiatkowska 2001). Once classified as “extinct in the wild” (EW) it was listed as one of the species of the highest conservation concern in several conservation catalogues (global IUCN, Annex II and IV of the EU Habitat Directive, Bern Convention) (Kaźmierczakowa, 2004). In the late 1980s five individuals from a transplanted population were used to establish the artificial site in the Botanical Garden of the Polish Academy of Sciences in Warsaw.

Erysimum pieninicum (Zapał.) Pawł. (Brassicaceae) (Pieniny Mts. wallflower) is a narrow Polish endemic species with distribution restricted to Polish part of Pieniny Mountains (Pawłowski 1946). Given its vulnerable status, *E. pieninicum* has been considered as a priority species for conservation in the Pieniny NP and listed in the Annex II and IV of the EU Habitat Directive and covered by the Bern Convention (Korzeniak, 2001). Throughout its small geographic range, *E. pieninicum* occurs as discrete populations varying in size from 10 to 1,000 plants (Fig.1.) (Vončina and Wróbel, 2004). The artificial population was introduced to the Botanical Garden of the PAS in Warsaw in 2001.

Dendranthema zawadzkii (Herbich) Tzvelev *(*Asteraceae*)* (Zawadzki’s chrysanthemum) is a very rare plant because its pleistocene relict sites in Poland are separated by a significant disjunction from the compact range, which is Eurosiberian with the centre in central and east Siberia (Zarzycki, 1976). This species, protected by law in Poland and in Europe by the Bern Convention refers to a few described from few populations ranging in size (from 12 to 100 individuals) in the Pieniny Mts. (Fig.1), two of which were sampled to create an *ex-situ* population in the Botanical Garden of the PAS in 2001.

In recent years empirical studies have employed the comparison of both types of population structure using molecular markers in order to further understand the genetic changes that occurred during the period of preservation in the botanical garden. The particular aims of our studies were to examine the level of genetic variation between an artificial *(ex situ*) and the source *(in situ*) populations and to analyze the efficiency of the *ex situ* conservation method in addressing issues to conserve species genetic variation

Materials and methods

Seven populations of three species were studied (*in situ* and *ex situ* for each species). All of the individuals were sampled from *ex situ* conserved populations of three analyzed species (Tab.1.). Samples from *in situ* populations were randomly taken from flowering plants. About 3–4g of fresh leaves per plant were collected and stored in zip–lock plastic bags with silica gel until thorougly dried. Total genomic DNA was extracted from the dried tissue following the protocol of A&A GenomicMiniAXPLANT kit (A&A Biotechnology).

ISSR (*Inter-Simple Sequence Repeat)* reactions were carried out in a volume of 10 µl containing 1.0 U of HotStart Taq Polymerase (Polgen), 1 x PCR buffer, 0.25 mM of each dNTP, 0.25 mM $MgCl_2$, 20 pM of a single ISSR primer and 15 ng of template DNA. Amplifications were performed in a Biometra ThermalCycler (TProfessional). Electrophoretic separation of the PCR products was done on an 1,5% agarose gel at 100 V for 3 hrs.

SAMPL (*Simple Amplified Microsatellite Polymorphic Loci)* profiles were generated following established procedures for SAMLP analysis (Spataro, 2007) with an amount of 125 ng of genomic DNA used in restriction. Preselective products underwent the selective amplification with a previous screening of 40 fluorescence-labelled primer combinations. Those revealing the clearest banding patterns were choosen. Selective amplified products were analyzed on 6% denaturing polyacrylamide gels. Electrophoresis was performed at a constant power of 50 W for 4 h on a Dual Dedicated Height Nucleic Acid Sequencer (C.B.S. Scientific Co.)

Electrophoresed PCR products were visualized using the ImageQuant 400 Imager and TyphoonTrio+ (GE Healthcare). SAMPL and ISSR profiles were scored for the presence or absence of a band in the 100 – 500 bp (SAMPL) and 100 – 1200 bp (ISSR) range for all individuals and recorded in a binary data matrix.

Data analysis

Genetic diversity for each population was estimated by a percentage of polymorphic bands (PPB), and Nei's gene diversity index using POPGENE version 1.31 (Yeh and Yang, 1999). The level of population differentiation between *ex situ* and *in situ* population was estimated using the coefficient of Nei's gene differentiation (G_{st}). The primary binary data were applied to obtain a Principal Coordinates Analysis (PCO) plot to visually represent the relative degree of genetic similarity among individuals and populations. PCO analysis was performed using an NTSYS package version 2.21c (Rohlf, 2006).

Results and Discussion

Having the facilities and expertise for growing plants means that botanic gardens should be in an ideal position to monitor plants in their collections and undertake experiments to answer questions relating to conservation. The study of living collections, especially of species that are threatened with extinction, has a long tradition in botanic gardens and has contributed significantly to the body of knowledge on threatened species and their conservation (Donaldson, 2009).

The main aim of this study was to investigate the extent of genetic variation conserved in *ex situ* populations of three endangered plant species in Poland and endemic or relict plant species using two types of molecular markers. There were some differences between the level of gene diversity and genetic differentiation indices obtained with ISSR and SAMPL markers, because both methods generate differences from different part of the genome. The results in terms of the indices of genetic diversity and genetic differentiation however were consistent for both types of molecular marker systems used in this study (Table 1).

The results of a comparative molecular analysis of *ex situ* and *in situ* populations showed significant changes in the genetic diversity level. The garden populations exhibited lower genetic diversity in comparison to their source populations for all the analyzed species (Table 1).

The level of genetic differentiation indicated striking differences between plants conserved in the garden and their source populations (Table 1). When observed on PCO plot, the individuals coming from both types of conditions formed two separated groups (Figure 2).

All of the above results suggested differences in genetic composition of the analyzed populations and implied homogenization of genetic structure of *ex situ* conserved population. A possible explanation for these findings is that the differences in genetic diversity and structure are related to founder effect and genetic changes occurring during the period through which the *ex situ* collections have passed during their time of preservation in the botanical garden.

The *ex situ* preservation resulted in a decrease of the species genetic diversity, implying that artificial populations only partly represent the primary genetic variability found *in situ* for analyzed species. It is of note that the garden's populations preserved about 50% of the gene pool represented by bands with moderate frequency (Table 2). However, the amount of genetic variation conserved in *ex situ* populations seems to be enough to implement target No. 9 of GSPC and to sustain long-term survival.

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Table 1. Genetic diversity and genetic differentiation indices within the *ex situ* and *in situ* populations

species	**population**	**No. of individuals**	**Polymorphic bands (%)**		**Nei's gene diversity**		**Genetic differentiation**	
			ISSR	SAMPL	ISSR	ISSR	ISSR	SAMPL
Cochlearia polonica	*In situ*	85 70	104 (44.2)	127 (51.2)	0.1558	0.1674	0.2015	0.1286
	Ex situ	26 24	68 (28.9)	65 (26.2)	0.1007	0.0761		
Erysimum pieninicum	*In situ*	47	65 (36.1)	125 (50.6)	0.0921	0.2044	0.1044	0.0702
	Ex situ	33	34 (18.8)	112 (45.3)	0.0508	0.1656		
Dendranthema zawadzkii	*In situ*	32	196 (81.3)	143 (42.8)	0.2840	0.1894	0.3654	0.1263
	Ex situ	12	45 (18.6)	101 (42.8)	0.0461	0.1214		

Table 2. The amount of genetic variation conserved in *ex-situ* populations of analyzed species

		N p>0.05 (p=1)		**Gd (%)**		**Gd (%) >0.05**		**1>Gd >0.05 (%)**	
		ISSR	SAMPL	ISSR	SAMPL	ISSR	SAMPL	ISSR	SAMPL
Cochlearia polonica	*Ex situ*	176 (131)	211 (111)	73.7	89.4	74.8	96.7	65.7	50.4
	In situ	235 (31)	218 (85)						
Erysimum pieninicum	*Ex situ*	155 (125)	235 (131)	90.9	98.8	93.4	95.9	57.7	85.3
	In situ	166 (114)	245 (123)						
Dendranthema zawadzkii	*Ex situ*	176 (131)	211 (111)	73.7	89.4	74.8	96.7	22.1	54.6
	In situ	235 (31)	218 (85)						

N p>0.05 number of amplified bands with a frequency >0.05 (band with frequency p=1)
Gd (%) percentage of genetic variation conserved in each population

Gd (%) >0.05 percentage of genetic variation conserved in each population - for bands with p>0.05
1>Gd (%) >0.05 percentage of genetic variation conserved in each population - for bands with 1>p>0.05

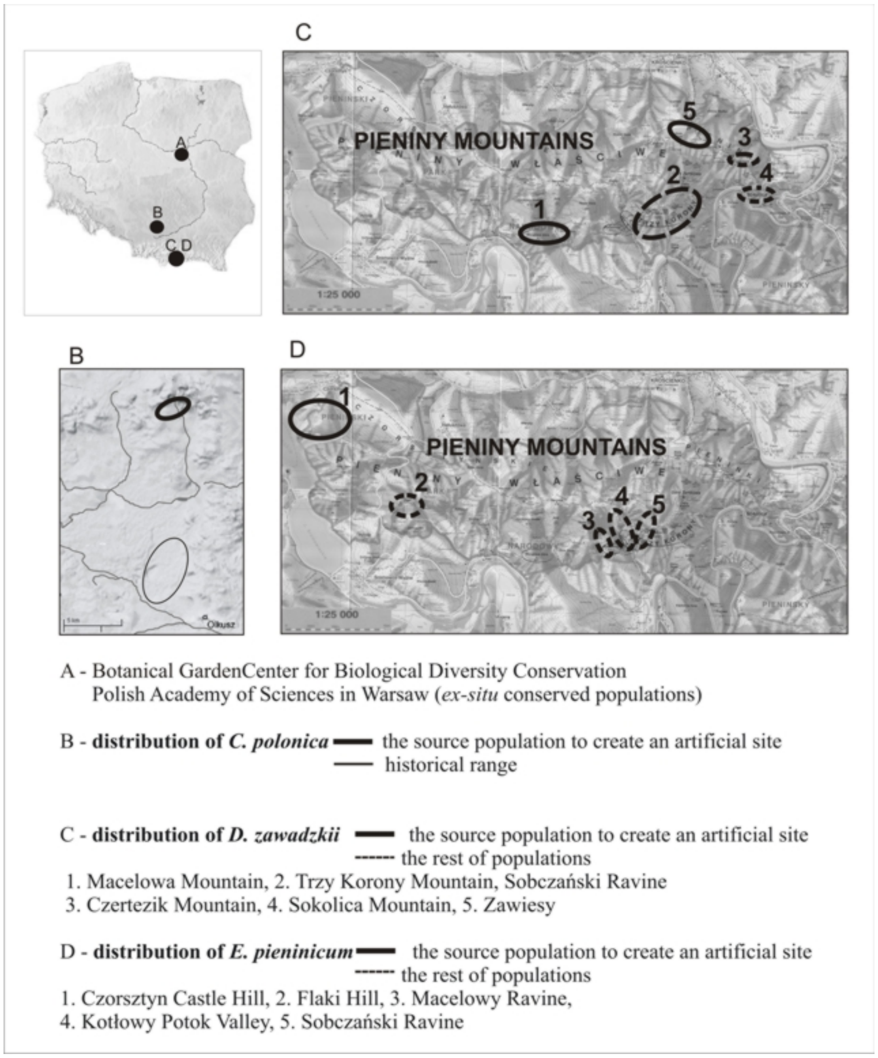

Fig.1. Origin and geographic information about the collection sites of the examined populations

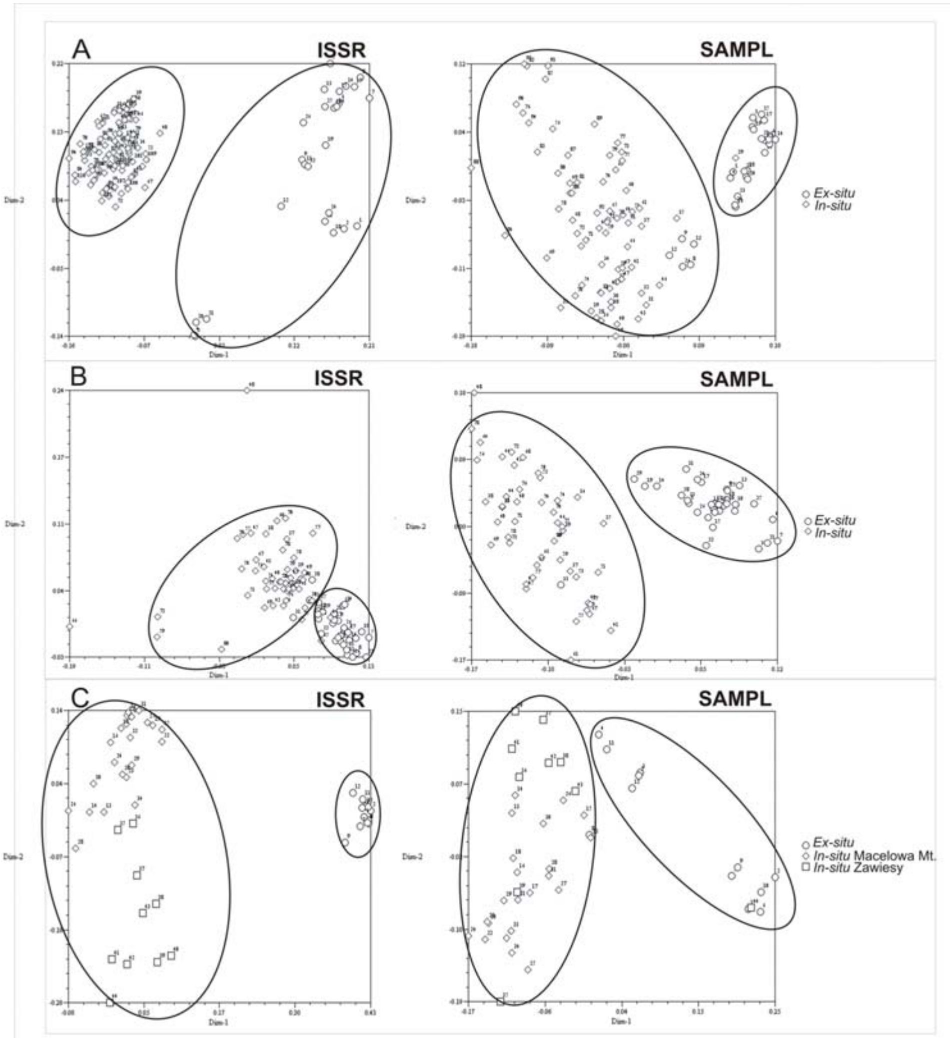

Fig.2. Principle coordinate analysis plot of individuals sampled based on ISSR and SAMPL data (A. *C. polonica* B. *E. pieninicum* C. *D. zawadzkii*)

Peperomia Reference Collection: an *ex situ* living plant collection for scientific research

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Abstract

Research projects on several plant groups in the Ghent University Botanical Garden are largely based on living collections. Among these is the largest living *ex situ* collection of *Peperomia* (Piperaceae) in the world. The strategy of building such a major scientific collection has proved very advantageous and of unique value, creating the opportunity to follow plants throughout their life cycle and to collect fresh material for immediate morphological, anatomical and molecular studies. An overview of the setup, maintenance, workability and accessibility of a plant collection used in high-standard scientific research is given, based on our experiences with *Peperomia*.

Key words: access and benefit sharing, collection and export permit, *ex situ* collection, IPEN, *Peperomia*, PlantSearch, scientific collection, Seed List

Introduction

The Botanical Garden of Ghent University, with more than 10,000 species spread over 2.75 hectares, was founded in 1797 and has been at its present location since 1902. The director, the curator and nine gardeners are responsible for management and maintenance. The tasks of the garden lie in three main areas: 1) education, 2) research and 3) services. This paper focuses on the research side.

Research projects in several plant groups, e.g. *Peperomia* (Piperaceae), Cyperaceae, Hydrangeaceae, *Epimedium* (Berberidaceae), are largely based on our living collections. The presence of a living *ex situ Peperomia* collection is invaluable for our research in this group (e.g. Wanke *et al.*, 2006; Samain, 2008; Horner *et al.*, 2009; Samain *et al.*, 2009). Studying living plants is essential, as many characteristics are no longer visible on herbarium specimens. The succulent nature of many *Peperomia* species often causes specimens to shrivel, rather than to dry well. To date, our living *Peperomia* collection consists of approximately 2,000 specimens of 700 species (nearly half the total number) from all continents where the genus occurs (Africa, America, Asia and Australia), although with a strong emphasis on America. It is also the most representative *ex situ* collection as it contains species from all currently recognized subgenera (unpublished data).

Peperomia (Piperaceae) consists of approximately 1,600 species and is one of the most species-rich angiosperm genera (Samain *et al.*, 2009). The genus has a pantropical distribution with its highest diversity in the Neotropics. Representatives grow in virtually any habitat between sea level and 4,600 m altitude, resulting in mega-diverse morphological adaptations. Most of this variation lies within vegetative characteristics, inflorescence architecture and fruit morphology, whereas the flowers are very homogeneous throughout the genus.

Our research on *Peperomia* includes a wide range of studies, such as systematics, taxonomy, contributions to floras, checklists, phylogenies, biogeography, character and growth form evolution, anatomy, biomechanics, speciation processes, genetic diversity, etc. Sufficient material was available in the Botanical Garden for research and exploration of the genus (Samain, 2008). Once we started to focus on particular monophyletic clades, it became necessary to collect in the field as these clades were underrepresented in living collections.

Setting up the scientific collection

Extending an existing collection or starting from scratch?

The plan for collecting and studying a genus or a family usually grows organically and/or historically. Hence, when starting a new project on a particular plant group, a living collection is often already available. However, the scientific usefulness of existing collections might be insufficient. Each plant should be labelled with a unique accession number, so its history can be traced, ideally from its collection in the wild to its current position in the garden. For most high-quality research a well-documented field locality is important, but this is often impossible to retrieve with older collections.

The requirements for high-quality research can be fulfilled more easily when a collection is started from scratch, as the researcher can personally determine what is needed for the work and will usually go into the field themselves to find and gather the necessary data. The success of setting up or expanding a collection within the research time frame has to be ensured. This is usually without problems for herbaceous plants with a relatively fast life cycle, but might be problematic for woody plants that take several years from seed or cutting to produce flowers and fruits. In the latter case, a collection should already have existed for several years in order to be useful for scientific research. It is also important that garden curators focus on setting up a limited number of groups to specialize in, rather than acquire new accessions randomly.

Obtaining plants from other gardens

A collection can be enlarged through exchange with other Botanical Gardens in several ways: 1) via Seed Lists (*Index Seminum*), allowing for specific search and selection, 2) via the PlantSearch database of Botanic Gardens Conservation International (BGCI), very useful for searching (rare) botanic garden accessions around the world, 3) during a personal visit to botanical gardens to obtain cuttings, ensuring more direct contact and more control of identification. Again, it is essential to give each accession upon its arrival a unique number which remains linked to the accession number of the original garden or the IPEN (International Plant Exchange Network) number. Membership of IPEN ensures that CBD rules are respected and that exchange of material is only aimed at conserving biodiversity and research and education. Plants can also be obtained via private collectors, but here only material that has been legally acquired can be accepted.

Collecting plants in the field

Field trips ideally are prepared based on locality data from 1) (digitalized) herbarium specimens, 2) literature, and 3) local botanists. It is challenging to keep plants alive in the field but our experience is that herbaceous plants at least can be treated as follows: 1) tape the roots together with humid mosses, forming a temporary flowerpot, 2) write the collection number on the tape and place the plants in a plastic box you can close during the day and open during the night, 3) return approximately every two weeks to a 'base camp' where someone can sprinkle your plants during your absence, and 4) place the temporary flower pots in pure moist TerraCottem®. At the end of the expedition, remove tape and mosses to prevent rotting during the return transport and place the plants in paper bags labelled with the collection number. Rhizomatous and tuberous plants usually do not need such treatment, but here also attention has to be paid to avoid rot and/or fungal diseases.

It is important also that local scientists, students and inhabitants can benefit from the expedition. Identification of the plant group(s) of your interest in local herbaria should be checked and updated where possible. This is not only useful for these herbaria but also for your own field trip and research. Other benefits might include 1) covering of expenses and training of local students who assist you during the trip, 2) hiring a local botanist as guide but also allowing him/her to spend some time collecting his/her own group, 3) giving local inhabitants information and a fee when they guide you in their neighbourhood or territory, etc. With larger projects, it might be possible to invite local students and botanists to your home institute for a short or long stay, to enhance cooperation.

Setting up a legal living collection at a research institute outside the country of origin is not straightforward. The authorities in some countries do not allow export of living plants (or at least not from plants collected in the wild), and some countries do not even issue collection and/or export permits at all. Whatever the case, doing everything strictly according to the rules requires a huge administrative effort.

Although *ex situ* conservation preferably takes place in the country of origin, botanical gardens in tropical countries often suffer from a lack of financial support, poor infrastructure and/or the absence of trained staff members. Unfortunately, some permit-issuing authorities apply the Convention on Biological Diversity (CBD) protocol very strictly and do not give an export permit for living plants, even though there is an absence of the necessary infrastructure and financial means in the country of origin. An ideal intermediate solution is to provide duplicates of each plant collection for both the country of origin and the reference collection at the home institute, although this might involve collecting more individuals at each locality. Efforts have to be made to convince authorities to distinguish between collection and export of material for scientific purposes as opposed to commercial goals, and to encourage them to facilitate access to genetic resources for scientific and conservation studies.

Maintenance of the scientific collection

Databasing and digitalization

The unique accession number of every specimen is essential. The database of the collection/garden should allow for flexible transfer of uniformized data between botanical gardens. Ideally, this database includes for every accession at least country of origin, detailed locality, coordinates, altitude, collector + number, collection date, IPEN-code, and additionally should also allow for taxonomical updates. Old data should be checked, e.g. in seed lists or notes. An inventory should be made on a regular basis or continuously updated, taking note of dead plants, position, and number of specimens for each accession. In addition to the garden database, a database for specific scientific purposes might also be useful, including additional data or links to specimens with photos or high resolution scans.

Labelling and ordering

The label of every accession should be durable and the data should be written with a pencil or printed, as water-resistant pens often do not withstand permanently wet conditions. The label should at least mention: garden accession number, collection number (this reference is easier for the collector), up-to-date name and country of origin. This label should be kept together with the plant at all times. To avoid confusion during repotting, only one plant with its corresponding label should be removed from its pot at any one time. Additional coloured labels are useful to indicate ongoing work, e.g. sample has been taken for molecular work, important plant that should be checked daily, etc.

The ordering of the plants within the collection might engender a conflict of interests between researchers and gardeners – for example, whether it should be alphabetically, systematically according to their relationships, or practically according to their size or water requirements. In our *Peperomia* collection, most plants are arranged according to their relationships, with the exception of plants that need special care or are placed in other greenhouses because they favour different conditions. A walk list/inventory of all accessions with permanent greenhouse structures (paths, pillars) as reference points makes it straightforward to localize specific accessions within the collection.

Usability and workability of the scientific collection

Collecting material and herborization

Flowers, stems, leaves, etc. should be continuously collected in 70 per cent alcohol, Kew mix, etc., for ongoing or future (micro)morphological, anatomical and ontogenetic studies. For DNA isolation, 2–3 young leaves should be collected in a paper bag or tea bag placed inside a hermetically sealed bag with silica gel (preferably with colour change upon water saturation), or in liquid nitrogen for immediate processing in the lab. A herbarium specimen (ideally with all vegetative and generative parts) should be made as a voucher for scientific publications on morphology, anatomy and for deposition of sequences in databases, or simply for study by other researchers.

Accessibility for other researchers and projects

This topic has been discussed here from the viewpoint of the person setting up the collection. It is important to provide access to the collection for other researchers through online databases (e.g. uploading your data to PlantSearch of BGCI) or upon request, which might also result in new cooperations. The detailed field data of the accessions and scientific results can helpt to bring about involvement in conservation and reintroduction projects.

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Central Mexico native plant horticulture at the Cadereyta Regional Botanical Garden.

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Abstract

The Cadereyta Regional Botanical Garden has developed Central Mexican native plant horticulture as a mechanism for *in situ* and *ex situ* conservation of wild species. Reproduced species presently total more than 100 taxonomic entities; nearly 50 of these now have protocols for germination and development. 38 species are plants with survival difficulties and 6 are listed in the CITES appendix I. A propagation procedure has been developed that employs conventional and micropropagation techniques, with a production process that ensures plant quality via a series of controls. Over the last three years a project was completed to reproduce native trees and shrubs for mixed ecological and economic uses. Propagated woody species are used for forestry and restoration in vegetative communities. The benefits of this gained knowledge are shared with society by supplying plants to local government agencies in charge of environmental stewardship and also via formal training, through courses taught in local communities and at the university level.

Keywords

Central México, conservation, endangered species, key species, native plants, procedure, propagation, restoration.

Introduction

The Cadereyta Regional Botanical Garden is located in the municipality of Cadereyta de Montes, (X 416.68; Y 2, 287.80; 2074 msnm; UTM WG584) in the state of Querétaro, México. The site is on the road to the old Tovares Hacienda, no number (Camino a la antigua Hacienda de Tovares S/N). It is situated at an altitude of 2,046 metres above sea level, and occupies a surface area of approximately 15.33 hectares. The climate is temperate semiarid with summer rains; the average minimum temperature is 12º C with a maximum of 19.4º C, registering an average minimum precipitation of 309 mm, and a maximum of 798 mm. The vegetation is constituted by a xerophilic desert matorral (Sánchez & Sanaphre, 2009).

It was founded on the 25th April 1991. However, it wasn't until the year 2003 when, due to a site redesign, that the foundation for adequate functioning began to be laid.

One of the strategic lines has been the instrumentation, innovation, and strengthening of reproductive systems for native plants. Initially, efforts focused on the reproduction of endangered species. These results were presented at the 3rd Global Botanic Gardens Congress, organized in Wuhan, China, by Botanic Gardens Conservation International in 2007. During the last three years, besides ongoing propagation of threatened species, a project has been undertaken whose objectives centre on the reproduction of important woody species from various habitats, which finally, over the long term, will contribute to on-site conservation by way of rehabilitation and restoration of local vegetation, especially in the highly urbanized central part of the state of Querétaro.

This article presents a summary of the advances obtained in the past 3 years. For example, the greenhouse space has expanded to cover an area close to 1,500 square metres. Within these greenhouses we have strengthened an official Wild Plant Propagation Unit (Unidad de Propagación de Plantas Silvestres (UPPS)). This unit is capable of determining agronomic procedures, through which we have achieved the propagation of native trees and shrubs with ecological, economic, and social value, which in conjunction with the species previously in propagation, total more than 100 species of reproduced native plants. All of the above signifies an advance toward the accomplishment of national and international goals for plant conservation.

Method

A procedure has been perfected for the reproduction of native wild species of interest (Sánchez, 2008). The method consists of 2 sequences with 5 possible steps. The general procedure can be described as follows:

I. Basic Sequence: Consists of three steps in which seeds are sown without pre-germination treatment, and in the case of unsuccessful attempts, pre-germination treatment(s) are applied.

Step 1. Seeds sown without treatment,

Step 2. Seeds sown with pre-germination treatment(s),

Step 3. Seeds sown with experimental, controlled treatment(s) meant to improve the results obtained in the previous steps.

II. Alternative Sequence: This is a complementary route meant to establish reproductive protocols in species that, for reasons such as scarcity (or unavailability) of seeds or for low germination rates, require preferential management by way of asexual or vegetative reproduction. This is done in two ways:

Step 4. *In vitro* cultivation,

Step 5. Vegetative reproduction.

This procedure was applied to a group of 45 trees and shrubs from the central region of the state of Querétaro that are considered key species in the local vegetation. An objective was established in terms of reproductive efficiency, with the goal of obtaining a percentage of 60% or higher of specimens developed per lot of propagules, in 20 or more of the selected botanical species.

Results

Since the last Global Botanic Gardens Congress, as a result of the efforts of the artificial reproduction programmes of the Wild Plant Propagation Unit (UPPS), we have managed to reproduce an additional group of around 35 mostly woody species of key significance for their utility and conservation value.

The reproduced species, with respect to their obtained method of propagation, are shown in the table I.

The obtained results are exemplified in figure 1, which describes the case of two species: first, for *Acacia farnesiana* (L.) Willd., a woody pioneer of great importance in the regeneration of xerophilic matorral and the tropical deciduous forest of the Queretaran Bajío; and second, for *Cedrela dugesii* S. Watson, an endangered species which in the wild appears only in mature tropical deciduous forests. The first is reproduced by the sexual route (seed), and the second via *in vitro* regeneration (micropropagation).

The propagation procedure for native trees and shrubs of central México includes a method with standards and controls that allows us to understand what are random or causal variations. This information will be part of the content of a book next to be published as a result of this project (figure 1).

Conclusion

The Cadereyta Regional Botanical Garden's Wild Plant Propagation Unit (UPPS) has strengthened its work with regard to wild native plant horticulture in the State of Querétaro and Central Mexico. This has been accomplished by establishing procedures permitting the reproduction of, under greenhouse conditions, more than 100 species representing 18 important botanical families in ecological, economic, and social terms (table 2). The Queretaran species under propagation include 27 species catalogued as endangered, meaning almost 46% of the presumably threatened species in this federal entity of the Mexican Republic. 11 other endangered Mexican species have also been propagated. The technical procedures have been perfected by developing explicit protocols that allow a controlled reproductive process and to obtain specimens of quality. One out of every two species reproduced in the greenhouse now possess a formal cultivation protocol that establishes appropriate germination and management techniques under the prevailing conditions in the Wild Plant Propagation Unit (UPPS).

The results obtained are continually made available to Mexican society at various levels, via different means of outreach such as publications, courses and workshops, and plant sales at subsidized prices. Of particular value is the advice given and native plants supplied to various local government posts responsible for environmental protection in their areas. The work we have undertaken provides the foundation for the protection of threatened flora in the Central and Southern regions of Querétaro state, as well as for the rehabilitation and restoration of ecosystems in this geographic zone of the world, continually subject to unrelenting pressure from the number of human beings inhabiting the area.

Acknowledgments

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Table I. Reproduced species by family and propagation method.

Method	Step	Family	Specie
Basic sequence	*Step 1*	Agavaceae	*Yucca filifera* Chabaud
		Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth
		Bombacaceae	*Ceiba aesculifolia* (Kunth) Britten & Baker
		Burseraceae	*Bursera fagaroides* (Kunth) Engl.
		Cactaceae	*Ferocactus histrix* (DC.) G. E. Linds.
		Fabaceae	*Albizia occidentalis* Brandegee
			Lysiloma microphyllum Benth.
		Lamiaceae	*Salvia mexicana* L.
		Oleaceae	*Forestiera phillyreoides* (Benth.) Torr.
		Rubiaceae	*Randia thurberi* S. Watson
		Ruscaceae	*Dasylirion acrotrichum* (Schiede) Zucc.
		Ulmaceae	*Celtis pallida* Torr.
	Step 2	Fabaceae	*Acaciella angustissima* (Mill.) Kuntze
			Acacia farnesiana (L.) Willd.
			Acacia pennatula (Schltdl. & Cham.) Benth.
			Acacia schaffneri (S. Watson) F. J. Herm.
			Erythrina coralloides DC.
			Leucaena leucocephala (Lam.) de Wit.
			Eysenhardtia polystachya (Ortega) Sarg.
			Prosopis laevigata (Humb. & Bonpl. Ex Willd.) M. C. Johnst.
			Senna polyantha (Collad.) H. S. Irwin & Barneby
			Zapoteca formosa (Kunth) H. M. Hern.
		Cactaceae	*Mammillaria zephyranthoides* Scheidw.
			Myrtillocactus geometrizans (Mart. ex Pfeiff.) Console
		Convolvulaceae	*Ipomoea murucoides* Roem. & Schult.
		Rhamnaceae	*Colubrina greggii* S. Watson
		Sapindaceae	*Dodonaea viscosa* (L.) Jacq.
	Step 3	Ruscaceae	*Dasylirion acrotrichum* (Schiede) Zucc.
Alternative sequence	*Step 4*	Meliaceae	*Cedrela dugesii* S. Watson
		Cactaceae	*Mammillaria mathildae* Kraehenb. & Krainz
		Rhamnaceae	*Karwinskia humboldtiana* (Roem. & Schult.) Zucc.
		Rutaceae	*Ptelea trifoliata* L.
	Step 5	Cactaceae	*Opuntia elizondoana* E. Sánchez & Villaseñor
			Opuntia robusta H. L. Wendl.
			Pereskiopsis diguetii (F. A. C. Weber) Britton & Rose

Figure 1. Two examples of the data that will be shown in the book for each species.

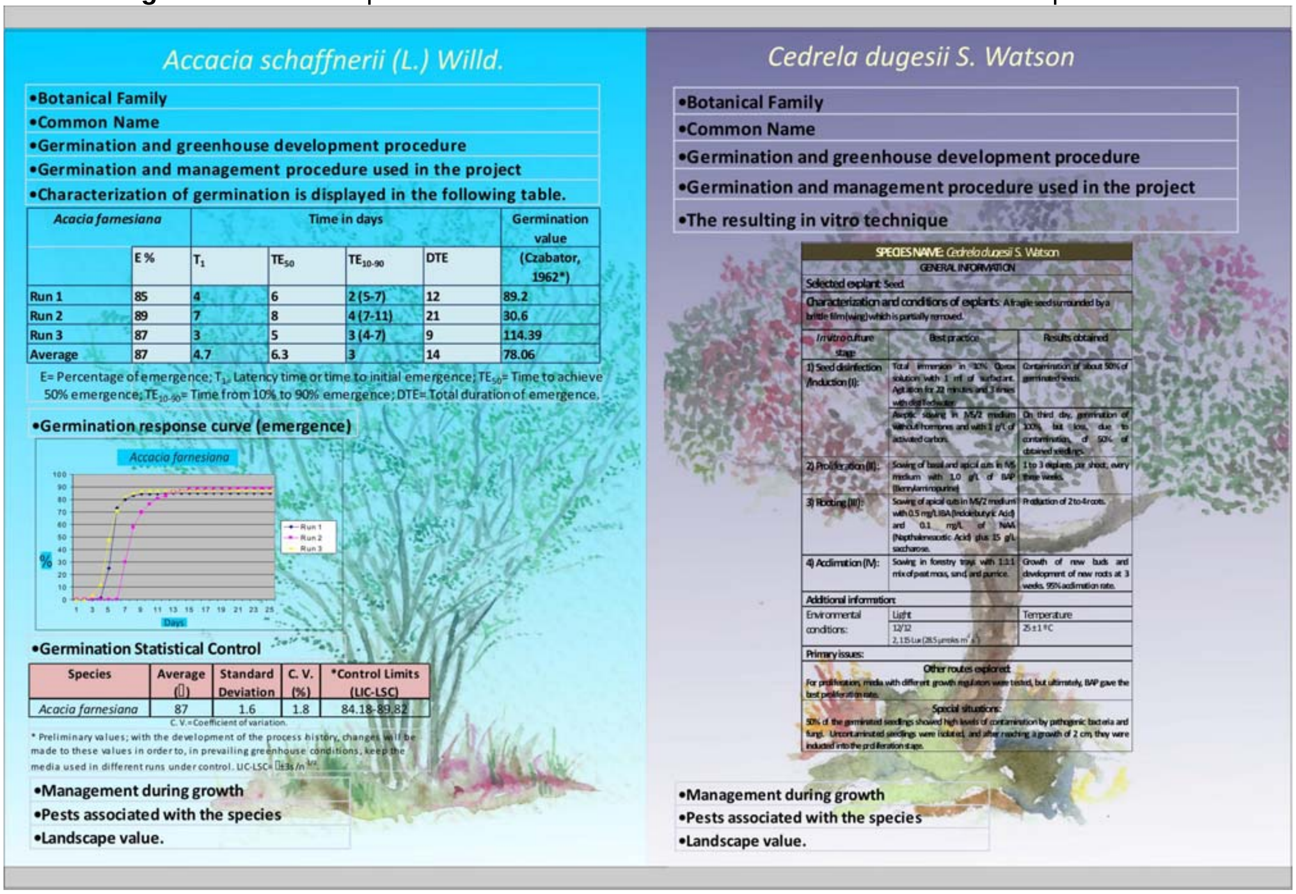

Table 2. Species that the Cadereyta Regional Botanical Garden reproduces in its Wild Plant Propagation Unit.

Family/number of species	Species in Mexican Conservation Status	Species in CITES Appendix I	Species with propagation Protocol
Agavaceae			
9	-	-	2
Apocynaceae			
1	-	-	0
Bignoniaceae			
1	-	-	1
Bombacaceae			
1	-	-	1
Burseraceae			
1	-	-	1
Cactaceae			
65	32	6	25
Convolvulaceae			
1	-	-	1
Euphorbiaceae			
1	-	-	-
Fabaceae			
12	2	-	12
Lamiaceae			
1	-	-	1
Meliaceae			
1	1	-	1
Oleaceae			
1	-	-	1
Rhamnaceae			
2	-	-	2
Rubiaceae			
1	-	-	1
Ruscaceae			
3	3	-	1
Rutaceae			
1	-	-	1
Sapindaceae			
1	-	-	1
Ulmaceae			
1	-	-	1
104 species	38	6	53

Building sustainable botanic gardens: Beyond architecture

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Gardens For Learning

Abstract

Too often in heritage settings the items that are used to engage with the site have a high environmental footprint both in miles and materials, not only in production and transportation, but also post-use. Plastics, once discarded, have enormous environmental consequences for marine life. Botanic gardens make public contemporary threats to plant-life through specimen display and education. However, loss of marine life is often 'unobserved'. In building our 'green theatres' we need to be conscious of the wider biomes in which humans exist and our impacts on them. Eighty percent of ocean pollutants originate on land and global use is in excess of 260 million tons of plastic per annum. By examining the smaller artefacts on site botanic gardens can add to the wider socio-environmental benefits of sustainable architecture, and through interpretation acknowledge the reasons why it is important to do so. This paper features a recent project in Glenveagh Castle Gardens, Donegal, Ireland in which local artists produced 40 'Nature Discovery Bags' made from hand-woven Donegal tweed, containing materials made from recycled paper, and garden plants to reduce the use of plastic, and celebrate the local landscape and associated artisan traditions.

Key Words

Culture, Nature, Education, Conservation, Ireland, Tweed, Plastic, Biomes.

Introduction

'The last fallen mahogany would lie perceptibly on the landscape, and the last black rhino would be obvious in its loneliness, but a marine species may disappear beneath the waves unobserved and the sea would seem to roll on the same as always'. (Ray in Derraik, 2002)

Botanic gardens publicise contemporary loss of plant-life through specimen display, interpretation and education. However, as Ray has stated loss of marine life is often 'unobserved'. In building our 'green theatres' we need to be conscious of the wider biomes in which humans exist and our detrimental impacts on them. Eighty percent of ocean pollutants originate on land and global plastic is in excess of 260 million tons per annum (Thompson *et al*, 2009). Of the 21 Albatross species alive in the world today, 19 are threatened or endangered. Modern plastic waste has replaced the ancient mariner's arrow (Coleridge, 1798). By examining the purchase, use and disposal of smaller artefacts botanic gardens can extend the wider socio-environmental benefits of sustainable architecture and, through interpretation, share the reasons why it is important to do so.

In his book 'Bringing the Biosphere Home' (2003) Thomashow states that: 'the biosphere will forever be an esoteric concept unless it receives the scientific, spiritual and artistic attention it deserves' (p.192). In developing the 'Nature Discovery Bags' at Glenveagh Castle Gardens we have considered how sense of place can be embodied in the educational tools we use to engage visitors with the gardens, and the physical and cultural landscape it is situated in.

The Nature Discovery Bags

Two local artists were commissioned to make the bags; one, Eddie Docherty to weave the Donegal tweed, the other, Clare O'Presco to design and make the bags. Natural dyes such as lichen, peat and seaweed produce the earthy tones of Donegal tweed. The colour palette is sourced from the landscape: granite grey, the shades of beech pebbles and the different warm tones found in bog-land grasses provide inspiration for these traditional textiles. As a hand-woven Donegal tweed supplier states on their website:

'From one generation to the next, the craft of hand weaving is still passed down in the cottages of Donegal. The looms are entirely hand operated and differ very little from 200 years ago. Thread by thread and inch by inch each weaver watches over his work taking two days to weave each piece. Donegal is a tapestry of the most breathtaking landscapes. Each piece of cloth reflects the colourful and wild landscape that has inspired the weavers for hundreds of years. Take the tweed between your thumb and forefinger. Close your eyes and imagine…the peat's ancient aroma, the roar of the Atlantic, and the click of the weaver's loom'
(Murphy, accessed June 3, 2010).

The contents of the 'Nature Discovery Bags' come from the garden or plant-based material; identification kits made from recycled handmade paper, viewfinders made from large leathery leaves, such as *Rhododendron spp*. In this way we have chosen materials that have a low carbon footprint and high biodegradability, contained in a bag that represents a local tradition. Forty 'Nature Discovery Bags' have been made and these are used with both visiting school groups and families.

Native vegetation

One of the rarest vegetation types in Ireland is indigenous oak woodland. The upper half of Glenveagh Castle Gardens is such a woodland, and the under-storey flora found within (varied rushes, ferns and mosses) integrates with the introduced plants. The gardeners at Glenveagh have made the native flora part of this garden rather than pushed it aside. Glenveagh Castle Gardens have unique value as an example of a long-term ecologically sustainable relationship between human culture and natural biodiversity. From the poorest wet peaty soil, in one of the most inhospitable locations in the region, a garden of great beauty has been established, supporting a team of craft gardeners and drawing visitors from many regions. The Nature and Outdoor Learning centre was set up in 2004 and seeks to foster an understanding of both natural and cultural heritage; the 'Nature Discovery Bags' are part of this important conservation mission.

Place-based conservation education

Ireland's biogeography is such that marine habitats are a significant part of her ecological portrait, thus a reduction in plastic pollution is a major concern in any biodiversity protection plan. Likewise, the ancient craft of Donegal tweed is under threat. In commissioning the bags, and reframing their contents, we have made a conscious decision to value both nature and culture in this unique landscape in the Derryveagh Mountains of Donegal, and importantly removed materials detrimental to marine biomes. A key part of the development process was to see the garden, and its wider environs, through the eyes of both gardeners and educators, and bring them together in mutual conversation to develop place-based conservation education. The story of the bag's construction and its relationship with the landscape is integral to the interpretation of this project. When children handle this bag they touch both the land itself and an important artisan history, as they walk through the gardens and look to the mountains, inspired by the natural palette they are witnessing.

Conclusion

This is a small action by one Irish garden. If we replicated this approach throughout the diverse community of botanic gardens represented by Botanic Gardens Conservation International we could create garden artefacts that symbolise both the nature, and culture of our individual garden settings. This development could generate planning models that examine changes in infrastructure and procurement informed by the need to protect both land and water-based biomes, while supporting sustainable artisan traditions. Perhaps then we might bring the biosphere home, both for our visitors and our own unique institutional identities.

Acknowledgements

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Conservation *ex situ* of bryophytes in the Botanic Garden of Tver State University (Middle part of European Russia)

Uliana Spirina

Abstract

The problem of growing endangered bryophytes *ex situ* is poorly studied. At the same time some phytocenotic groups of these plants are rather vulnerable. Experimental research leading to the conservation of bryophytes *ex situ* is urgent and important. In 1998 we started research on the introduction of bryophytes in the Botanic Garden of Tver State University. The objective of the research is to evaluate the potential of conservation of rare bryophytes *ex situ*. At present the collection numbers 27 species. Alongside rare and endangered bryophytes, we also study common species representing vulnerable ecological complexes. This approach enables us to single out suitable model species that have the same ecological preferences as the rare ones, and to choose the best cultivation techniques. Bryophytes of the basiphil-epiphytic complex, *calciphilous* species, ground mosses of dry pinewoods are quite stable in culture. It is possible to propagate and use such species in decorative plant growing to promote biodiversity conservation of wild populations *ex situ*.

Keywords

Bryophytes, conservation *ex situ*, introduction

The problem of growing endangered bryophytes *ex situ* in Russia is poorly studied. The need for special experimental research in this field is underestimated. Even the authors of Red Data Books attach no importance to the cultivation of rare bryophytes. At the same time some phytocenotic groups of these plants are rather vulnerable. For example, in many regions of Central Russia the basiphil-epiphytic complex are rapidly degrading as their components are very sensitive to acid air pollution. The species composition of bryophytes in mynerotrophic marshes has seriously deteriorated; the area of distribution of this group of plants is dwindling. Unfortunately in most cases this deterioration is connected with destruction of natural habitats or the global processes of antropic dynamics in the atmosphere and landscape. In the latter case it is difficult to suggest any effective strategy to mitigate the impact of the limiting factors. The vegetation cover is degrading so rapidly that in many cases it is impossible to control the negative dynamics of different components of the phytocenosises. In this connection, experimental research providing the opportunity of conserving rare and vulnerable species of bryophytes *ex situ* becomes very important.

The Tver region is situated in Middle Russia, near the border with North-Western Russia. The territory has one of the biggest hydrosystems in Europe. It is the starting point of the Volga river, West Dvina river, the rivers of the Neva basin, and the Dnieper (closer to the south border of the territory). The complex lake system of Holocene origin and high geomorphologic diversity make this region especially interesting. The region is situated at the intersection of important ecological zones and is notable for its diverse vegetation cover and rich and heterogeneous flora.

The upper reaches of the Volga are of special conservation importance. Within the upper reaches of the Volga river there are several unique nature complexes. The most important of them is Rzev-Staritsa Povolzhye. The relief of the area can be described as vast valley complexes with carbonate outcrops. The longest of the valleys (20 km) is called “The Gateway to Staritsa”. The vegetation cover of the steep riverbanks is as diverse as the relief of the area. Here you can find fragments of coniferous, small-leaved, and mixed forests with occasional broad-leaved trees, pine and birch forests with steppe elements, meadows with moss synusias, fragments of mineratrophic and oligotrophic marshes. The typical ecology and phytocoenosis of the region is determined by the rich biodiversity of plants and other living organisms in the area. The area boasts of the richest species composition compared to other areas of the Tver oblast.

Unfortunately much of the territory faces multiple pressures from agriculture (overgrazing, invasive weeds, agrochemical misuse), timber felling, quarrying and mining, industrial and domestic building and uncontrolled tourism. Most potentially serious of all are plans to increase exploitations of the Volga basin water resources. The territory has no protection status necessary for the implementation of effective conservation measures.

In 1998 Tver Botanic Garden started the research on introduction of bryophytes. The objective of the research is to evaluate the potential of conservation of rare species *ex situ*. The research was carried out on the basis of the bryophytes collection held at the garden. The collection materials were collected during floristic expeditions. At present the collection numbers 27 species (25 mosses and 2 liverworts). 8 bryophytes are listed in the Red Data Book of Tver Region. As far as we know all the bryophytes have never been introduced into culture in Russia before. Alongside with rare and endangered plants we study common species representing vulnerable ecological complexes. This approach enables us to single out suitable model species that have the same ecological preferences as the rare ones, and to choose the best cultivation techniques. At the moment the following plants groups are studied:

1) Bryophytes of the basiphil-epiphytic complex
2) Species of minerotrophic marshes
3) Calciphilous bryophytes
4) Plants that favour habitats with discontinuous vegetation
5) Ground mosses of forests and meadows.

The preliminary stage of the experiment was the study of the species in their natural habitats in order to define their ecological, phytocoenotical and biological characteristics. Next we defined the habitats allowing the collection of plants for the experiment without endangering the population of rare bryophytes. Alongside the experiments in the nursery and at the collection sites we conducted a number of field researches to study plant populations in the wild.

It is not always possible to use the experience of growing seed plants when dealing with bryophytes. It is necessary to take into account the specific features of their biological and life cycles, their dependence and confinement to local microhabitats. Special difficulties are caused by the fact that bryophytes have no root system. The plant material should be taken from natural habitats in large fragments or you should chose the substrate corresponding to the natural one in all its ecological characteristics. The plant material taken from the natural habitats is planted out in the experimental site into the soil or the substrate corresponding to the ecological preferences of the species. When planted into rich soil the accompanying plants become more vigorous and start to suppress the growth of rare vulnerable species. For this reason the substrate with mosses is isolated from the ground with the layer of sand. This technique of growing has proved its efficiency.

As a research result we created and applied an 18-point estimation scale of bryophytes introduction stability (Table 1). First, in this scale we take into account the possibility of artificial vegetative reproduction by tuft fragmentation. Success of this process essentially affects further introduction results because all material comes in a collection as living plants. Second, we deal with the change of a vital condition in culture. One of bryophytes features is their low competitive capacity in comparison with vascular plants. Therefore during cultivation special value is placed on an estimation of character of mutual relations between mosses and vascular plants and between different species of mosses. Next in our scale we consider the degree of cultivation laboriousness and ability for vegetative proliferation in accordance with similar criteria for vascular plants. Finally we notice sporophyte production possibility in culture. The complexity of phenological spectra studying for bryophytes lies in irregular sporophyte production in many (especially pleurocarpous) species. We have estimated the results of introduction for all 27 bryophytes species (Table 2).

The experiment has proved that some bryophytes of the basiphil-epiphyllous complex can be planted out on limestone substrate. For example, *Anomodon longifolius* grows well on limestone powder. It is possible to continue the experiment and try planting other species of this complex on carbonate substrate. Among the species of mineratrophic marshes, *Philonotis fontana* has proved to be more stable in culture, and to have broader ecological amplitude compared with other species of this complex. Such species as *Anomodon longifolius*, *A. viticulosus*, *Philonotis fontana*, *Encalypta streptocarpa* are quite stable in culture. The specimens of *E. streptocarpa* propagated in culture have been used in decorative planting. In the future it may be possible to propagate and use such species in decorative plant growing to promote biodiversity conservation of wild population *ex situ*.

In 2000 we started the development of living plant displays and exhibitions devoted to the unique natural complexes of the region. The displays imitate the most interesting fragments of these complexes. The display “the Gateway to Staritsa” demonstrates the most interesting fragments of the Volga Valley with the large outcrops of the maternal stratum. The flora of this region, as mentioned earlier, is very rich and heterogeneous and includes different botanical and ecological plant groups. The display contains 25 vascular species and 10 species of bryophytes taken from their natural populations. The display “the Flora of Minerotrophic Marshes” demonstrates the rare hygro- and hydrophytes taken from the different districts of the region (*Eleocharis quinqueflora, Herminium monorchis, Sonchus palustris, Juncus inflexus, Bryum schleicheri*). The display “Secretive Garden” is especially dedicated to vascular spore plants and bryophytes. Here visitors can get a closer acquaintance with plants that do not produce flowers and fruits, and can reflect upon the fact, that not everything in plants, as well as in the life of human beings, is ostentatious aimed at outshining and providing a visual impression.

In our work we place emphasis on regional biodiversity conservation research and educational work with different groups of the visitors as well. At the garden people can get acquainted with common species of bryophytes which are found in our territory, and also see vulnerable species. Special lessons on bryology are conducted for university students on the basis of the botanic garden bryophytes collection. Students study features of mosses morphology, life cycle, taxonomy and ecological varieties, and learn about the value of these plants in nature and human life.

The collection is going to be augmented and enriched with the species of other ecological groups with the aim of continuing the experiments. We are inviting other botanic gardens to join us in our research.

Table 1. Estimation scale of bryophytes introduction stability

Criteria	Estimation scale
Artificial vegetative reproduction	1 - badly transplanted species, in most cases perishes at this stage; 2 - well transplanted species (to 50 % of cases and more); 3 - always well transplanted species
Vital condition in culture	1 - condition in culture goes down; 2 - condition in culture is stable also does not change; 3 - condition in culture raises
Competitive capacity in culture	1 - accompanying plants substantially oppress the moss; 2 - character of competitive mutual relations is the same, as in natural communities; 3 - activity of the moss becomes more than in natural communities
Agrotechnics	1 - cultivation demands creation of a specific mode and the constant control of conditions; 2 - cultivation does not require creation of a specific mode, but the regular control of conditions is necessary; 3 - cultivation does not require use of special agrotechnics
Vegetative prolifiration	1 - vegetative proliferation is not observed; 2 - insignificant vegetative proliferation; 3 - active vegetative proliferation
Sporophyte production	1 - sporophytes are not formed in culture; 2 - sporophytes form sometimes in culture; 3 - sporophytes form regularly in culture
Total estimation	1-7 - species in culture is not steady; 8-13 - species in culture is steady; 14-18 - species in culture is very steady

Table 2. Bryophytes introduction stability

Species	Total estimation
Abietinella abietina (Hedw.) Fleisch.	14
Anomodon longifolius (Brid.) Hartm.	13
A. viticulosus (Hedw.) Hook. et Tayl.	15
Bryum schleicheri Schwaegr.	8
Campylium stellatum (Hedw.) C. Jens.	10
Cratoneuron filicinum (Hedw.) Spruce	14
Ditrichum flexicaule (Schwaegr.) Hampe	9
Drepanocladus aduncus (Hedw.) Warnst.	10
Encalypta streptocarpa Hedw.	13
Fissidens taxifolius Hedw.	9
Hylocomium splendens (Hedw.) B.S.G.	10
Limprichtia cossonii (Schimp.) Anderson, Crum & Buck	9
Paludella squarrosa (Hedw.) Brid.	9
Philonotis fontana (Hedw.) Brid.	12
Plagiochila porelloides (Torrey ex Nees) Shust.	9
Plagiomnium undulatum (Hedw.) T.Kop.	11
Pogonatum dentatum (Brid.) Brid.	16
Polytrichum strictum Brid.	16
Preissia quadrata (Scop.) Nees	12
Pseudocalliergon trifarium (Web. et Mohr) Loeske	9
Racomitrium canescens (Hedw.) Brid.	10
Rhytidiadelphus squarrosus (Hedw.) Warnst.	10
Rh. triquetrus (Hedw.) Warnst.	13
Scorpidium scorpioides (Hedw.) Limpr.	9
Seligeria campylopoda Kindb.	13
Thuidium philibertii Limpr.	12
Tomentypnum nitens (Hedw.) Loeske	9

Revealing the 'warts' to build a sustainable Australian National Botanic Gardens

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Abstract

Building sustainable botanic gardens requires more than retrofitting infrastructure and implementing efficient water and energy use measures. Sustainability principles must be intricately layered into the people, plants and place. Strategic planning is a key tool to provide a framework for this and to guide the implementation process. As the Australian National Botanic Gardens (ANBG) approaches its 40th birthday in October 2010, a series of evaluation and planning processes have resulted in the development of a strategic plan for guiding this institution towards becoming a sustainable botanic garden. Over the past 18 months, the ANBG has questioned its relevance, engaged with local and national stakeholders to examine its scientific, conservation and educational profile, explored its role as a national institution and evaluated its living collection. Such planning and review processes are confronting for any botanic garden, but this paper argues that reflection and in-depth review, in conjunction with effective planning tools, can help to ensure a relevant contemporary botanic garden.

Key words

Community consultation; national botanic garden; perceptions and expectations; strategic planning; sustainable botanic gardens

Introduction

Regardless of whether botanic gardens are managed by the public, private or charity sectors, there is mounting pressure for these institutions to demonstrate accountability, efficiency, effective programmes and their relevance to society. In fact, their sustainability depends on their capacity to do this. Building sustainable botanic gardens requires more than retrofitting infrastructure and implementing efficient water and energy use measures. Sustainability principles must be intricately layered into the people, plants and place.

The aim of this paper is to critically discuss the recent reflection, in-depth review and strategic planning processes undertaken at the Australian National Botanic Gardens to guide it to become a sustainable botanic garden. Arguably there is an ongoing challenge in applying sustainability principles to botanic gardens because these complex multidisciplinary institutions are unique because of their individual social, cultural, political and environmental contexts. Consequently, where the emphasis needs to be placed to create sustainable botanic gardens may vary depending on these contexts and therefore, needs to incorporate high level planning processes.

The context in which the ANBG operates

A brief examination of the political, environmental, social and cultural context in which the ANBG operates highlights its uniqueness and the challenges it faces to be a sustainable botanic garden.

Political context

The ANBG is based in Australia's capital city, Canberra, and is part of a portfolio of national institutions alongside the National Gallery of Australia, National Museum of

Australia, National Library and Australian War Memorial. The ANBG is the only national institution with a 'living collection' and the only botanic gardens in Australia with a national remit for its work.

The administration, management and control of the Australian National Botanic Gardens (ANBG) is the function of the Director of National Parks, a statutory authority responsible for the Australian Government's Commonwealth protected areas. Consequently, the ANBG is governed by a system primarily designed for national parks and reserve management.

Environmental context

> Australia is a vast island garden, full of contrasts and extremes. Many of our plants have learned to survive, thrive in and even become dependent upon harsh growing conditions and unbelievably impoverished soils. This is why we are able to experience almost every possible plant form in our great land. (Cundall, 2001:5).

Australia has a diverse landscape and is home to between 600,000 and 700,000 species. About 84% of plant species are endemic to Australia (Department of the Environment, Water, Heritage and the Arts 2008) and the 20,000 vascular plants represent 10% of the world's plant species (Chapman, 2005). The main threats to Australia's biodiversity include invasive species, the loss, fragmentation and degradation of habitat and climate change resulting in such conditions as prolonged drought (National Biodiversity Strategy Review Task Group (NBSRTG) 2009).

The local environmental context also needs consideration when building a sustainable national botanic gardens. Canberra has experienced hotter drier conditions in recent years. In 2006, for example, the annual rainfall was 360.6mm, in contrast to the long-term average of 622.8mm (Australian Bureau of Statistics (ABS) 2007). Furthermore, the number of days exceeding 30 degrees Celsius were 64, compared to a long-term average of 30 days (ibid).

Social and Cultural context

By 30 June 2004, three quarters of Australia's population (15.1 million people) lived in urban areas (areas with population greater than 100,000 people), mostly in the eight capital cities (Australian Bureau of Statistics, 2006). One of the concerns relating to an increasingly urban population is the unknown consequences of people spending less contact time with plants and animals (Maller *et al*. 2002 cited in Crilley and Price ,2006:1378).

An overview of the ANBG

The ANBG is a unique institution in the history of Australian botany. There are around 75,000 plants in its living collection, with around 80% of Australian plant families and more than 30% of the genera represented (Carmen, 2010). This collection has added value because it is a national living collection with known provenance. The institution's leading work in native plant horticulture provided a catalyst for the development of regional botanic gardens cultivating Australian plants throughout the country.

Despite its important history, assets and significance in its field, in more recent years the ANBG was suffering from insufficient resources. By 2008 it was in need of rejuvenation, both physically and financially. Factors including changing climate, rising costs (e.g. salaries, goods and services), lack of a clear vision and brand and a loss of some stakeholder support was challenging management and resulted in a decline in the status of the ANBG as a national institution. The timely need for a new strategic management plan, a legislative requirement, provided the ANBG Executive with an important opportunity to set a strong long term future for the ANBG guided by a holistic approach to strategic planning. As part of the process, careful consideration also needed to be given to what sustainability would mean for the ANBG (Table 1).

Approach to strategic planning

Within a competitive society, a strong conceptual framework providing a blueprint for actions to guide operations in terms of sustainability principles is necessary for any organisation (Smith, Bucklin and Associates Inc. 2000: 3), including botanic gardens. At the Australian National Botanic Gardens, the new strategic plan had to reflect the changing needs of Australian society and new challenges being faced socially, economically and environmentally, as well as outline priorities for strengthening the ANBG in its role as a national institution.

Stage 1 Starting with the 'big picture' - setting the future direction of the ANBG

a) In December 2008, input was sought from a panel of national and international experts to develop a strategic framework for the management of the ANBG. Panel members were asked to consider:

- the purpose, scope and role of a national institution
- the relationship of the ANBG to other botanical institutions in Australia
- a 10 year and 50 year vision for the ANBG
- opportunities for a national institution to achieve economic sustainability in Australia
- appropriate 'champions' (i.e. figureheads) to support the ANBG.

b) Outcomes from the expert panel meeting informed the 'Future Vision' workshops with ANBG staff, key partners and other existing and potential stakeholders. During these workshops discussion focussed on planning the ANBG's future and more specifically:

- creating a 10 year and 50 year vision
- reviewing the ANBG's mission
- discussing the values and principles that underpin the work of the ANBG
- investigating stakeholder expectations, perceptions of the ANBG and how they wanted the ANBG to be perceived
- gathering opinions on the relevance of the ANBG to Australian society.

c) The outcomes from the expert panel meeting and 'Future Vision' workshops were then considered by the ANBG Executive and select high level stakeholders.

Stage 2 An Internal review

The internal review process involved executive staff from the ANBG undertaking reviews of the sections within their responsibility and making recommendations for future priorities in light of the vision, mission and goals.

a) Communication and Visitor Services –programs and services delivered during the previous seven years under the 2002 – 2008 ANBG Plan of Management were evaluated. The ANBG's school programs, visitor services, public programs, events, marketing and media liaison were benchmarked against other botanic gardens and national institutions. Stakeholders were engaged in discussions on the future direction of the ANBG's programs and services through focus groups and interviews. The review was overseen by an external expert to ensure transparency during the process. A workforce planning exercise, involving external advisors, was also undertaken to critically evaluate the section's ability to deliver the new strategic direction and identify where additional expertise was needed.

b) Horticulture and Landscape Services (living collection) - this review primarily focussed on the living collections. To strengthen the role of the ANBG as a national institution, a detailed review was needed to examine the value of the collection, its role within the national and international botanic gardens community, and consider opportunities and strategies for future development and management (see Mathams, 2009; Sutherland and Cosgrove, 2010).

c) Science and Information - The majority of the ANBG's scientific work is delivered through the Centre for Plant Biodiversity Research (CPBR). The Centre was formed in 1993 as a joint venture between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Director of National Parks to be a national centre of research excellence in plant systematics and conservation biology. An independent review of the Centre addressed the scientific performance and priorities, governance arrangements, operational arrangements, value for money and the future of the partnership.

Stage 3 National consultation (run concurrently with Stage 2)
According to legislation, the ANBG must invite community members, via notices in national papers, to prepare written submissions on the institution's future. These submissions are considered in the preparation of the management plan. As a national institution, a wider reaching consultation was considered to be important to engage the Australian community in setting the future for their national botanic garden. The consultation involved a range of approaches across the country (Table 2).

Revealing the warts

It must be acknowledged that taking this rigorous approach to planning is a brave and confronting step for any institution because the 'warts' revealed during the process highlight management and operational weaknesses and issues to staff, executive management and the senior bureaucrats who oversee the institution's broad operations. Nevertheless, arguably revealing and examining the 'warts' helps to guide the determination of future priorities to improve institutional performance, relevance and the appropriate allocation of resources to build a sustainable institution in the longer term.

The national community perceptions of the ANBG revealed it to have less of a local and national profile, in comparison to other Australian capital city botanic gardens. Moreover, the consultation with botanic gardens senior staff and community members throughout Australia highlighted some perceived weaknesses and misconceptions (Table 3). The 'warts' outlined in Table 3 needed to be considered in terms of their implications for the ANBG's sustainability. A poor profile and misunderstanding of the work of the institution could affect future strategic partnerships and funding opportunities and risk the loss of stakeholder support. In fact, this was found to be the case in terms of science. The CPBR was not always perceived as part of the ANBG and therefore, the lack of understanding of the ANBG's role in science resulted in it being overlooked for collaborative projects with other botanic gardens. There is also the risk that this could be the case with other core activities, such as being overlooked for collaborative conservation projects or education and learning focussed collaborations.

Through identifying these perceptions and misconceptions, it was evident that the importance and relevance of the ANBG was not well understood. It highlighted the need to prioritise strategic marketing, as well as train and build staff capacity to raise the profile of their institution and more specifically, their work in science and conservation.

Furthermore, the need to clarify, develop and promote the unique position of the ANBG as a national institution was evident. Australia's federation of states and territories challenges the role of a national botanical institution. There were varying opinions among community members and staff in Australia's botanic gardens as to whether the ANBG had a national role, or was a capital city botanic garden for the Australian Capital Territory. Nevertheless, views emerged about botanic gardens needing to be a stronger force and have solidarity to help each other when facing challenges in securing resources, as well as providing support for ongoing work, services and facilities. There was perceived to be a role for the ANBG in creating this solidarity by providing leadership, raising awareness amongst politicians and government agencies of the value and role of botanic gardens nationally, and supporting a network of botanic gardens.

Furthermore, botanic gardens staff saw the need and potential for a botanical institution focussed on national priorities. For example, the need for the ANBG to take a lead on making international instruments (i.e. *Global Strategy for Plant Conservation* and the *Convention on Biological Diversity*) accessible to Australia's botanic gardens was seen as an obvious priority. Discussions also highlighted the potential for the ANBG to take the lead to strengthen the work of botanic gardens in Australia's biodiversity agenda. For example, suggestions included being an advocate for the Australian Seed Bank Partnership and facilitating an awareness raising campaign to increase national understanding of the conservation role of Australia's botanic gardens and the value of *ex situ* conservation.

The consultation also revealed strong opinions of the ANBG's national remit in education and learning. Many community members expected the ANBG to be a centre for information about Australian native plants and Australia's botanic gardens. Of even greater interest to planning the ANBG's future, was the strong voice throughout Australia that the institution should reflect the essence of Australian culture through its living collection and interpretation and education services. The ANBG was expected to tell the 'Australian Story'. The 'Australian Story' was seen as the cultural link between Australia's natural heritage and its cultural heritage and reinforced the importance of the ANBG as both a scientific and cultural institution. The story emerging from the consultation tells of plants and landscape and the interconnection with national identity, the nation's development, the nation's economy, Australian traditional and contemporary society and Australian garden history.

Concluding remarks

This consultation, review and strategic planning process have no doubt been a confronting experience. Nevertheless, it is argued that this process is helping to ensure that the ANBG becomes a sustainable botanic garden and is relevant and contemporary. To continue to be relevant the ANBG needed to reveal the 'warts' and use these findings to guide its strategic direction and its operational priorities over the next 10 years and into the future.

It is suggested that perceptions of an organisation held by management and staff are not necessarily held by the wider community. Staff at the ANBG could argue that the value of the institution is reflected in its annual visits, support from Friends, web hits, database queries, herbarium and garden inquiries and use of the on-line photo library. Nevertheless, the consultation process revealed issues with its profile as a national institution, highlighted misconceptions of its roles in science and conservation, and provided a clear direction and priorities for education and learning for the ANBG as a national institution.

In these times of competition for resources and support, building a sustainable botanic gardens requires more than retrofitting infrastructure. The ANBG has been working through strategic planning processes to build sustainability principles into its people, plants and place. This reflective process has shown a clear vision for its role and relevance as a national institution, highlighted the national stakeholder support for the ANBG as an institution and a visitor attraction, and clearly enabled it to establish future priorities to address the current 'warts'.

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Table 1: Defining sustainability in the context of the ANBG

• Financial ability to deliver core business effectively and in a contemporary manner.	• Demonstrating social inclusion by diversifying visitor demographics and adapting and accommodating different visitor needs.
• Managing its living collection to high curatorial standards.	• Demonstrating environmental best practice site operations, including water and energy management.
• Providing engaging and accessible learning experiences interpreting Australia's unique flora and landscapes to a local and national audience.	• Being dynamic, flexible and adaptable to ensure ongoing relevance.

Table 2: Summary of ANBG's national consultation methods

Consultation method	**Focus of the consultation**
Engaging stakeholders Corresponding with stakeholders following a stakeholder mapping exercise	Encouraging written submissions on the ANBG's future management.
Consulting botanic gardens experts - semi-structured interviews with 31 senior staff from six state botanic gardens and two regional botanic gardens	Examination of : - perceptions of the ANBG - expectations of a national botanic garden in Australia - opportunities for providing national leadership - research directions and priorities to identify new directions and opportunities for the ANBG - botanic garden governance and financial management models - approaches to business planning and strategic partnerships - partnership and collaborate opportunities to benefit biodiversity conservation in Australia - relationships with regional botanic gardens.
Consulting the national community – focus groups with members from Friends groups and/or volunteer guides of six state botanic gardens and two regional botanic gardens	- gain insights into the perceptions of the ANBG and expectations of, and value placed on, a national botanical institution in Australia.
Consulting the local community **–** presentations and discussions with targeted community groups; focus group discussions open to all members of the local community	- the visitor experience/expectations of a national botanic garden - communication with the Canberra community - economic sustainability - the living collection - Attracting the 18-30 year olds to the ANBG - scientific and conservation role - Education and learning - environmental sustainable management

Table 3: ANBG 'warts' revealed from the national consultation

Botanic garden colleagues	Australian community
• perceived to have lost its vision	• poor local and national profile
• Centre for Plant Biodiversity Research is highly valued and seen to make a significant contribution to knowledge, however, confusion over its relationship with the ANBG results in poor recognition of ANBG's science programme	• little awareness of the contributions of ANBG to science
• not perceived to undertake conservation focussed work	• lacks a 'wow' factor that challenges the ordinary and ensures a broader appeal

Source: Sutherland 2009a and Sutherland 2009b

Conserving plants in a changing climate – an Australian perspective

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Abstract

Climate change is projected to significantly affect south-eastern Australia, with current assessments indicating lower rainfall and higher temperatures. The effects will be compounded by the concentration of urban development in coastal areas, relative aridity of the existing climate, and limited altitudinal and or geographical 'escape paths' for flora. Successful adaptation strategies for *ex situ* plant conservation must address both temperature rise and uncertain water supply. Individual botanic gardens should consider specific climatic projections for their location to ensure that collection planning and conservation activities are well informed and effective. Sourcing plants from current and projected homoclimes (geographic regions of similar climate) is essential to ensure that plants are well matched to the local environment. Microclimate variability and diverse landscape styles in botanic gardens offer prospects for the protection of taxa sensitive to the effects of climate change. It is anticipated that robust regional partnerships embracing landscape management, plant curation and research will enhance *ex situ* plant conservation programmes.

Key Words

Climate change, collections, conservation, homoclimes, microclimate, rainfall, temperature

Current situation and problems

Increased temperatures and number of hotter days on average are commonly projected across south-eastern Australia. Decreases in average rainfall are projected for most south-eastern Australian cities including Adelaide, Melbourne and Sydney (Suppiah *et al*., 2006; CSIRO 2007; CSIRO 2008; SEACI 2009).

The current situation in Australia (Figure 1), with decreasing rainfall in the west, south and south-east, has to a large extent driven increasing public awareness of climate change. Most major cities have had, or continue to experience, water use restrictions.

Northern hemisphere examples (Figure 2) show the amplitude and speed of temperature change in the past 100 years, compared to the last 1,300 y. However, all Australian Botanic Gardens are less than 200 years old and were largely designed and developed on the basis of European landscape interpretation in a different climatic period. This resulted in plant selections that need significant resources to survive and raises the question of what these landscapes would look like if developed under current or projected conditions.

Current climate change models are generally following the higher emission scenarios as projected by the Intergovernmental Panel on Climate Change (IPCC), but in some cases the projected changes are taking place more quickly than anticipated – showing more rapid and serious change (Climate Change in Australia 2009; Steffen 2009).

In this context, the need to consider 50+ year scenarios of worst case temperature and rainfall changes, lends weight to a precautionary approach to botanic garden planning as the prime risk management strategy. Contemporary risk management doctrine (Standards Australia, 1999) is not as applicable when considering the protection of dynamic living systems and the extensive lead time required to protect plants by translocation of genotypes and development of more climate-resilient collections.

Global climate changes are combined with existing threats to plants *in situ*. For example, in the Sierra Nevada Mountains, California, ecological niches of montane flora and fauna appear to be shifting to higher altitudes (*Pinus ponderosa* has retreated upwards about 200 metres, linked to an increase in minimum monthly temperatures of 3^{o} C over the last 100 years, Moser *et al.,* 2009).

Australia is particularly vulnerable to changing climatic conditions as there are limited escape paths for flora. Its mean altitude is the lowest in the world at 330 metres and montane regions, such as the Great Dividing Range, average just 600–900 metres in height (http://www.ga.gov.au/education/geoscience-basics/landforms/elevations.jsp). Flora in southern Australia also cannot migrate readily over ocean to adapt to increasing temperatures (CHABG 2008; CSIRO 2008; Hawkins *et al.,* 2008).

Managers of biodiversity must consider extreme weather events. The projected increase in annual average temperatures may also result in increases of individual, or flushes of consecutive, extreme temperature days (Figure 3). While this extreme can occur at daily or monthly temporal scales, there are also yearly considerations. In January 2009, a heat wave was experienced in Melbourne (Figure 4) where three consecutive days above 45° C (eight days above 40° C for the year) resulted in significant damage to many taxa across the Royal Botanic Gardens Melbourne (RBG Melbourne), especially to cool temperate species. Of concern is that the current trend indicates an annual increase in hot days (Table 1).

The shift in average temperature bandwidth can also be compared to rainfall changes. Long-term annual average reduction in rainfall for Melbourne is projected to be up to 11 per cent less (CSIRO 2008). However, there may be an amplified reduction for the average 10th percentile (that is, the 1 in 10 driest) rainfall years. It is reasonable to assume that one year of extremely reduced rainfall is enough to be severely detrimental to plant health.

Projected seasonal changes to climate may already be impacting upon regions in south-east Australia, and may be related to projected trends for the Southern Hemisphere (Figure 5). Murphy and Timbal (2007) found that there had been a 61 per cent decline in autumn rainfall between 1997 and 2006, and that there is likely to be an influence from global warming on the climate of south-east Australia, at least for temperature.

For many major botanic gardens, the urban heat island (UHI) effect is expected to magnify temperatures projected under climate change scenarios as UHI influences are not factored into long term projections (Coutts *et al*., 2009). In Melbourne, the UHI effect shows an increase in the average temperature of between 2 and 4^{o} C, with daily peaks to 7^{o} C in certain areas of the city (Coutts *et al*., 2009). The UHI phenomenon in the past has assisted the curation of warmer climate taxa, but in the future is likely to become a collection management problem.

While reductions in annual rainfall for south-east Australia are projected, changes to daily rainfall intensity and duration also have considerable effects on the precipitation actually reaching the soil for plant growth, or that which is 'effective'. Rainfall in RBG Melbourne is strongly attenuated by canopy interception (Figure 6) (60 per cent coverage) and wet-canopy evaporation. Interception losses of 60 per cent have been recorded, falling to 30 per cent in the largest rainfall events. Current research indicates that Melbourne is experiencing an increasing trend towards low rainfall intensities (Dunkerley pers.comm, 2009), and therefore increasing interception rates.

Solutions

The early adoption of water efficiency programmes has shown immediate benefits in climate change resilience through savings in energy, materials and labour, and water (Figure 7).

Fluency in climatic and soil information is an underdeveloped skill-set for botanic gardens. There is a higher imperative to understand the soil environment (or edaphic) and to invest in researching and testing. Assessment of microclimates and soil types should be factored into landscape planning and collection development (Figure 8). Soil moisture sensing (Figure 9) is one technology to inform plant water use, soil hydraulic performance and assess rainfall effectiveness. Current research in RBG Melbourne is establishing baselines for the influence of the current climate on plant water use (Symes *et al*., 2008), and in assessing future trends.

Other useful technology includes site-specific automatic weather stations. These have considerable benefits for collections planning and management, such as:

- tracking temperature changes
- evapotranspiration estimation
- degree day estimation (heat accumulation)
- cross-referencing of plant phenological studies.

Comparative climatic assessments are one of the large challenges to overcome. The simplest models use comparisons between evaporation, temperature and rainfall to predict a soil-water balance. RBG Melbourne is currently adapting climate matching methodology (Gentilli, 1971) for future plant selection and landscape succession (Figure 10). It can be seen clearly that it would be very difficult to support the health of Kunming flora and that our current irrigation practice is well outside Melbourne's existing, let alone projected, climate.

On the presumption that long lead times are required to establish more resilient living collections, then worst case scenarios in both temperature and rainfall changes need to be applied to landscape planning. A delayed response, combined with worst projections, will likely result in greater losses of plants and biodiversity.

The benefits of proactive strategic planning are obvious, but specifically include:

- an increased understanding of biodiversity risks
- greater investment in plant conservation
- transition of many living landscapes to more sustainable states
- enhancement of employee skills, and
- further development of botanic gardens networks and partnerships.

Plant selection of the future must become increasingly provenance-based, not only because of important conservation value, but also due to specific ecotypic variation for tolerances to drought and heat. However, there are large information gaps for many of the plants we grow – especially climatic preferences, environmental tolerances, and natural habitats. Consequently, it is crucial to up-skill curators in *both* climate and plant knowledge. This plant knowledge should also be stored in readily accessible national/global databases to reduce duplicated research.

In 2007, RBG Melbourne considered climate change projections in its review of the landscape Masterplan and Living Plant Collections Plan, leading to recommendations that vulnerable species be strategically replaced by those more suited to the projected climate. The focus is now on selecting plant species for their suitability to the local climatic, edaphic conditions and projected homoclimes, while maintaining the style of the respective landscapes.

Recent living collection developments at RBG Melbourne, such as the Californian Garden, the Water Conservation Garden, the Lower Yarra River Habitat (indigenous flora of Melbourne) and Guilfoyle's Volcano (Figure 11) are more likely to be suited to the projected drier and hotter conditions of the future. The Guilfoyle's Volcano project integrates heritage, climatic plant selection, water re-use, water treatment, efficient irrigation and education.

RBG Melbourne is the custodian of important collections not well adapted to Melbourne's homoclime. At least some of the taxa in these collections will need to be duplicated with other botanic gardens. RBG Melbourne and the Botanic Gardens Trust, Sydney, are examining the possibilities for duplication/transfer of wild-collected Southern Chinese flora.

In summary, we must take a precautionary and long-term approach in planning for climate change. Climatic extremes must be considered, and flexible planning policy developed for changing conditions. Collection planning should begin from an edaphic and microclimate perspective, and current collections should be evaluated for suitability under future climates. Protection of plants needs integration on both regional and global scales. Finally, we must continue to build knowledge of plant environments, to pursue an understanding of climate science, and the impacts of these changes for our respective botanic gardens and plant habitats.

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Figure 1 Climate change awareness driven by water scarcity

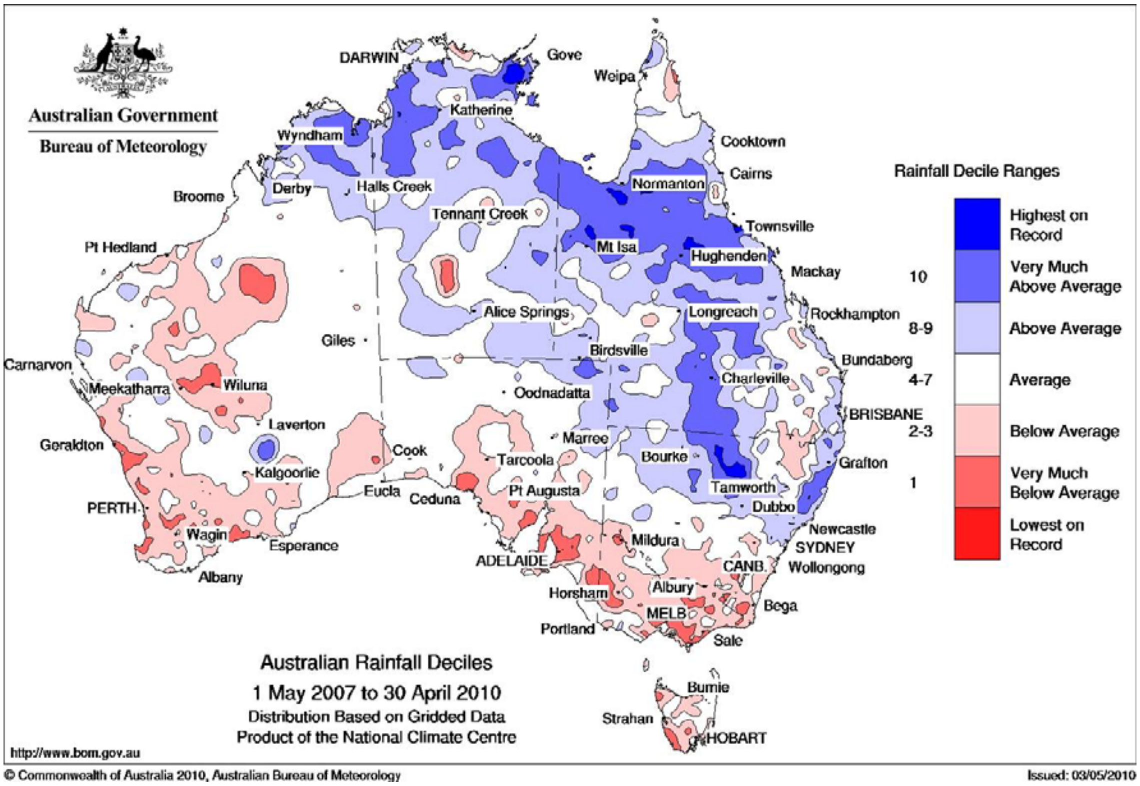
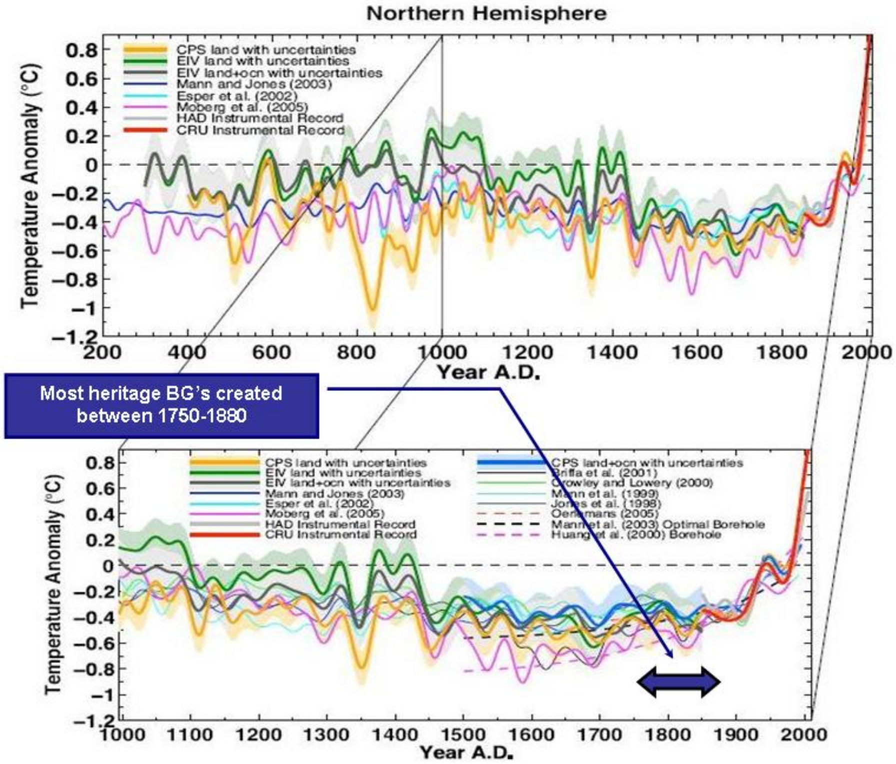
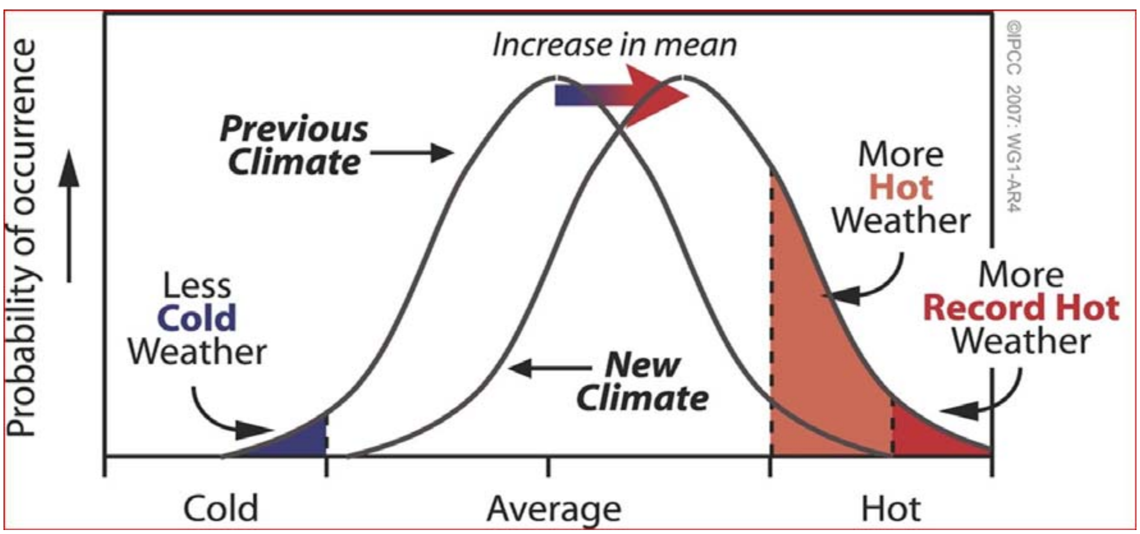


Figure 2 Reconstructions of hemispheric and global surface temperature variations



Source: *Proceedings of the National Academy of Sciences*, Vol 105, No 36, pp 13252-13257, 9 September 2008.

Figure 3 Consider the dangers of applying 'average' climate data in landscape planning



Source: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf.

Figure 4 Extreme temperatures trend – RBG Melbourne

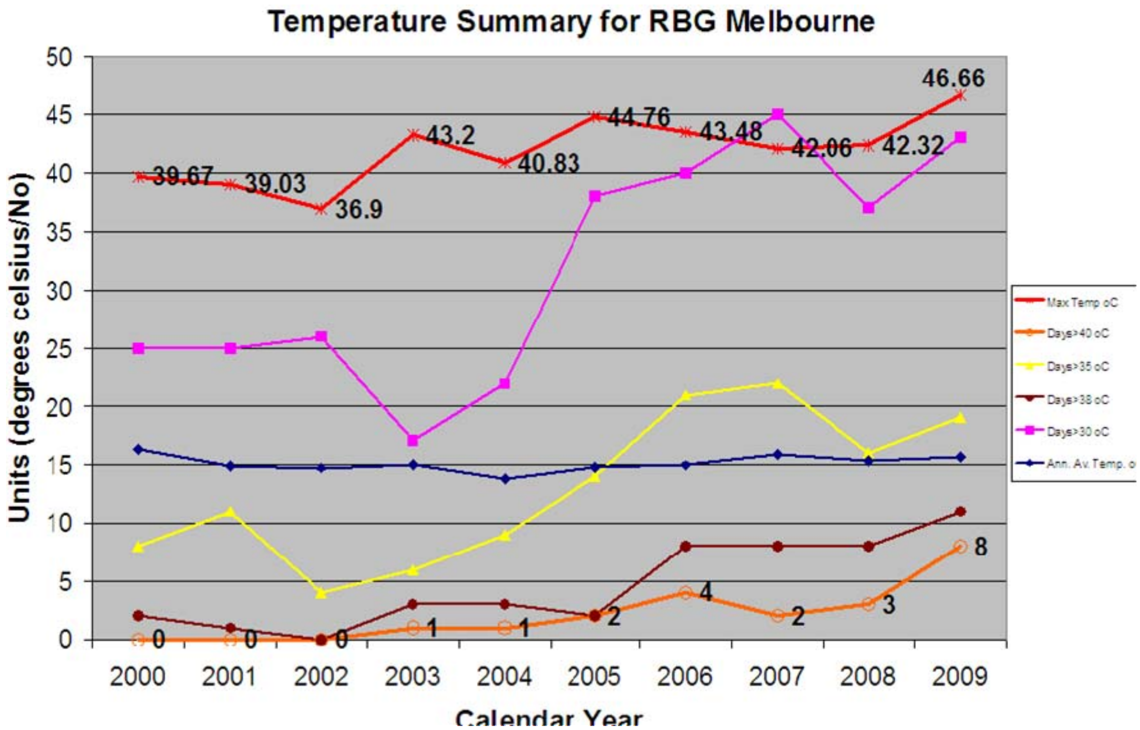
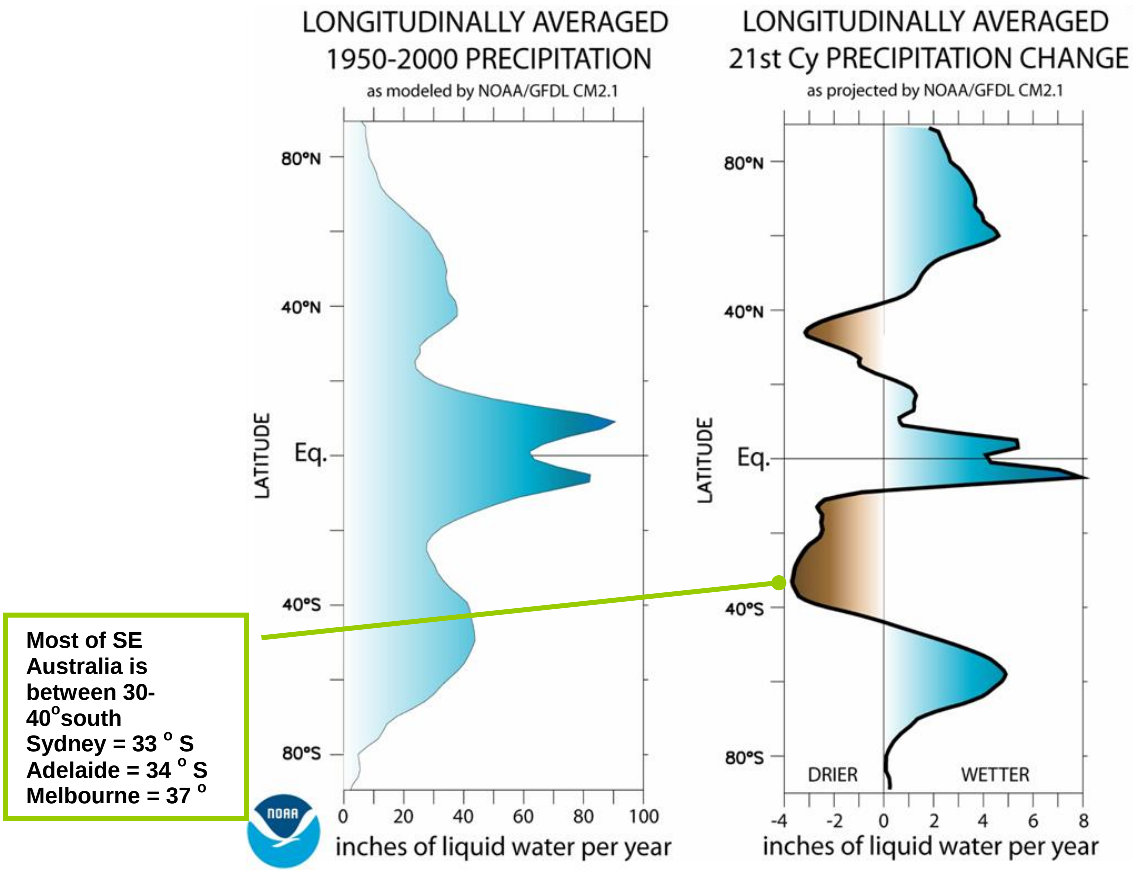


Table 1 Selection of projected climatic variables for Melbourne compared to RBG Melbourne Automatic Weather Station (AWS) records

Parameter	*Current*	*Average RBG AWS 2000–2009*	*2009*	*2030*	*2070*
Frosts	3	0.2	0	2 to1	1 to 0
Temperature change	15	15.1	15.58	+0.6 to +1.1	+0 to +3.7
Annual average evaporation	1241	1278	1359	-1 to +5%	-1 to +17%
Average annual rainfall	648	498 (-23%)	407 (-38%)	0 to -8%	-6 to -24%
Days over 30°C	30	**31.8**	**43**	**33—37**	**35—62**
Days over 35°C	9	**13**	**19**	**10—13**	**12—26**
Days over 40°C	1	**2.1**	**8**	**2**	**2—8**

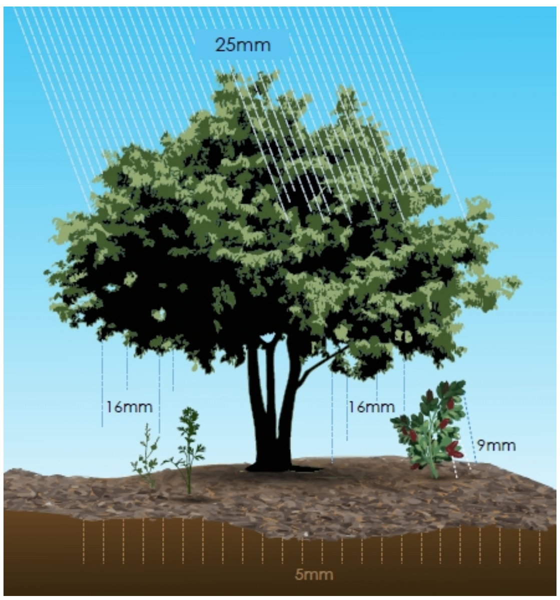
Figure 5 Changes to longitudinal precipitation



Source: http://www.gfdl.noaa.gov/will-the-wet-get-wetter-and-the-dry-drier.

Figure 6 Up to 60 per cent of rainfall can be intercepted by the canopy per month

Throughfall measurement in the Australian Forest Walk Collection, RBG Melbourne



Schematic of rainfall interception by vegetation canopy
(used with permission – D. Dunkerley, Monash University)

Figure 7 Continuous improvement in water management efficiency

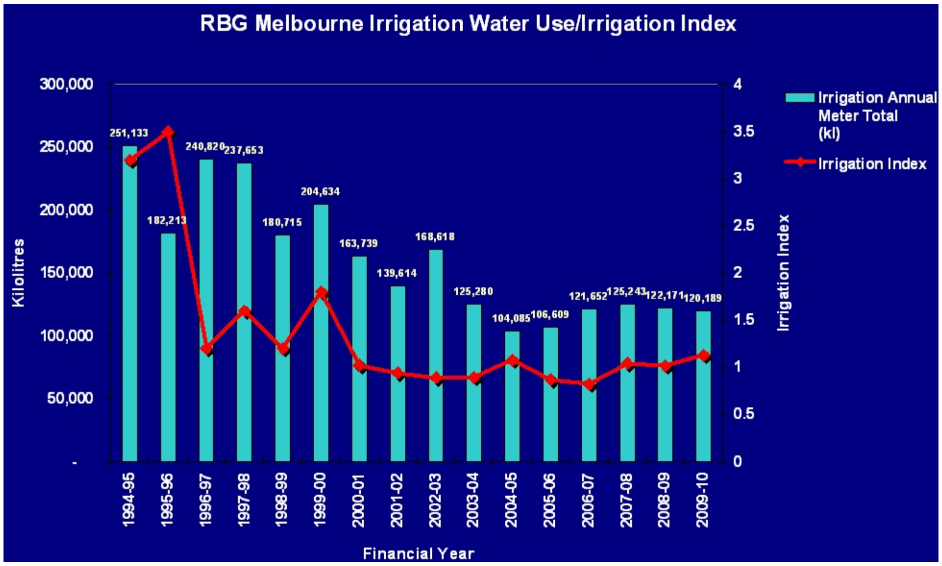


Figure 8 Soil and Microclimate Mapping

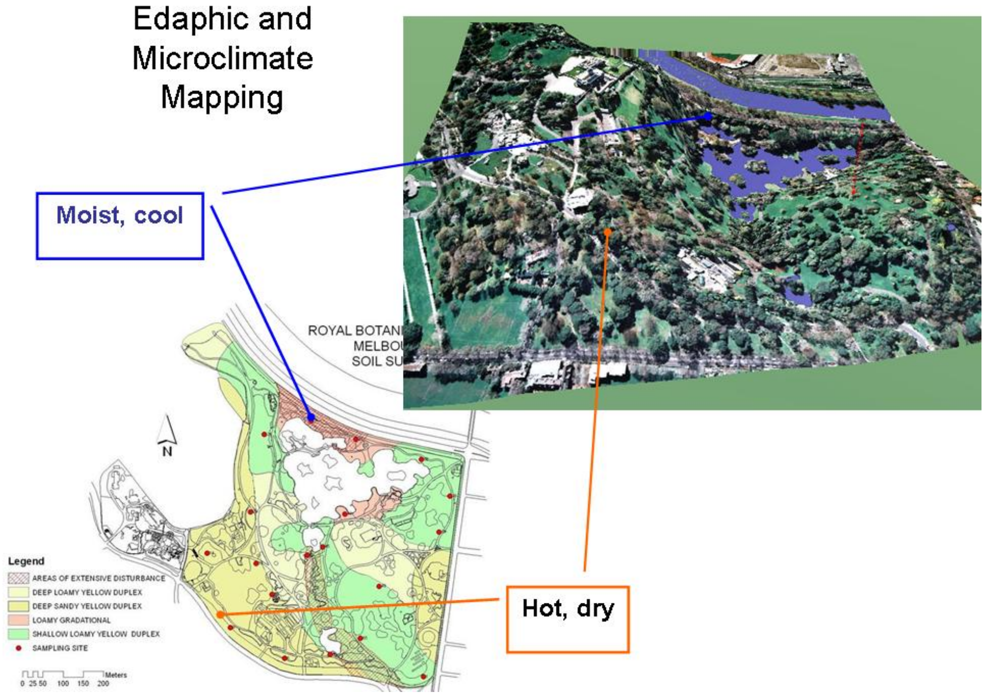


Figure 9 Soil moisture sensing

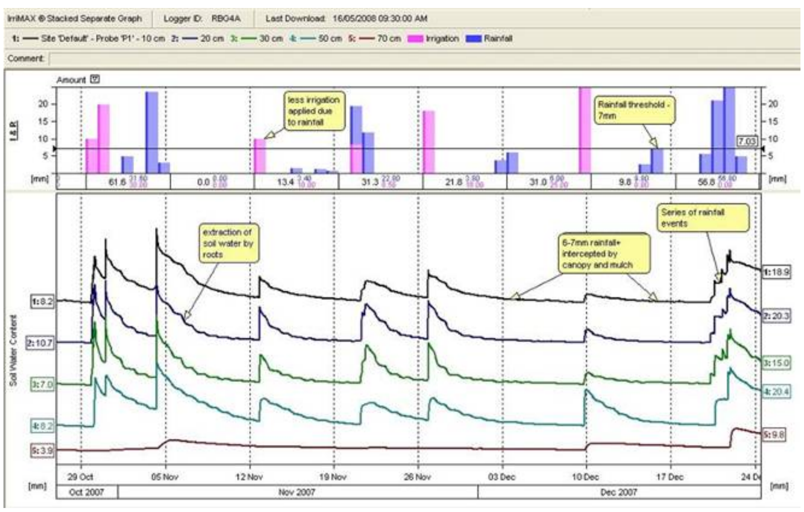
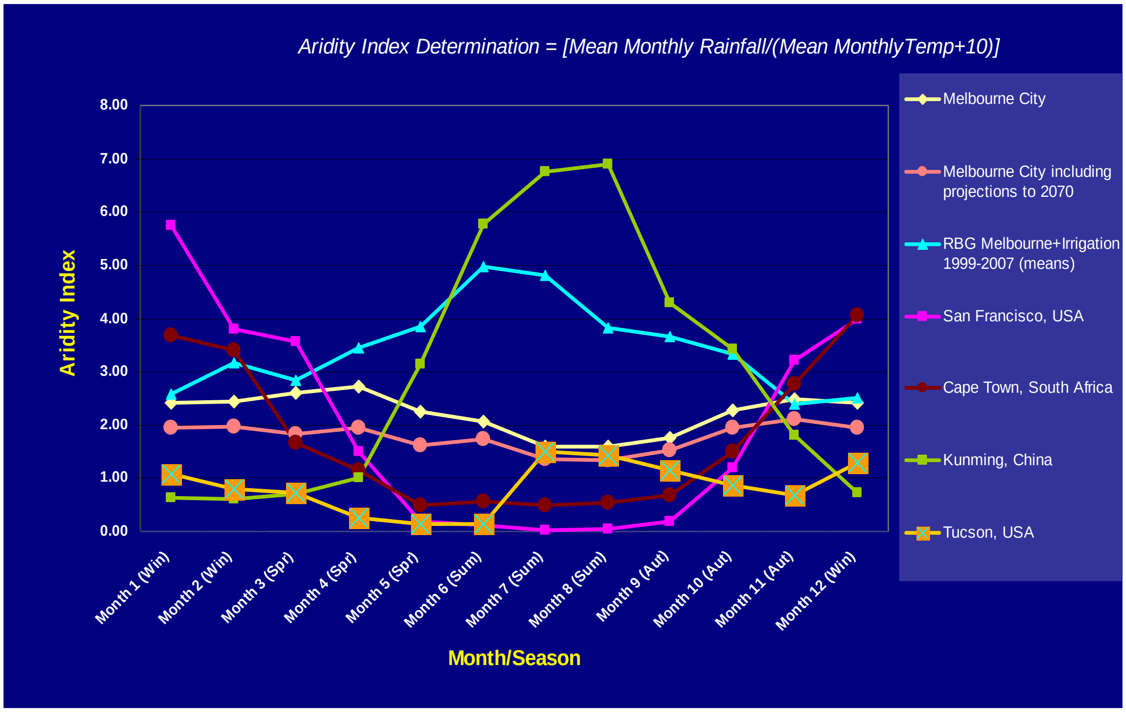
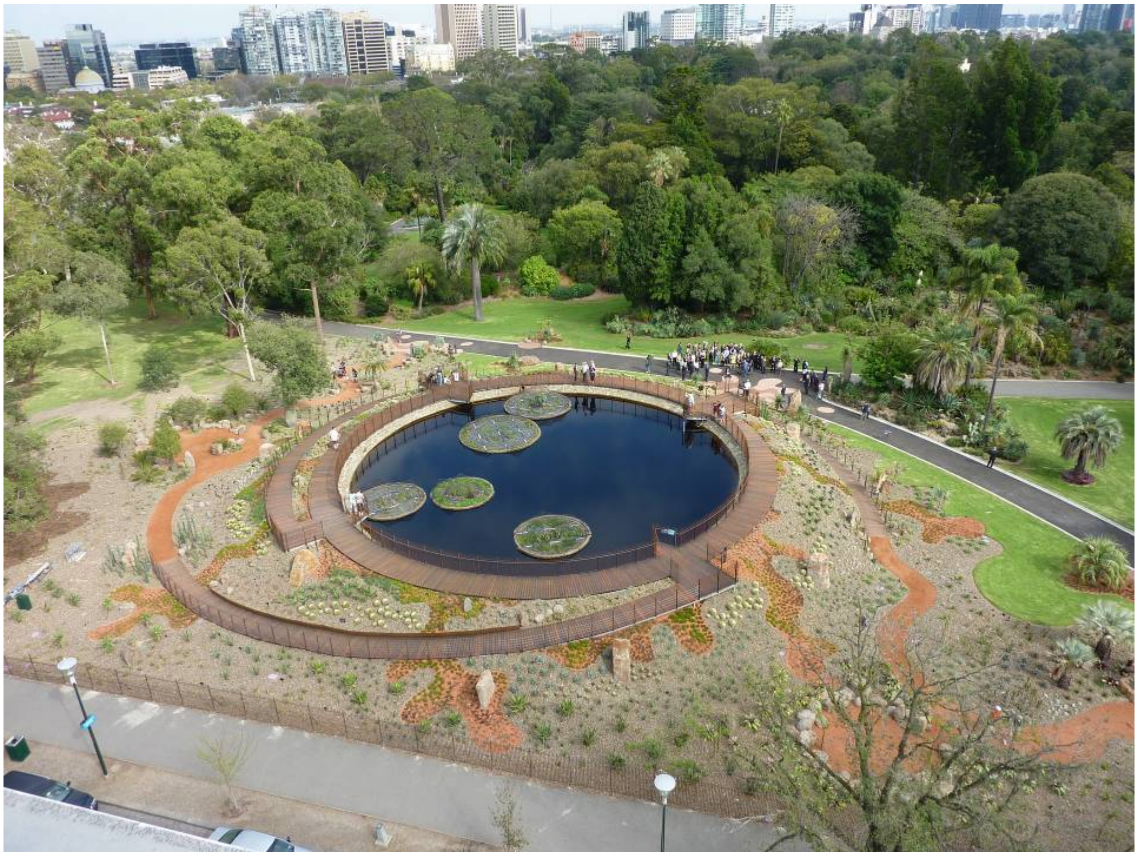


Figure 10 Climatic assessments (Aridity Index)



(Month 1 is equivalent to July ((winter)) in Melbourne.)

Figure 11 Guilfoyle's Volcano Project – long-term, climate suited collections



Conservation of orchids, medicinals, and Agarwood in Vietnam, Laos, Burma, and Cambodia

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Abstract

Very little is known of the state of plant conservation in countries such as Burma, Laos, Vietnam, and Cambodia. This slide presentation is an attempt to provide information on newsworthy joint projects between Botanic Gardens Conservation International (BGCI) and:

1. Hanoi University of Pharmacy and their collaborative work with ethnic Dzao and Cao Lan traditional herbalists to save threatened medicinal species such as *Stephania dielsiana* and *Ardisia gigantifolia* in Bavi National Park
2. Cambodia Ministry of Environment and their efforts to help the O Toch villagers (Bokor National Park) sustain their livelihood through rehabilitating degraded forests after their traditional collecting areas were closed due to construction of a hydroelectric dam.
3. Laos Research Institute of Science and their conservation of threatened Agarwood (*Aquilaria crassna*)
4. Burma Forestry Division in documenting the native orchids of Shan State.

In addition, three public exhibitions on conservation of forestry resources in Laos, Burma and Vietnam are described, as well as commercial farming of *Aquilaria* which poses conservation challenges in these countries.

The slide presentation attempts to provide some positive news regarding conservation as opposed to the commonly heard “doom and gloom” stories in the media. There is a tremendous amount of conservation work to be done in Indo-China but the outlook is cautiously optimistic – there are good local partners and “conservation champions” in these countries who are effecting change for the better.

Keywords

Agarwood, Burma, Cambodia, Collaboration/Partnership, Conservation, Laos, Medicinal plants, Vietnam.

Introduction

Botanic Gardens Conservation International (BGCI) is the world’s leading agency for plant conservation. From 2004 to 2009, I worked as their Southeast Asia Programme Coordinator, based in Indonesia and Singapore. Among the many countries where I worked, four of them – Vietnam, Cambodia, Laos and Burma – stand out as being “under the radar” when it comes to plant conservation. One rarely hears news about plant conservation in these countries, and with this slide presentation I hope to give a brief glimpse of plant conservation projects there.

These projects help to support the Millennium Development Goals. In particular:
Goal 1 – eradication of extreme poverty and hunger
Goal 7 – ensure environmental sustainability
Goal 8 – develop a global partnership for development

Hanoi University of Pharmacy, Vietnam

BGCI has had a relationship with the Hanoi University of Pharmacy (HUP) since the 1990's. Established by the French about 100 years ago, HUP's main remit is to train students in the identification and taxonomy of medicinal plants, research the ethnobotany and cultivation of medicinal plants, and work on their conservation. BGCI's contact there is Dr. Tran Van On, who is on the faculty at the University and director of the campus botanic gardens, which displays and maintains medicinal plants.

Vietnam's first exhibition on medicinal plant conservation was held at the HUP, and involved many stakeholders – academics, researchers, manufacturers of traditional medicines, conservationists, policy makers, schools, and ethnic traditional herbalists. The exhibition relied less on conventional poster panels, and more on living plant displays interpreted and explained by traditional herbalists. For example, along one side of a row of potted plants, herbalist Trieu Thi Thanh from the Dzao hill tribe would explain how her culture uses these plants medicinally, while on the other side of the same row of plants, Cao Lan herbalist Luong Thi Loc would explain her use of these plants, and each culture's use of each species was different.

For the species recovery project, Dr. On, his staff, and the traditional herbalists selected *Stephania dielsiana* (Menispermaceae) and *Ardisia gigantifolia* (Myrsinaceae), two threatened species in Vietnam, and both are listed in the Vietnam Red Book. The former is used as a tranquilizer and to treat rheumatism, while the latter is used for tuberculosis and women's post-partum health. Both are rare in the wild due to overharvesting for medicinal use.

Staff of the Bavi National Park were consulted and included in this project, which resulted in the establishment, at the edge of the National Park, of a conservation collection of *Stephania* and *Ardisia* of documented wild origin. An important component of this collection was the construction of a propagation facility, where the best methods of propagation (seed and cutting) were researched. Cuttings were found to be the best method of propagation, and many hundreds of small propagules were created. Half of these were distributed to the traditional herbalists for planting in their home gardens, and half were planted within the National Park to boost the native populations.

The herbalists living adjacent to Bavi National Park were also taught how to propagate these medicinal plants. Traditionally, these species are grown in their home gardens but in very small numbers. Most of the materials for medicine are harvested from the forest and often from distant and relatively inaccessible hilly locations. The herbalists were delighted to acquire new plants for their gardens because it meant fewer hours of hard trekking to obtain these plants in the wild. And they seldom dig any wild plants to bring home to their gardens because the plants are difficult to transplant from the wild and survival rates are very low.

The ultimate outcome of this project is envisioned to be a "forest farm" where these and other medicinal species are cultivated and made into medicines. Most medicinal species are found in woodland habitat, so this farm would involve forest restoration. This would not only facilitate conservation of rare medicinal species but also provide habitat for many other species of woodland plants and animals. The farm would be a cooperative, owned and operated by the traditional herbalists, who would spend their time cultivating and processing their medicines, rather than trekking into the forests and harvesting from the wild.

Research Institute of Science, Lao PDR

The main goals of the RIS are to:

- Conduct research regarding economically important plants, such as *Aquilaria*, and traditional dye and medicinal plants
- Maintain a laboratory for botanists and researchers

- Conserve rare and endangered flora species
- Support and promote environmental education

Dr. Sourioudong Sundara has been our main contact as director of RIS, and our first project was to conduct an exhibition on the conservation of forest resources. Collaborators included staff and faculty from the departments of Forestry and Biology, National University of Laos, who loaned us live plants and exhibition materials, and who were on hand to explain the exhibits to school children.

The exhibition focused on native orchids, dye plants, and agarwood culture and inducement. One of the most popular parts of the exhibition were informal quizzes conducted at the end of school visits. These were invariably well received with great enthusiasm and delight. Students who gave correct answers were given notebooks and pens.

A brief explanation follows regarding agarwood and how it is produced. Agarwood is the extremely fragrant and valuable resin-infused wood produced by trees of the genus *Aquilaria* (Gratzfeld & Tan, 2008). It is mainly used as incense and perfume. The fragrant resin is produced in response to physical injury and subsequent fungus infestation. Wild trees are now extremely rare because they are indiscriminately felled even though they may not contain any agarwood.

BGCI has assisted RIS to survey and document remaining wild populations of *Aquilaria* in Laos, and produce a database of the wild populations, including voucher specimens. Tissue culture techniques have been used to mass-produce native *Aquilaria* plants for distribution to local farms and growers. The RIS has isolated three varieties of fungus and are working with some local farmers in inoculation trials of these fungi. Holes are drilled into the *Aquilaria* trees using an electric drill. Small wooden plugs inoculated with fungus are then hammered into the holes. Agarwood formation then commences and the agarwood can begin to be harvested after 3-5 years. One of the plantations I visited was owned my Mr. Sieng Sa in Borikamsay Province. He is a strong proponent of conserving and growing only native Lao *Aquilaria*, claiming that plants imported from other neighbouring countries are not as sturdy as local plants, and that local *Aquilaria* produces superior agarwood. The ultimate goal of this project is to conserve native Lao *Aquilaria* and to alleviate poverty by sharing agarwood inducement techniques with rural farmers.

Division of Forestry, Nature and Wildlife Conservation Department, Burma (Myanmar)

The Forestry Division aims to conserve, protect, and manage forests in Burma. My main contacts are Ms. Kyu Kyu Thinn, an orchid specialist, and Mr. Thet Thun, a botanist. I met them when they were working at the National Kandawgyi Gardens located in Pyin Oo Lwin (Maymyo), in the mountains above Mandalay. Ms. Thinn had developed a good collection of native wild orchid species, and Mr. Thet Thun had established a propagation programme to conserve the rarest plant species in the Botanic Gardens.

At the Gardens, we held the nation's first exhibition on forest and nature conservation, targeted at primary and secondary school children. Staff of the Gardens, and of the Nature and Wildlife Conservation Department were on hand to explain the exhibits to visitors, including traditional Burmese herbalist Ms. Khin Myint Oo who showed visitors various medicines and the live plants from which they were made. Other collaborators included Myanmar Timber Enterprise, University of Yangon Botany Department, Myanmar Agricultural Service, and Lao Forest Research Institute, who provided additional materials for the exhibition.

Burma (Myanmar) has an incredible variety of climates and habitats, from the glaciers in the mountainous far north to the deltas of the Ayeryawaddy (Irrawady) River. It therefore is home to an incredible biodiversity, notably the orchids. However, they are threatened by over-collecting, illegal trade to neighbouring countries, and habitat degradation and loss. Our project with the Nature and Wildlife Conservation Department involved identifying and documenting populations of wild orchids in Shan State, and establishing a living conservation collection of native orchids at the Inle Lake Wetland Wildlife Sanctuary. A shade house was constructed at the Sanctuary Headquarters in Naung Shwe, to house approximately 130 orchid species collected from nine locations within the state. Each of the plants is tagged and the field collection data has been entered into a computerized database. In addition, Ms. Kyu Kyu Thinn has trained the Wildlife Sanctuary staff in orchid taxonomy and identification, collection of field data and plants, and orchid cultivation. Future initiatives include: a conservation education programme for local villagers and orchid hunters, conducting a similar survey for Natmataung National Park in Chin State, and propagation and distribution of orchid plantlets for cultivation by villagers, to promote wider community participation in orchid conservation.

General Department of Administration for Nature Conservation and Protection, Ministry of Environment, Cambodia (GDANCP)

The GDANCP has jurisdiction over the country's national parks, and focuses on documenting and conserving the flora of Cambodia. BGCI had worked previously with Mr. Khou Eanghourt on a number of projects, such as a botanical field techniques training course for GDANCP staff. The current project grew in response to Cambodia's largest hydroelectric dam being constructed within Bokor National Park in southern Cambodia. The villagers of O Toch community, located adjacent to Bokor National Park, rely on harvesting and weaving bamboo and rattan for their subsistence livelihood. Their best bamboo harvesting areas will be flooded by the dam, and these areas are now off-limits due to the dam construction.

The GDANCP, in consultation with village elders of O Toch, came up with a solution that focused on developing a livelihood strategy for O Toch Village, while improving biodiversity conservation through reforestation of a degraded area using bamboo, rattan, and other NTFPs (non-timber forest products). A socio-economic survey was conducted to quantify O Toch's dependence on bamboo, and to identify other potential livelihood activities. Bamboo and rattan harvesting and weaving was overwhelmingly the most important occupation of the villagers. About ninety-five percent of O Toch families produce baskets for sale, and eighty-eight percent who produce baskets report that bamboo resources play a very important role for their livelihood.

A 47.1 hectare CPA (Community Protected Area) was established, consisting of degraded evergreen and semi-evergreen forest, which had been heavily logged in the past. One of the main purposes of the CPA was for the O Toch community itself to participate in natural resource protection and sustainable use. A plant nursery was established at the CPA to facilitate propagation and maintenance of bamboo and rattan. Seeds of *Dipterocarpus*, *Hopea*, and *Aquilaria* have also been germinated as part of the forest rehabilitation effort. A small dam was constructed near the nursery for irrigation during the dry season. Large areas of the CPA are now planted with bamboo, and due to its fast growth, it will provide shade for the establishment of other forest species, especially valuable timber trees which will form the semi-permanent canopy of the rehabilitated forest.

A nucleus of an *Aquilaria* conservation collection has been established at the CPA, with seedlings from at least 4 wild populations in the Bokor National Park area. One location consists of two trees in the compound of a Buddhist temple known as the Ruolos Pagoda. The elderly head abbot has fiercely protected these trees which are at least eighty years old, and indeed, seeds from these trees are much sought after by local agarwood plantation farmers who claim that local native trees perform much better than those imported from neighbouring countries.

Agarwood plantations are fast cropping up in all countries where *Aquilaria* is native, but there are certain problems associated with the provenance of the seed and saplings. In Cambodia and Laos, almost all plantations consist of trees grown from seed imported from Thailand. It is doubtful that anyone has studied these imported seeds to determine what species is/are being imported, and how these will affect native wild populations. It is feared that if the imported Thai *Aquilaria* are conspecific or closely related to the Cambodian/Lao species, then genes from the Thai plants may "contaminate" native Cambodian/Lao populations, and that these native germplasms will be lost over time.

The urgent needs are to:

- Conduct nation-wide surveys to document and collect germplasm from wild populations,
- Establish living conservation collections of native wild material,
- Determine level of threat from Thai seedlings
- Research inoculation and harvesting methods to determine best sustainable methods.

Conclusion

There is a tremendous amount of conservation work to be done all over the world, but especially in biodiversity rich – resource poor regions such as Southeast Asia, and particularly in countries whose governments may not see the need to protect and sustain their natural resources and the environment.

Finding good collaborators is important for success. I count myself extremely fortunate to have worked with diligent, responsible partners and collaborators, whose vision and broader goals resonate with conservation and sustainable development. I am convinced that for every story of environmental gloom and doom we hear, there must be an equal, if not greater, number of positive success stories of individuals or groups of individuals who are working for the greater good of the planet. Each of the collaborators and partners I've worked with can be considered as "champions for conservation", who give me renewed hope for a healthier, sustainable planet.

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Conservation status of plants in the Caribbean Island Biodiversity Hotspot

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Abstract

We present an overview of the conservation status of plants in the Caribbean Islands. We discuss the major accomplishments, gaps and limitations towards the 2010 Global Strategy for Plant Conservation (GSPC). A questionnaire on plant conservation nationally was distributed among the authors of this paper to be completed for their respective island(s). Additionally, we reviewed the accomplishments towards the 2010 GSPC for each independent country including the latest National Reports to the United Nation's Convention on Biological Diversity and additional literature. Because all the targets rely primarily on Targets 1 and 2, this study is particularly focused on reviewing the achievements related to them. To study progress towards Target 4, the ecoregions and the world protect areas databases were mapped using ArcGIS. Success for the implementation of the Targets of the 2010 GSPC has been extremely variable across the Caribbean. Whereas substantial progress has been made for many targets in Cuba, the Cayman Islands, Guadeloupe and Martinique, accomplishments in other islands, including Jamaica, The Bahamas, and some of the Lesser Antilles are limited. Some of the priority needs and knowledge gaps for the region include limited financial resources, understaffing, lack of local training and appropriate equipment, important plant areas lacking of adequate protection, ineffective enforcement of environmental laws, limited flow of information, including difficult Internet access, and lack of environmental awareness in the public. Although there has been is considerable activity in the Caribbean, there is relatively little collaboration among island plant conservationists. We therefore advocate that a regional and global oceanic island plant conservation network should be initiated to strengthen current efforts in island conservation, to share experiences and best practices and to provide a forum for a wider discussion and support.

Keywords

Bahamas Archipelago, ecoregions, endemism, Global Strategy for Plant Conservation (GSPC), Greater Antilles, IUCN Red List, Lesser Antilles, West Indies

Introduction

Oceanic island floras are known to possess larger numbers of endemics when compared to continental floras. As a result of high level of localized endemism and increasing threats to their biodiversity, it is likely that a substantial portion of their flora are vulnerable to extinction (Caujapé-Castells *et al.*, 2010). Some of the most diverse and threatened hotspots on Earth are located in insular systems, including the Caribbean Island Biodiversity Hotspot (henceforth, Caribbean) (Mittermeier *et al*., 2005). This region is comprised of 124 main islands and over 3,500 cays and rocky islets in a land area of 229,550 km^2 (Figure 1). The islands are grouped in three archipelagos (the Greater Antilles, the Lesser Antilles, and the Bahamas) and a few islands off Venezuela and Honduras. Their geological origin is complex, but overall, they were formed by volcanic activity and joined by landblocks that arose since the middle Eocene (49 Ma) (Graham, 2003). Limestone is also widespread. Altitude ranges from -40m to over 3,100m, both in Hispaniola. Mean annual temperature and precipitation ranges from 28°C and 390mm at sea level to 12.5°C and 2,674mm at the montane extreme (Lugo *et al.*, 2000). Volcanoes are still active in some of the Lesser Antilles. The entire region is prone to hurricanes.

Habitat diversity in the Caribbean comprises 28 of the World Wildlife Fund (WWF)-defined terrestrial ecoregions, covering six Neotropical biomes. Apart from one that is shared with Venezuela they are all endemic to the Caribbean. Subtropical dry broadleaf forests (coastal and lowlands) are the most extensive (40%; see Figure 1) and most endangered (WWF, 2010).

The spermatophyte flora comprises 205 families and 1,447 genera; 191 of the latter are endemic (of which 95 are monotypic) (Acevedo-Rodríguez & Strong, 2008) (Table 1). The region comprises c.13,000 native vascular plant taxa (Adams, 1997), forming c.2.3% of Earth's flora (Myers *et al.*, 2000). About 7,868 spermatophyte taxa are endemic to the Caribbean (61%) (Acevedo-Rodríguez & Strong, 2008. Pteridophytes have not been widely included in these estimates due to the lack of information, but in addition to the estimate above, there are at least 156 further single island endemics (Proctor, 1977, 1985, 1989; Adams, 1997). All pteridophyte endemicity is infrageneric.

The Caribbean was first settled 6,000-7,000 years ago (Fitzpatrick & Keegan, 2007) and later colonized by Europeans from 1492. Today, many landscapes are considerably altered. Politically, the Caribbean is very complex, consisting of 12 independent nations and 15 territories under diverse status. The population in 2009 was estimated to be 40 million, with densities ranging from 50 inhabitants/km^2 (Bahamas) to 800 (St. Maarten) (Central Intelligence Agency [CIA], 2010). The main economic drivers include tourism, agriculture, and offshore banking (CIA, 2010). The political, socio-economical and cultural heterogeneity translates into a wide spectrum of realities that limits effective implementation of conservation policies as a region (Maunder *et al.*, 2008).

The main threat to the flora is habitat destruction and deforestation (for tourism, mining, agriculture and urban development). For instance, 46% of Cayman Islands' flora is threatened by development (Burton 2008). In 2007, only 26% of forest cover remained, ranging from 3% in Haiti to 92% in St. John, US Virgin Islands (Brandeis & Oswalt, 2007; Food and Agriculture Organization, 2010). Other major influences on plant diversity include invasive alien species (*e.g*. *Dichrostachys cinerea* (marabú) invades large areas in Cuba), pests and diseases (*e.g*. pine scales in Turks & Caicos Islands), fires, unsustainable harvesting of native species, and climate change that is predicted to cause severe drought, increase in hurricane intensity and frequency, and reduction of coastal habitats. Inadequate management of ecosystems and enforcement of conservation laws continues to be a challenge in the Caribbean.

In this paper, we present an overview of the conservation status of plants in the Caribbean Islands. We discuss the major accomplishments, gaps and limitations towards the 2010 Global Strategy for Plant Conservation [GSPC] (http://www.cbd.int/gspc/).

Methods

A questionnaire on plant conservation nationally was distributed among the authors of this paper to be completed for their respective island(s). Additionally, we reviewed the accomplishments towards the 2010 GSPC for each independent country included in the latest National Reports to the United Nation's Convention on Biological Diversity (CBD). For the United Kingdom Overseas Territories (UKOTs), we consulted the UKOTs Online Herbarium (http://dps.plants.ox.ac.uk/bol/UKOT/Home/Index). For the French Overseas Departments, Dutch Overseas Territories, United States Territories, and all other islands, additional literature was reviewed (cited throughout the work). Information for the Swan Islands (Honduras) and the Federal Dependencies of Venezuela were not available, however, these small low-lying islands are currently under protection. The Caribbean Islands Ecosystem Profile was also reviewed as it represents the most up-to-date conservation assessment for the region conducted using a multi-agency approach (BirdLife International *et al.*, 2009). Because all the targets rely primarily on Targets 1 and 2, this study is particularly focused on reviewing the achievements related to them. Of particular interest was also Target 4, because in the case of the Caribbean all ecoregions except one are endemic and achieving the target will have an important impact towards achieving this Target globally. To study Target 4, the dataset of the WWF Ecoregions (http://www.worldwildlife.org/wildworld/profiles/terrestrial_nt.html) and from the World Database on Protect Areas (www.wdpa.org) were mapped using ArcGIS 9.3 (ESRI 2010).

Results

Success for the implementation of the Targets of the 2010 GSPC has been extremely variable across the Caribbean. Whereas substantial progress has been made for many Targets in Cuba, the Cayman Islands, Guadeloupe and Martinique, accomplishments in other islands, including Jamaica, The Bahamas, and some of the Lesser Antilles are limited (Table 2).

Target 1 ("A widely accessible working list of known plant species"). Floras for many Caribbean islands have been substantially completed or completed, reflecting significant progress towards Target 1. Although some floras are over 30 years old, they still provided the framework to develop a widely available Online Catalogue of Seed Plants of the West Indies (Acevedo-Rodríguez & Strong, 2007). Other online checklists are available for the Netherlands Antilles and Aruba (Mori *et al.*, 2007 onward; Caribbean Research and Management of Biodiversity, 2009), the Lesser Antilles (Carrington, 2007), St. Lucia (Graveson, 2010) and for Cuba (Greuter & Rankin Rodríguez, 2010). The revised edition flora of the Cayman Islands (Proctor, in review) is currently in review at Royal Botanic Garden, Kew (Kew). A supplement to the Flora of Hispaniola was recently published by Liogier (2010). The modern Flora of Cuba, a work in progress since 1992, comprises 16 published fascicles covering 64 families (less than 35% of the families) (Greuter & Rankin Rodríguez, 2010). Working lists are available for Montserrat, British Virgin Islands, and Turks & Caicos Islands (UKOTs Online Herbarium, 2010). The major taxonomic gaps include a flora for pteridophytes, monocots, and Cactaceae for Hispaniola, and a widely accessible working list of the Pteridophytes of the Caribbean. The completion of a treatment for the Poaceae of Puerto Rico (in progress), and a publication of a new synopsis of the Puerto Rican flora (Axelrod, in press) will bring the island close to fully achieving Target 1.

Target 2 ("A preliminary assessment of the conservation status of all known plant species"). The conservation status of plants has been primarily evaluated using the IUCN Red List Criteria (IUCN, 2001). Puerto Rico and US Virgin Islands mostly rely on the conservation assessments of the Endangered Species Act (US Congress, 1973). The Red Listing of Caribbean plants has been previously compiled by the World Conservation Monitoring Centre (IUCN, 1997) and IUCN-SSC Action Plants have been developed for some plant groups, including cycads, palms, orchids, conifers and cacti & other succulents plants (IUCN-SSC, 2010). A total of 604 taxa have been globally assessed of which 477 are considered threatened (IUCN, 2010). Thus, less than 7% of the Caribbean Islands endemic plants were evaluated. A few islands have made substantial progress towards implementing Target 2 nationally, while only palms have been evaluated regionally (Zona *et al.*, 2007). The Cayman Islands, in collaboration with Kew, published a Red List of their entire flora in 2008, fully accomplishing Target 2 (Burton, 2008). Cuba and Antigua & Barbuda have progressed significantly by using rapid assessments to evaluate over 70% of their flora (Pratt & Lindsay, 2008; Leiva & González-Torres, 2010). Cuba has published several Red List assessments (see www.uh.cu/centros/jbn/textos/16.html), the most recent being a Red List for the plants in Pinar del Río Province (Novo Carbó *et al.*, 2010). Other islands in the Caribbean have taken similar approaches to evaluate their flora, like Guadeloupe and Martinique (Sastre, 1978; Gargominy, 2003; Ministère de l'Écologie et du Développement Durable, 2006), the British Virgin Islands (Pollard & Clubbe, 2003), Jamaica (Kelly, 1988, 1991), Puerto Rico and the US Virgin Islands (US Fish and Wildlife Service, 2010). The Dominican Republic is now beginning to develop a national Red List (Peguero & Jiménez, 2008), but due to their high floristic richness they will probably need further international assistance. The New York Botanical Garden in collaboration with the Smithsonian Institution, and the University of Puerto Rico are currently assessing the entire flora of Puerto Rico using herbarium vouchers from their collections.

A confident estimate of threatened plants in the Caribbean is not yet possible because the available assessments were conducted nationally, including species shared with other islands, which makes computation difficult. However, we estimate that over 1,553 (22%) single island endemic plants from the Caribbean are threatened with extinction (IUCN categories VU, EN, CR) and that at least 445 (6%) of them are critically endangered (CR).

Target 3 ("Development of models with protocols for plant conservation and sustainable use"). The Caribbean has recently convened a biodiversity hotspot profile where key biodiversity areas (KBA) were identified, including areas with high plant diversity. A strategy for investment and prioritization in KBA was outlined particularly for biological corridors (BirdLife International *et al.*, 2009). The Conservation Action Plan for Botanic Gardens in the Caribbean was developed in 1998, which contains a framework for conservation activities to implement the CBD (Burbidge & Wyse Jackson, 1998). Cuba is developing the Cuban Strategy for Plant Conservation using the 2020 GSPC Targets and also operates a botanic gardens national network. The Cayman Islands produced a Biodiversity Action Plan including Species Action Plans for threatened plants (UKOTs Online Herbarium, 2010). Other islands have adopted an ecosystem approach. For example, the identification of important plant areas in the Cockpit Country (Jamaica), the Jaragua-Bahoruco-Enriquillo Biosphere Reserve (Dominican Republic), and the Centre Hills and Silver Hills (Montserrat). In other instances, conservation strategies implemented are based on a species approach. Kew has developed propagation protocols for some UKOTs plants (Hamilton *et al.*, 2007; Corcoran *et al.*, 2008); an epiphytic orchid was transplanted after a hurricanes in Puerto Rico (Tremblay, 2008); actions plans for 10 Cuban plant species have been developed (Leiva *et al.*, 2008); recovery plans exist for 48 species of

Puerto Rico and US Virgin Islands (US Fish and Wildlife Service, 2010); and a fire management plan for the endemic *Pinus caribaea* var. *bahamensis* (Bahamian pine) has been written (Myers *et al*., 2004).

Target 4 ("At least 10 per cent of each of the world's ecological regions effectively conserved"). Less than 25 percent of the Caribbean (terrestrial) is under some sort of legal protection (see Figure 1; Estrada *et al.*, 2008; WDPA 2010). For instance, Martinique has 69% of habitat protected, St. John (US Virgin Islands) has 62%, and Dominican Republic has 25%. Progress has been good for some islands, but the effectiveness of their protection remains an issue for many islands. A comprehensive estimate of the percent of each ecoregion protected remains to be analyzed, but it was out of the scope for this work.

Target 5 ("Protection of 50 per cent of the most important areas for plant diversity assured"). Progress has been patchy and remains a long way short of protection of 50% of the most important areas of plant diversity. However, several islands including Cuba, Puerto Rico, Turks & Caicos Islands, Cayman Islands, and Montserrat have identified Important Plant Areas (IPA) (Figueroa Colón, 1996; Areces *et al*., 2000; Hamilton *et al*., 2008; Williams, 2009; UKOTs Online Herbarium, 2010).

Target 6 ("At least 30 per cent of production lands managed consistent with the conservation of plant diversity") has neither progressed nor has it been effectively quantified.

Target 7 ("60 per cent of the world's threatened species conserved *in situ*") has been fully accomplished by Cuba under the current protected areas network (Leiva, 2009). In islands with relatively low numbers of threatened plants work is in progress, but the actual conservation status of most of their flora has not been evaluated.

Target 8 ("60 per cent of threatened plant species in accessible *ex situ* collections, […] and 10% of them included in recovery and restoration programmes") has been accomplished for more than 60% of the 48 species listed as endangered in Puerto Rico and US Virgin Islands. Seeds from most threatened species of the Caribbean UKOTs are stored in the Millennium Seed Bank and they are also in cultivation locally. Cuba houses 16% of the threatened plants in *ex situ* cultivation and has reintroduced 75 species through several multi-agency projects (Leiva, 2009).

Target 9 ("70% of the genetic diversity of crops and other major socioeconomically valuable plant species conserved, and associated indigenous and local knowledge maintained") has not been achieved, but perhaps it has not been effectively quantified. For islands where agriculture has been historically important, local universities often maintain a living collection of important crops, and in Puerto Rico, the US Department of Agriculture also houses such collections.

Target 10 ("Management plans in place for at least 100 major alien species that threaten plants […]"). The management of invasive alien species (IAS) in the Caribbean primarily focuses on animal conservation. There has been considerable work to quantify IAS in the Caribbean (Kairo *et al.*, 2003), UKOTs (Varnham, 2005), Dominican Republic, Jamaica, and Bahamas (IABIN Invasives Information Network I3N, 2008), Puerto Rico (Torres-Santana, 2007), and a more recent study of pathways of invasive plants (Meissner *et al.*, 2009). Control of *Casuarina equisetifolia* (ironwood) has been successfully achieved on some offshore keys in Cuba (Matos Mederos & Ballate Denis, 2006) and several alien plant species were controlled in the Virgin Islands National Park (Stocker *et al.*, 2006). A large island-wide project for mammal eradication is being conducted in the Desecheo National Wildlife Refuge in Puerto Rico (J. Schwagerl, US Fish and Wildlife Service, pers. comm.).

Target 11 ("No species of wild flora endangered by international trade") can be considered to be achieved by all islands. CITES has been adopted by most islands and there is little or no international trade in plant species.

Target 12 ("30 per cent of plant-based products derived from sources that are sustainably managed") and **Target 13 ("The decline of plant resources and associated indigenous and local knowledge, innovations and practices** that support sustainable livelihoods **[…] halted")** have neither progressed nor have they been effectively quantified. Dominica is the only island were indigenous populations (Caribs) remain and a forest reserve has been set aside to preserve some of their living conditions and culture (Petersen, 1997).

Target 14 ("The importance of plant diversity and the need for its conservation incorporated into communication, educational and public –awareness programmes"). The amount of work in many local botanic gardens across the region to raise public awareness is noteworthy. Successful efforts are those of Cuba's and Dominican Republic's National Botanic Gardens, and The Queen Elizabeth II Botanic Garden on Cayman Islands.

Target 15 ("The number of trained people working […] in plant conservation increased […]") has progressed considerably in the Caribbean and there are more trained people, but the Plant Conservation Report notes the need for the number of trained plant conservationist to double in the next 10 years (CBD, 2009). The Universities of Havana and Puerto Rico are the only institutions offering doctoral degrees in plant conservation. Cuba has greatly increased the number of trained people in plant conservation. Other local universities offer M.Sc. degrees and more commonly B.S. in biological science, which include botany. Kew has been developing capacity, and building botanical infrastructure in the British Virgin Islands (Clubbe, 2005), as well as in other Caribbean Islands. Red Listing workshops have been offered in Cuba, UKOTs, and Puerto Rico. Additionally, botanists from Jamaica, Cuba, British Virgin Islands, Turks & Caicos Islands, Cayman Islands, Anguilla, Barbados, St. Lucia, and more recently, from Haiti have successfully completed International Diplomas courses in plant conservation offered by Kew.

Target 16 ("Networks for plant conservation activities established or strengthened at national, regional and international levels."). The Caribbean has several regional networks that hold meetings occasionally and discuss topics on plant conservation. These groups include the Caribbean Botanic Gardens for Conservation, Red Mesoamericana de Herbarios, and Asociación Latinoamericana de Botánica. Some botanical gardens are member of Botanic Gardens Conservation International (BGCI) and the Center for Plant Conservation. The UKOTs have established a strong international partnership with Kew. Most islands in the Greater Antilles have also established collaborations with Fairchild Tropical Botanic Garden and the New York Botanical Garden. Other relevant national networks include the Cuban Network of Botanic Gardens and Le Conservatoire Botanique des Antilles Françaises.

Additionally, priority needs and knowledge gaps were identified for some of the Caribbean Islands. They include limited financial resources, understaffing, lack of training and appropriate equipment, important plant areas lacking of adequate protection, ineffective enforcement of environmental laws, limited flow of information, including difficult Internet access, and lack of environmental awareness in the general public. Although there has been a great deal of work conducted in the Caribbean, there is relatively little collaboration among island plant conservationists. We therefore advocate that a regional and global oceanic island plant conservation network should be initiated to strengthen current efforts in island conservation, to share experiences and best practices and to provide a forum for a wider discussion and support.

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Archipelago	Area (km^2)[a]	No of WWF Ecoregions[b]	Spermatophyte genera (G End)[c]	Native vascular plant taxa	SIE taxa (%)
Greater Antilles	**208,062**	**16**	**--------**	**------**	**--------**
Cuba	110,992	6	1,210 (65)	7020[e]	3,474 (49)
Hispaniola	76,420	5	1,103 (33)	6000[f]	2,050 (34)
Jamaica	10,991	3	810 (6)	3304[g]	923 (28)
Puerto Rico & Virgin I...	9,397	6	793 (1)	2585[c,g]	332 (13)
Cayman Islands	264	3	-- (0)	415[h]	29 (7)
Lesser Antilles	**6,477**	**7**	**765 (1)**	**2406[c,i]**	**358 (15)**
Bahamas & TCI	**13,880**	**3**	**507 (0)**	**1145[j]**	**130 (11)**
Aruba-Bonaire-Curacao	**1,067**	**2**	**-- (0) [d]**	**~ 468[g]**	**25 (5)**
Caribbean Islands Total	**229,550 km^2**	**28 Ecoregions**	**1,447 (191)**	**13,000[g]**	**6,984 (54%) SIE 7,868 (61%) RE**

Table 1. Floristic composition and habitat diversity in the Caribbean Island Biodiversity Hotspot. Pteridophytes have not been included in some of these estimates due to the lack of reliable information for several islands. Acronyms in table, G End = generic endemism, TCI= Turks & Caicos Islands, WWF = World Wildlife Fund, SIE = Single Island Endemics (vascular plants), RE = Regionally (Caribbean) endemics. Legend to the superscripts: [a]CIA (2010); [b]WWF (2010), [c]Acevedo-Rodríguez & Strong (2008); [d]van Proosdij *et al*. 2001; [e]Greuter & Rankin Rodríguez (2010); [f]Peguero & Jiménez (in prep); [g]Adams (1997); [h]Proctor (in review); [i]Howard (1974–1989); [j]Correll & Correll (1982).

Island(s) [Sovereignty]	Documenting plant diversity			Conserving plant diversity							Using plant diversity sustainably			Education/awareness	Building capacity	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Anguilla [UK]	2	2	2	2	2	1	2	2	2	2	5	1	1	2	3	2
Antigua & Barbuda	4	4	1	3	2	2	2	2	2	2	2	2	2	4	2	3
Aruba [Netherlands]	5	1	1	2	1	1	1	1	1	1	1	1	1	3	3	3
Bahamas	4	2	2	2	2	2	2	2	2	4	4	2	2	2	2	3
British Virgin Islands [UK]	4	4	3	3	3	1	3	3	3	3	5	1	1	4	4	4
Barbados	4	2	3	2	2	2	2	2	3	2	3	2	2	3	3	2
Cayman Islands [UK]	5	5	4	4	3	1	4	3	1	4	5	1	1	4	4	4
Cuba	4	4	4	4	3	3	5	3	3	4	5	3	3	4	4	4
Dominica	4	3	3	4	3	1	3	3	1	1	1	1	4	4	3	3
Dominican Republic	4	3	3	4	3	2	3	3	1	3	3	1	3	3	3	3
Granada	3	2	3	3	3	1	3	1	1	1	1	1	1	3	3	3
Guadeloupe [France]	5	4	4	4	3	1	3	3	1	3	5	1	3	4	4	4
Haiti	3	2	1	2	1	2	1	1	1	1	1	2	2	3	3	3
Jamaica	4	3	3	3	3	2	3	3	2	4	3	2	3	3	2	3
Martinique [France]	5	4	4	5	4	1	3	3	1	3	5	1	3	4	4	4
Montserrat [UK]	5	4	3	3	3	1	3	3	1	4	5	1	1	4	4	4
Netherland Antilles [Netherlands]	5	1	3	4	4	1	1	1	1	1	1	1	1	4	3	3
Puerto Rico	4	4	4	4	3	3	3	4	3	4	5	3	3	3	3	4
St. Barthélemy [France]	5	4	3	2	2	1	1	1	1	1	5	1	3	3	4	4
St. Kitts & Nevis	4	3	3	3	3	1	1	1	1	3	1	1	3	3	3	3
St. Lucia	5	2	2	4	3	2	2	3	3	2	5	3	3	3	3	3
St. Maartin [Netherlands/France]	5	4	3	2	2	1	1	1	1	1	5	1	3	3	4	4
St. Vincent & The Grenadines	3	1	3	3	2	1	1	3	3	3	1	2	3	3	1	3
Turks & Caicos Islands [UK]	5	4	3	4	3	1	3	4	1	4	5	1	1	4	4	4
US Virgin Islands [US]	4	3	3	5	3	3	4	4	1	4	5	1	3	4	3	3

Table 2. Summary of Caribbean Islands' accomplishments towards the 2010 Global Strategy for Plant Conservation (CSPC). Category numbers (1 to 5) indicate the degree of progress towards the GSPC, being 5 (light green shading) for Target completed; 4 (light yellow) for good progress made; 3 (tan) for target initiated / some progress; 2 (red) for no progress; and 1 (no color) for data not available. Category numbers for St. Maartin include only the French part.

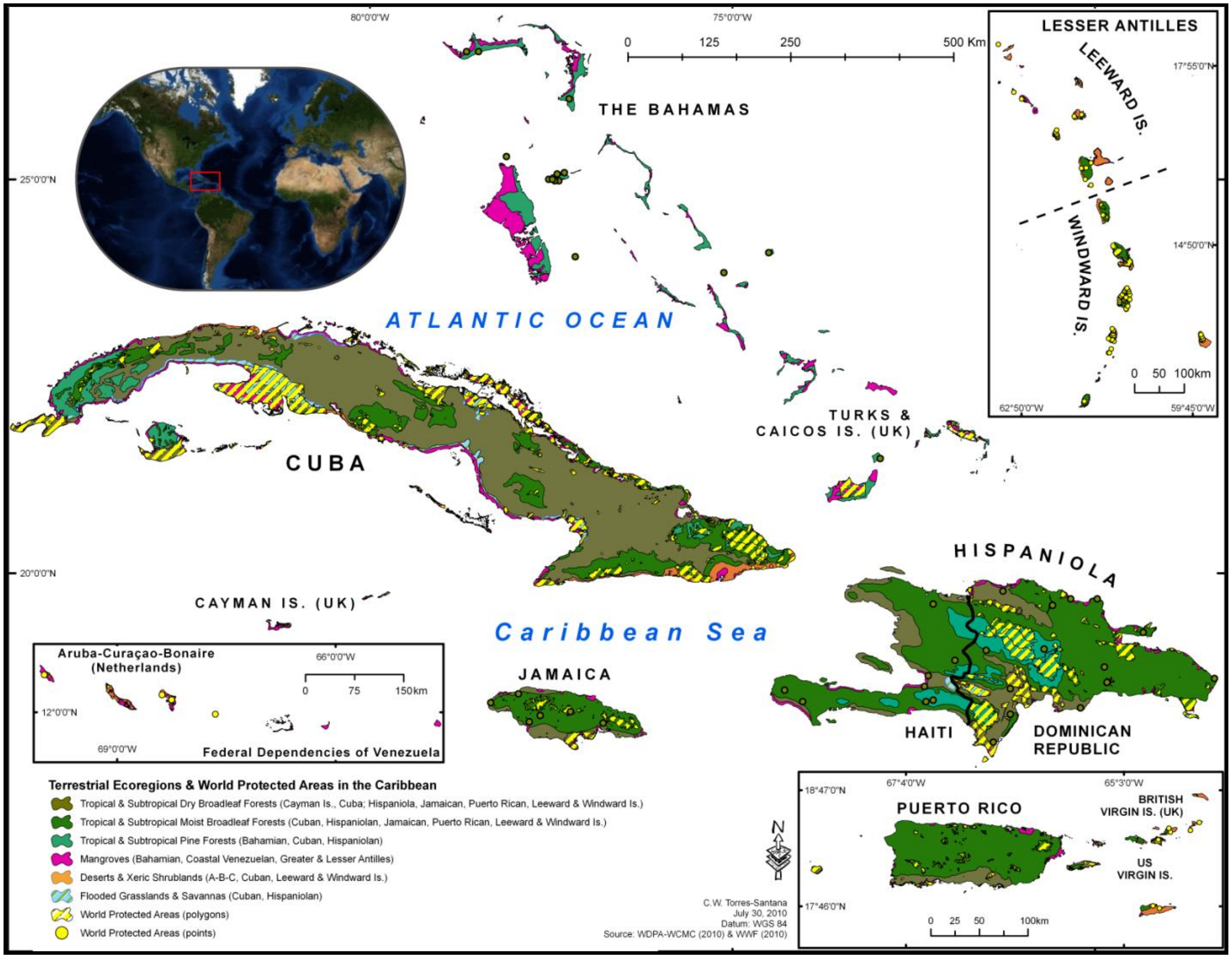

Figure 1. Caribbean Islands' terrestrial ecoregions with the protected areas. The legend represents six Neotropical biomes and each ecoregion is considered to be endemic to each island or island group (except the Coastal Venezuelan mangroves). The Greater Antilles include the Cayman Islands, Cuba, Jamaica, Hispaniola, Puerto Rico and the Virgin Islands. From the legend, A-B-C = Aruba-Bonaire-Curaçao (Netherlands).

The state of plant conservation on Pacific islands

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Abstract

We examine the status of plant conservation in Oceania, where most islands have experienced two waves of anthropogenic habitat alteration and extinction, following Austronesian and European contact. The most important islands for plant conservation are the high volcanic and makatea islands, since atolls carry exceptionally poor native floras with few or no endemics. Knowledge of the status and distribution of Pacific plants is generally poor and based largely on 20th century brief surveys. Few plant species have been Red-listed except where global assessments have been carried out. Among Red-listed species, proportions threatened are exceptionally high, suggesting that species selection for Red-listing has been based on foreknowledge of threatened status. With a few exceptions, the threat factors having impacts on Pacific plants are poorly known, and conservation is often based on inference from evidence gathered elsewhere. Priority actions include more survey, more Red-listing, more studies of threatened species, more conservation management plans and action, establishing a more comprehensive protected area system robust to climate change, more effective networking and increased international collaboration and assistance.

Keywords

Oceania, Pacific, island, plant, conservation, Red-list

In this paper we consider the state of plant conservation on the Pacific islands of Oceania. This excludes Hawaii and the islands of the eastern Pacific that have recently been reviewed by Caujapé-Castells et al. (2010), and most islands belonging to Pacific rim countries, the Philippines and Indonesia. Our review covers islands belonging to 24 countries and territories (American Samoa, the Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, the Marshall Islands, Nauru, New Caledonia, Niue, Norfolk Island, the Northern Mariana Islands, Palau, Papua New Guinea, the Pitcairn Islands, Samoa, the Solomon Islands, Tokelau, Tonga, Tuvalu, US Minor Outlying Islands, Vanuatu, Wallis and Futuna). Oceania covers some 30% of the earth's surface but the land area is tiny and many countries have very small human populations, rendering international cooperation both essential and difficult. Countries with populations of a few thousand rely on such international cooperation to achieve their conservation goals, but communication and skill-sharing across such a large region of small islands is expensive. Most Pacific countries lack sufficient financial resources for effective plant conservation, and with their small human populations cannot be expected to provide comprehensive conservation services unaided. Long-term international financial and technical assistance is therefore crucial.

The main threats to the flora of these islands stem from two waves of human contact and settlement: the early Austronesian voyagers from SE Asia who settled most of the islands of Melanesia, Micronesia and Polynesia, and the European influence of the past 500 years. These brought about habitat alteration through land-use change, direct over-exploitation of a few species and, currently most importantly, two waves of introduction of alien species, with consequent extinctions of native plants and animals.

Three kinds of island carry different kinds of flora in the Pacific. Atolls are low-lying and species-poor. As an example, Kiritimati (Christmas) Island (Kiribati) is the atoll with the largest land area in the world, but has a native vascular flora of only some 19 species. In part this results from most atolls having been submerged during sea-level high-stands during the last interglacial. Makatea islands are raised atolls, with a richer, limestone flora, while the most diverse Pacific island floras are found on high volcanic islands (together with the continental fragment islands of New Caledonia and Papua New Guinea). For example, Upolu and Savai'i, the two main islands of Samoa, together make up about four times the land area of Kiritimati, but carry a native vascular flora of c. 800 species, or 40 times as many as Kiritimati, of which about 30% are endemic to Samoa. Makatea and high volcanic islands are therefore the highest priorities for plant conservation.

Knowledge of the status and distribution of Pacific plants, as measured by the IUCN Red List, is poor, apart from conifers and cycads which have been the subject of a global assessment (Table 1). A recent analysis of the Red List for the Pacific (Pippard 2009) reveals that other global assessments, such as for birds and marine species, have resulted in relatively high numbers of species assessed in Pacific countries (Fig. 1), but that virtually no plants have been assessed in most Pacific countries; exceptions include French Polynesia (155 assessments) and the Melanesian countries of Fiji (132), New Caledonia (278), Papua New Guinea (264), the Solomon Islands (60) and Vanuatu (24), but no other Pacific country has more than nine plant assessments. The number of Red-listed plants is thus low for all countries and for the region as a whole, and there are no comprehensive Red Lists of island endemic plants.

However, among the Red-listed plants, high proportions are threatened (Critically Endangered, Endangered or Vulnerable) (Fig. 2). New Caledonia has the highest proportion of threatened plants in the region (80% of those red-listed), and c. 50% of those listed for Fiji and Papua New Guinea are threatened. Other countries with few assessments have disproportionately high numbers of threatened plants: 100% in the Cook Islands, Nauru and the Northern Marianas, although absolute numbers are small since so few species have been assessed. A conclusion from this is that botanists doing Pacific plant Red-listing have tended to focus on species that they already know or suspect to be threatened.

Our knowledge of the status and distribution of Pacific plants depends largely on checklists and floras of island groups, which were mostly written during the 20th century and often based on short visits by botanists. These data could be used for additional Red-listing but accuracy would be improved by additional survey. We also know little in detail about threats to Pacific island plants. The impacts of the most important threat factors are mostly inferred from landscape scale effects (e.g. land clearance) or studies elsewhere (e.g. invasives impacts). Introduced species are widely considered to be the greatest current threat, but impacts of most invasives, especially plants, are largely unstudied in the region. Further, local-scale effects of global climate change are almost entirely unknown, as global climate models do not permit reliable prediction at the scale of individual islands. Red-list evaluations of threats are therefore often vague at best. The result of this uncertainty and inference is that conservation action is often based largely on parallels: information on threats and conservation needs collected elsewhere. In some cases this is valid, as inference based on landscape-scale changes such as habitat clearance are often obvious, and at least good enough for immediate conservation planning to be carried out with some confidence of success. In other cases, threat effects are obscure and require on-site study to inform the development of adequate conservation plans.

Based on the above, priority needs for plant conservation in the Pacific can be summarised as:

- More survey and floras, especially on high islands and makatea.

- More Red-listing, especially for mosses, algae, ferns, lichens and flowering plants.
- More threat and impact studies and conservation management plans for plants and vegetation communities.
- Down-scaling of climate change predictive models.
- A more comprehensive and representative protected area system, robust to climate change effects.
- Improved networking to maximise learning from experiences elsewhere.

Possible initiatives to improve networking and collaboration include the formation of a global island plant conservation network and a Pacific island plant specialist group within IUCN's Species Survival Commission. Among the species that have so far been Red-listed, there are some obvious candidates for immediate conservation action, while others would benefit from biological study to elucidate threats. Climate change is the great unknown for Pacific islands. Sea-level rise can be confidently predicted to cause the loss of low-lying but species-poor atolls, and probably to bring about a general increase in the frequency and intensity of cyclones, which will cause greater disturbance to the detriment of native vegetation (especially forests) and the probable benefit of more adaptable invasive plants. However a general increase in temperature may translate into different effects at local level, while changes in rainfall patterns across the Pacific are highly uncertain at present. Both temperature and rainfall will bring about changes in vegetation zonation, especially on high islands, but we cannot yet predict what kind of change will occur on individual islands.

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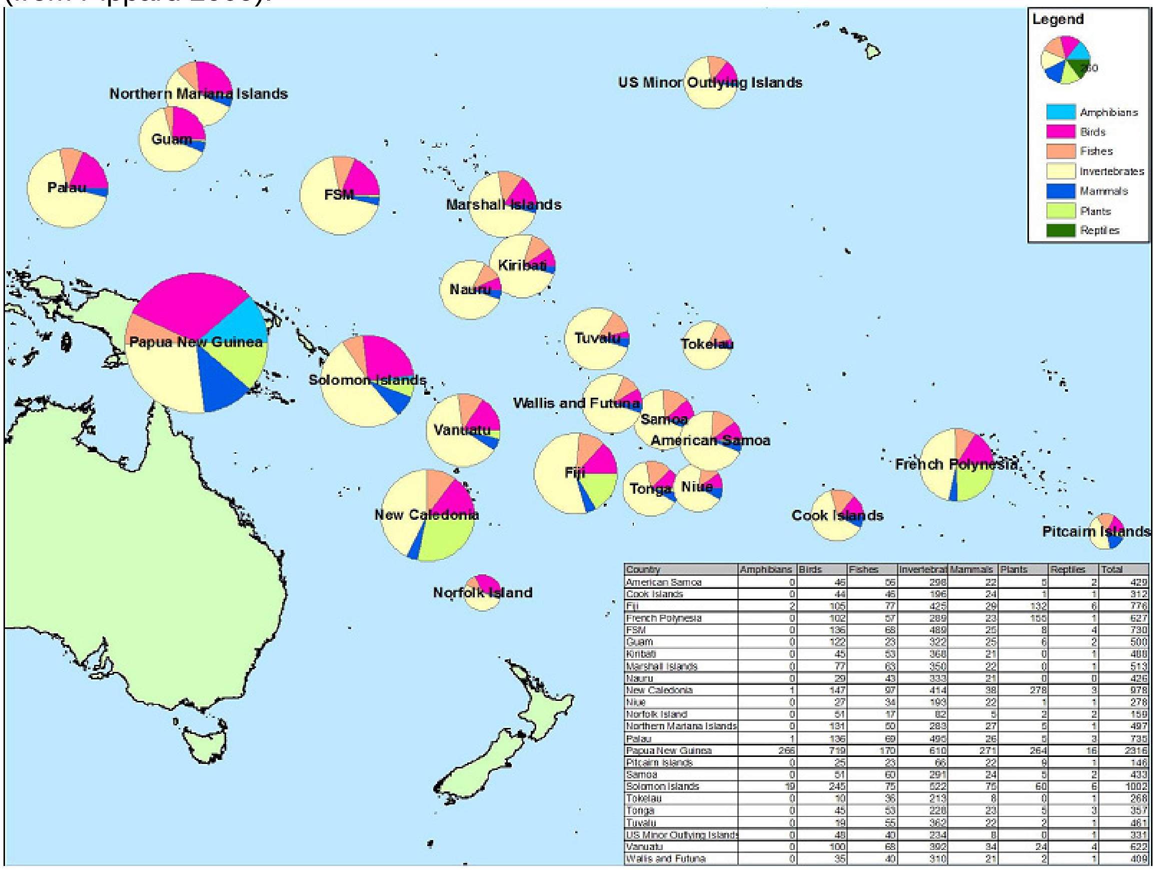
Table 1. Status of plant red-listing in the Pacific (adapted from Pippard 2009).

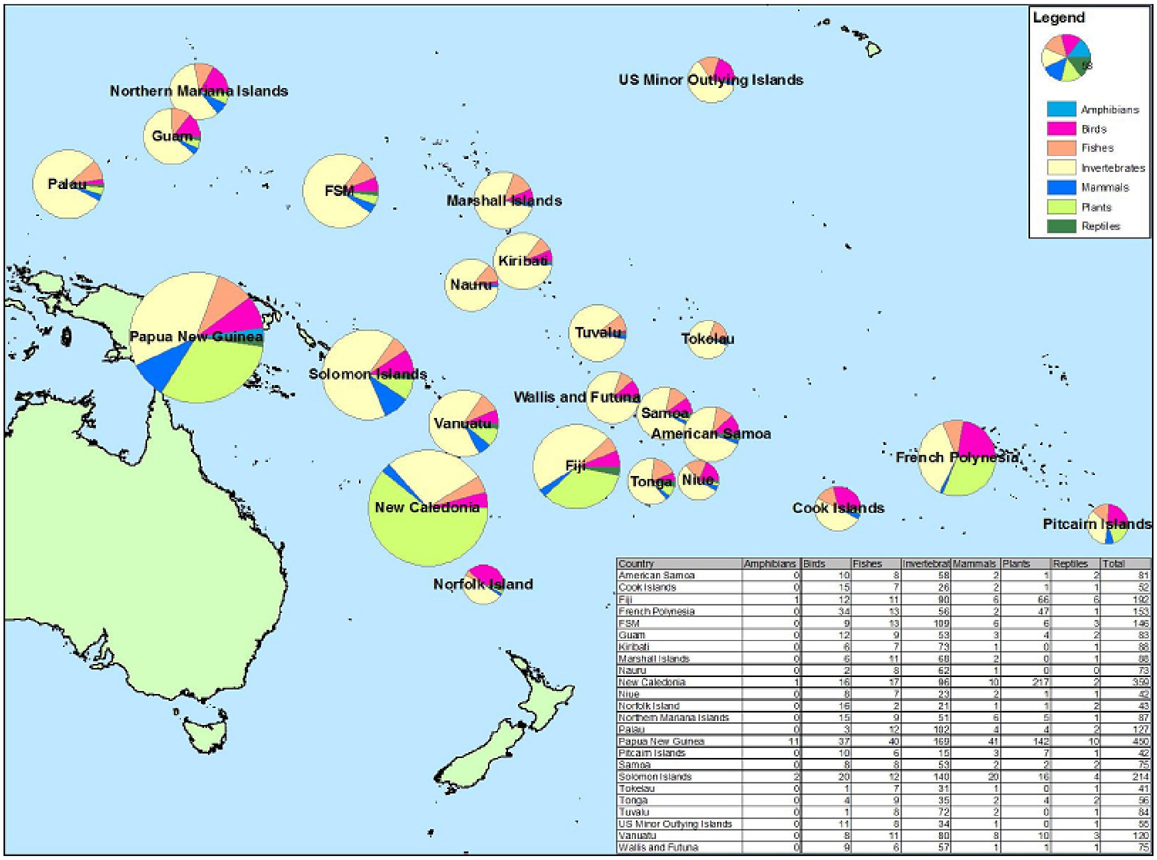
"PLANTS"	Estimated number of described Pacific island species	Number of assessed Pacific island species	Estimated % of Pacific island species assessed
Bryophytes	2650	5	<1%
Pteridophytes	2680	0	0
Gymnosperms	254	96	38%
Dicots (Magnoliopsida)	14138	703	5%
Monocots (Liliopsida)	6087	71	1%
Green Algae	285	0	0
Red Algae	406	0	0
Fungi	2627	0	0
Others	225+	0	0
TOTAL	29352+	875	3%

Figure 1. The numbers of Red-listed species in the Pacific, by country and taxonomic group (from Pippard 2009).



Country	Amphibians	Birds	Fishes	Invertebrat	Mammals	Plants	Reptiles	Total
American Samoa	0	46	56	298	22	5	2	429
Cook Islands	0	44	46	196	24	1	1	312
Fiji	2	105	77	425	29	132	6	776
French Polynesia	0	102	57	289	23	155	1	627
FSM	0	136	68	489	25	8	4	730
Guam	0	122	23	322	25	6	2	500
Kiribati	0	45	53	368	21	0	1	488
Marshall Islands	0	77	63	350	22	0	1	513
Nauru	0	29	43	333	21	0	0	426
New Caledonia	1	147	97	414	38	278	3	978
Niue	0	27	34	193	22	1	1	278
Norfolk Island	0	51	17	82	5	2	2	159
Northern Mariana Islands	0	131	50	283	27	5	1	497
Palau	1	136	69	495	26	5	3	735
Papua New Guinea	266	719	170	610	271	264	16	2316
Pitcairn Islands	0	25	23	66	22	9	1	146
Samoa	0	51	60	291	24	5	2	433
Solomon Islands	19	245	75	522	75	60	6	1002
Tokelau	0	10	36	213	8	0	1	268
Tonga	0	45	53	228	23	5	3	357
Tuvalu	0	19	55	362	22	2	1	461
US Minor Outlying Islands	0	48	40	234	8	0	1	331
Vanuatu	0	100	68	392	34	24	4	622
Wallis and Futuna	0	35	40	310	21	2	1	409

Figure 2. Numbers of threatened species in the Pacific, by country and taxonomic group (from Pippard 2009).



Country	Amphibians	Birds	Fishes	Invertebrat	Mammals	Plants	Reptiles	Total
American Samoa	0	10	8	58	2	1	2	81
Cook Islands	0	15	7	26	2	1	1	52
Fiji	1	12	11	90	6	66	6	192
French Polynesia	0	34	13	56	2	47	1	153
FSM	0	9	13	109	6	6	3	146
Guam	0	12	9	53	3	4	2	83
Kiribati	0	6	7	73	1	0	1	88
Marshall Islands	0	6	11	68	2	0	1	88
Nauru	0	2	8	62	1	0	0	73
New Caledonia	1	16	17	96	10	217	2	359
Niue	0	8	7	23	2	1	1	42
Norfolk Island	0	16	2	21	1	1	2	43
Northern Mariana Islands	0	15	9	51	6	5	1	87
Palau	0	3	12	102	4	4	2	127
Papua New Guinea	11	37	40	169	41	142	10	450
Pitcairn Islands	0	10	6	15	3	7	1	42
Samoa	0	8	8	53	2	2	2	75
Solomon Islands	2	20	12	140	20	16	4	214
Tokelau	0	1	7	31	1	0	1	41
Tonga	0	4	9	35	2	4	2	56
Tuvalu	0	1	8	72	2	0	1	84
US Minor Outlying Islands	0	11	8	34	1	0	1	55
Vanuatu	0	8	11	80	8	10	3	120
Wallis and Futuna	0	9	6	57	1	1	1	75

The critical difference between extinction and survival: *ex situ* conservation of *Encephalartos* species in the Lowveld National Botanical Garden, SA.

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Abstract

Worldwide the cycad flora consists of about 297 species, of which an astronomical 82% are currently listed as threatened. In South Africa the rate is slightly higher – 89% of the indigenous *Encephalartos* species are threatened. In the 1980s the Lowveld National Botanical Garden started a project to collect endangered *Encephalartos* species. Specimens of the same species but from different geographical areas and differing morphologically from each other are housed in separate seed orchards (for example *E. ngoyanus, E. lebomboensis*). The seed orchards are currently well established, with most plants producing cones on a regular basis. The ultimate objective with seed produced from plants in the seed orchards is enhancement or reintroduction in the wild. However, pressures on wild populations and garden collections by irresponsible collectors often prevent success in this regard. The alternative at this stage is to propagate highly sought after species and sell them to the public to relieve the pressure on wild populations. Intensive management and involvement in cycad conservation (*ex situ* and *in situ*) over the past three years have highlighted problems, successes and challenges for the conservation of *Encephalartos* species in South Africa.

Keywords

Encephalartos collections, threatened plants, *ex situ* conservation, Botanical Gardens, South Africa.

The International Union for Conservation of Nature – Cycad Specialist Group - reported in 2003 that 82% of the world's cycad species are threatened with extinction in the near future, while in South Africa, 89% of the 36 recognized species are currently listed as Extinct, Extinct in the Wild, Critically Endangered, Endangered or Vulnerable (IUCN Red List – SANBI 2008). Although the reasons why these ancient seed plants are facing such a bleak future are not unique to South Africa, unscrupulous harvesting of mature plants from their natural habitat for use in landscaping and private collections is the biggest reason for the rapid decline of many species.

The South African National Biodiversity Institute (SANBI) has a network of 9 National Botanical Gardens throughout South Africa. One of them, the Lowveld National Botanical Garden (LNBG) represents the sub-tropical climate of the north-eastern part of the country. During the early 1980's the LNBG has started to intensify collection efforts in the genus Zamiaceae focussing on African and South African species. Soon afterwards the severity of the extinction threat to many South African species were realized, which prompted the LNBG to extend *Encephalartos* collections to be more genetically representative. These collections aimed to be mostly from wild collected seed, but in some instances included plants which were confiscated by conservation authorities from private collectors when it was found to be illegally possessed. *Encephalartos* species obtained for conservation purposes were planted in field gene banks, which are fenced off and for security reasons not accessible to the public. The *Encephalartos* collection has subsequently grown and unfortunately also attracted some unwanted attention, which lead to a series of thefts, which necessitated the use of alarm systems and security guards to protect these valuable collections in LNBG. Currently there are 36 *Encephalartos* species recognized in South Africa; 19 of these are represented in LNBG as viable *ex situ* collections which can be considered to be genetically representative of at least one known locality for each species. A further 9 species are present in LNBG, but although these plants are mature and cone-producing, they are typically small collections and many from unknown localities. The remaining species are represented as single plants, and mostly do not cone on a regular basis.

The initial cycad collections were planted in the cultivated areas of LNBG and are grouped either according to different geographical areas or families. During a new wave of cycad thefts from 2005, Botanical Gardens in SA with significant cycad collections became a target for collectors, and this necessitated the translocation of many valuable species from landscaped areas to the field gene banks where security measures could be installed. The *Encephalartos* field gene bank at LNBG is an extensive open air planting with South African *Encephalartos* species, which have been collected with the aim of establishing viable *ex situ* conservation collections. *Encephalartos* species are divided into different sections, and in cases where a species is represented from more than one geographical locality, these collections are housed separately and are also managed as separate collections to ensure genetic purity. This ensures that the collections can be used for restoration, reintroduction or enhancement when the opportunity arises. Intensive management of the collections in the gene bank includes the simulation of natural phenomena such as wet and dry seasons, as well as fires. Plants from fire climax grasslands are burned on a biennial cycle by covering the plants with dry grass and setting it alight during the fire season which is between August and September. Effective management of the conservation collection is achieved by attaching a label with a unique number to each plant and this is linked to a photographic record and an electronic database. The electronic database includes all the collection information of the plant, accession numbers, GPS reading of the current locality in the garden, sex of the plant, number of suckers, year cones produced, month cones mature, number of cones, and in the case of females – pollination data such as date and method used, number of seeds harvested, number of seeds viable, number of seeds germinated after 1 year. Any other information regarding fertilization, pests, diseases and treatments are also indicated on the database.

As part of the Threatened Plants Project in LNBG, cycad seedlings are propagated on a large scale primarily to satisfy the public demand for these unique plants, but ultimately the aim is the reintroduction of seedlings into the natural habitat once these plants can be safeguarded. The large collection of *Encephalartos* species in a confined area makes it important to intensively manage the plants especially during their reproduction stage to prevent hybridization between closely related species. Hybridization is prevented by taking the following steps:

- Male cones are removed once they reach maturity and start to shed pollen. The procedure for removing the male cone involves cutting the stalk carefully with a sharp knife while ensuring that the cone is kept in an upright position. Once the cone is free, it is laid down on newspaper and stored in a draft-free room for three days to allow all the pollen sacs to open. Pollen is then collected in labelled containers and stored in a fridge at 4°C for up to two years. Stored pollen is used to pollinate female cones in LNBG, and the surplus is made available to the public and the local cycad society's pollen bank.

- Female cones of the genus *Encephalartos* are fully receptive for pollen when the cone scales become loose and this creates a small gap between the scales on the top half of the cone. In nature this allows insects access into the middle of the female cone and by rubbing their pollen covered bodies against the sticky ovaries ensures pollination. The access of insects into the cones is prevented in LNBG by covering the mature cone with a nylon stocking before the cone scales separate. The stockings are left on for up to 3 weeks after artificial pollination was done. During the pollination period, cones are monitored on a daily basis and once the gap between the scales is observed, a small amount of water is poured into the scale opening, if the water runs through the cone and appears at the bottom, the cone is ready for pollination. There are two pollination methods used in LNBG; the first is a wet method, where one teaspoon of pollen is mixed with 100ml clean water and poured into the cone. The second method is a dry method where pollen is blown into the scale openings by using a syringe or turkey baster. The pollination method is repeated twice during the period when the female is most receptive. Where possible females are pollinated with pollen obtained from the male plants of the same geographical area.

- At the first sign of disintegration, the female cones are removed to prevent seed predation by baboons and monkeys. Seed is then prepared for short term storage by removing the fleshy outer layer, and after its has been treated with a fungicide, it is hung in a well-ventilated room until the start of the warmer seasons when the seed is transferred to unheated sand beds in the cycad germination house and moistened with a mist spray at 2 hour intervals. Once the seed has germinated and the radicle has reached a minimum length of 2cm, the seedling is planted into a 4lt plastic plant bag with a soil medium of 50% river sand and 50% compost and placed in the cycad seedling nursery where it is grown on for purposes ranging from sales, landscaping in LNBG or second generation *ex situ* conservation collections.

Revenues generated from the sale of cycad seedlings are used to fund all *in situ* and *ex situ* plant conservation activities in Mpumalanga and it is this project that enables the LNBG to provide valuable *in situ* conservation support to the critically endangered *Encephalartos middelburgensis*. A project proposal was accepted in which LNBG and the local conservation authority, Mpumalanga Tourism and Parks Agency, are combining resources to re-assess all the sub-populations of this species, and based on the results from the assessment, female plants that have become isolated due to removal of mature plants by poachers, are currently artificially pollinated according to scientifically accepted standards. A species action plan for *E.middelburgensis* is being developed which includes an updated species assessment, reports on all sub-populations as well as conservation action recommendations for each sub-population.

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The ecology and population biology of the critically endangered succulent - *Adenium swazicum.*

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Abstract

Southern Africa has large concentrations of threatened species when compared to the rest of the world and although many of these species are represented in nature reserves and protected areas, there is no guarantee of their effective conservation. *Adenium swazicum* is a succulent shrub belonging to the Apocynaceae family and has a near-endemic status ranging from the Kingdom of Swaziland in the south to the province of Mpumalanga, South Africa in the north. The International Union for the Conservation of Nature (IUCN) classified *Adenium swazicum* as critically endangered (CR) in its 2008 assessment, based on an estimated past and future habitat loss of 80% due to agriculture and exploitation of the plant for its medicinal properties. The Lowveld National Botanical Garden (LNBG) has a threatened plants project which is focussing on the ecology and population biology of *A.swazicum* in order to manage both *in situ* and *ex situ* collections effectively.

Keywords

Adenium swazicum, critically endangered, ecology, population biology, medicinal plant, Lowveld National Botanical Garden.

Adenium swazicum is a succulent, deciduous shrub from the Apocynaceae family which was described in 1963 by L.E. Codd (Flora of SA, 26), it has also been known by the homotypic synonym *Adenium boehmianum* Schinz var *swazicum* (Stapf) by G.D. Rowley, as described in the Cactus Succulent Journal (Los Angeles) 46 (4):164.

A.swazicum grows to a maximum height of 1.2m and occurs in low-laying sodic/brackish areas within deep clay soils and has a near-endemic status occurring in Mpumalanga, South Africa and Swaziland. As the common name, Summer Impala Lily implies, the plant produces its striking pink flowers during the summer months, which is from November to April, but it is not uncommon for flowering to continue to May. The IUCN classified *A.swazicum* as critically endangered in the latest IUCN Red List (Riamondo *et al*, 2008) based on past and future habitat loss of 80% with actual and potential levels of exploitation for its horticultural and medicinal properties. Although there have been no scientific studies into the medicinal uses and chemical composition of *A.swazicum,* other species in this genus are widely used for arrow poison (van Wyk & Gericke, 2000). The tuber of *A.swazicum* is extensively harvested throughout its distribution area and personal communication with traditional healers in Nelspruit, Mpumalanga, South Africa revealed that the tuber is boiled and the extract is drunk to cure stomach ailments.
Although most horticultural aspects of *A.swazicum* have been intensively studied, no studies have focussed on its population biology or ecology. As mentioned previously in the near future *A.swazicum* faces a serious risk of extinction outside protected areas, and although the plant occurs in the relative safety of the Kruger National Park, the extent of the population or ecological aspects are currently unknown.

LNBG has a dedicated threatened plants programme focussing on *ex situ* and *in situ* conservation of threatened plants in the summer rainfall areas of South Africa and since *A.swazicum* occurs within the same climatic conditions as the LNBG, this plant has become one of the garden's priority species with a three year monitoring programme focussing on population size and structure, regeneration aspects, biotic and abiotic aspects, as well as *ex situ* conservation research.

The programme was started in 2008 by obtaining historical distribution records from the South African National Herbarium and the herbarium at the Royal Botanical Gardens, Kew, UK. The aim is to conduct a full population count, but only fifty (50) plants in four (4) sub-populations are monitored in terms of the following:

- Plant size and growth: Once a year the height of the plant, maximum canopy diameter, diameter at right angles to maximum canopy diameter, and number of stems are measured to determine canopy cover and canopy volume.

- Regeneration capacity: The average number of flowers per plant per season is determined, as well as the total number of follicles produced. The ratio between flowers and follicles as well as number of seeds released per plant per season is calculated.

- Pollination aspects: The pollinator for the genus *Adenium* is still unknown (Rowly, 1980). Plants in *ex situ* collections at LNBG are not naturally pollinated even if the plants are left exposed. Initial pollinator studies have indicated limited insect activity around flowering plants during the day, and the hypothesis is that the plants are pollinated by a crepuscular insect.

- Determine the regeneration capacity of *A.swazicum*. Three (3) quadrats were established *in situ* to determine the seedling survival rate as well as herbivore impact on seedlings. All three (3) experimental quadrats were planted with 100 *A.swazicum* seeds which were harvested from the same sub-population during the previous seed season. The first quadrat was left exposed and all herbivores (mammals and insects) had access to the seed and seedlings. The second quadrat consisted of a 1m x 1m steel frame which was covered with 30mm poultry mesh to exclude mammals but allow insects access to seed and seedlings. The third quadrat also consisted of a steel frame which was covered with 30mm poultry mesh as well as mosquito net which excludes all mammals and insects. Quadrats were placed in corresponding positions in the veld with the same sun/shade exposure. Preliminary results indicated that less than 6% of the seed/seedlings survived in the exposed quadrat with as much as 57% survival rate in the quadrat which excluded all herbivores.

- Monitoring disturbance – Insect impact *in situ*. Data reveals that *A.swazicum* forms an important part of the insect ecology and is heavily utilized by various insect groups such as the leave beetle *Chrysolina (Naluhia) confluens* who uses the plant as a host species for larvae and adults, and the fruit fly *Dacus frontalis* which was responsible for up to 95% seed predation in 2009.

  With an *ex situ* collection of more than 2,000 flowering *A.swazicum*, LNBG is in the ideal position to test and monitor different disturbance regimes impacting on *A.swazicum*.

The disturbance regimes were conducted to simulate natural impacts such as the occurrence of fire and herbivores. Eighteen plants were selected and the experiments were done in September 2008 to coincide with the natural fire season. Six plants were covered with dry grass and burned to simulate natural fires, six plants were debarked at various scales to simulate the impact of grasshoppers, branches were removed to various degrees and lastly all the above-ground parts were removed from two plants, but the tuber was left undisturbed. In all the experiments, the plants recovered completely with some flowering in the same season.

- Establish propagation protocols. Seeds used for the propagation protocols were obtained from the natural populations as well as from hand-pollinated plants in LNBG. Variables tested included different soil mediums, water regimes, three different depths of sowing, germination success of seed of different ages and shading aspect.

Botanical Gardens have a wealth of experience and expertise when it comes to plants, their propagation and ecological processes. This information can provide essential *in situ* conservation support to many threatened species. Well managed living *ex situ* collections provide invaluable opportunities to determine aspects which are difficult to determine in nature such as optimum germination temperatures, soil medium and the effect of different watering regimes on seed germination and seedling establishment.

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The Open Key Editor: a tool for generating flexible digital identification keys for mobile devices

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Abstract

The Open Key Editor (OKE) is a tool for editing and enriching existing identification keys and to produce localized 'minikeys' that apply to local flora and fauna, such as in parks, nature reserves and school gardens or keys that apply to a particular season. The minikeys are easier to use than their originals, simply because of the fact that they deal with less species, their language can be adapted to a particular audience (e.g. pupils) and because they always point to species that are known to be present. Output of minikeys can be tailored for display on computers, smartphones or PDA's.

Keywords

Biodiversity informatics, field guides, identification software, iPhone, smartphones, PDA.

Introduction

Identification keys are often written by experts and aim at an 'academic' audience. Once they are published, they are more or less carved in stone and leave little room for adaptation to a specific audience, a particular region or season. In the case of plants, such a key can - for instance - encompass 1,900 species for the Netherlands or even 5,000 species for Spain and 6,000 species for Italy. Long keys are complicated and have redundant information when used in a region with fewer species, such as a park or nature reserve, or even a school garden. An increasing number of identification tools is published on the internet (Visser & Veldhuijzen van Zanten; Martellos & Nimis, 2008) offering an opportunity for tailoring them to particular audiences and situations. The Open Key Editor (Martellos *et al.*, 2010) allows users to 'crop' a master key and customize it for a given set of species. The 'cropped' key can then be edited for language and illustrations (e.g. to suit a particular user level, or platform such as a mobile phone).

The Open Key Editor

The KeyToNature *Open Key Editor* is a simple, easy-to-use Open-Source tool for editing and enriching a key with user-generated content. It was developed since June 2009 and is written in the PHP 5.2 language, and runs on a MySQL 5.0 database. The code is Open Source and available under the Creative Commons Attribution Non-Commercial (CC-BY-NC) licence. The programme can import dichotomous and polytomous keys with a compatible structure. It is downloadable since December 2009 from the Web Portal of project KeyToNature (http://www.keytonature.eu), together with sample keys. The current version is 1.1.

With the Open Key Editor the user can browse existing master keys and edit them. The first step in making a customized 'mini-key' is to create a filter: this is a list containing a subset of the species of the main key. Such a list can be made by selecting species from the original key, or by importing a text file with species names from an external source. The filters can be stored for later editing so many mini-keys can be tailored from the same basic dataset. In the Open Key Editor new couplets can be added to the key for identifying species that are absent in the original key.

The unprocessed mini-key will contain three kinds of questions from the original key:

1. valid questions that still separate (groups of) species.
2. questions that used to be like type 1, but now have only a single remaining branch.
3. questions that no longer lead to any species at all.

Questions of type 2 and 3 will have to be removed. Once a filter is defined, the programme starts with the species that were removed and traces them back in the key until it encounters a question that is still relevant. All questions downstream are ‘dead wood’ (type 3) and will be removed. The application repeats this process with the remaining species in order to find questions of type 2. When it encounters a question that no longer separates at least two species, the question is removed from the decision tree, but its parent and child questions are connected in a new branching pattern. Because there is a chance this new branching pattern will also contain questions of type 2, the whole process is reiterated until no more changes have to be made. The result is a key in which only questions of type 1 remain.

Special problems are reticulated keys. These are keys in which a question branches to another part of the key that is not ‘downstream’ of the present node. This problem is solved by controlling the creation of loops and unravelling them during the processing of the key.

The Open Key Editor can generate ex-novo a virtually unlimited number of ‘filtered’ keys from a single ‘master’ key. After filtering, the ‘cropped’ key becomes a separate entity, which can be edited independently from its master counterpart. All text from the key and the species descriptions can be edited or translated, while maintaining the structure of the key. A filtered key can be made available on the web, or given to a user for further editing. Any changes in texts or illustrations of a filtered key will not interfere with the original master key.

Identification keys can be used at home or in a laboratory, but they can be also used in the field, while exploring the biodiversity of an area. The Open Key Editor can export the master key, or any of the filtered keys, in the form of stand-alone packages. The stand-alone versions can be stored on CD- or DVD-ROMs, or used on mobile devices, such as PDA’s and smartphones like the Apple iPhone or Google Android. These devices, when equipped with a camera, can be also used to enrich the key with original pictures.

Discussion

With the Open Key Editor, existing identification tools can be modified and their use can be made much easier by removing species that are absent from a particular region or season. Text of keys and species descriptions can be edited or translated so as to adapt them to user groups like pupils. Modified keys can be turned into stand-alone applications for computers, websites, smartphones or PDA’s.

A key with 50 common species is much easier to use than a ‘true’ flora with thousands of species. This is enhanced by the fact that all the species in the key will be present in the field, park or school garden. As a result, motivation among pupils will be higher when they actually identify a species.

In the case of smartphones, exciting new possibilities emerge with the introduction of GPS receivers. Now it will become possible to use location data for identifying species within a certain area.

Acknowledgements

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Pupils using a customized identification key on a smartphone.

Hortus botanicus Leiden **and** ***Hortus Botanicus Amsterdam*** **- two modern interpretations of renaissance gardens, a comparison**

Gerda van Uffelen and Hanneke Schreiber

Abstract

The *Hortus botanicus Leiden* and the *Hortus Botanicus Amsterdam* are among the oldest botanic gardens in the Netherlands. Documentation of their earliest history in the form of both written and printed source material is available for both gardens. Based on these historical sources, both the *Hortus botanicus Leiden* and the *Hortus Botanicus Amsterdam* recently chose to recreate their original gardens. This has led to two new, exciting and beautiful gardens with many similarities, but also with distinct differences. Whereas in Leiden a detailed reconstruction was laid out, Amsterdam opted for a modern interpretation. This comparative study gives insights to the contemporary use of old sources, creating new opportunities to learn from each others choices and experiences. Moreover, comparison of both gardens illustrates shifts from traditional collecting and teaching methods toward a focus on modern education, research and conservation.

Keywords

Source material, Reconstruction, Interpretation, Comparative study, Hortus botanicus Leiden, Hortus Botanicus Amsterdam

History and modern times

The origin of modern botanic gardens is often traced to European gardens known as *physic gardens*, the first of these being founded during the Italian Renaissance in the 16th century. The *Orto botanico di Pisa*, established in 1544 as part of the *Università di Pisa*, and known as the worlds' oldest botanic garden, housed a collection of medicinal plants. This emphasis on medicinal plants changed in the second half of the 16th century, when the introduction of new plants from different parts the world initiated the establishment of botany as an autonomous science.

The *Hortus botanicus Leiden* is the oldest botanic garden in the Netherlands. It was founded by the University of Leiden in 1590, on a site obtained from the Town of Leiden, under the condition that it would become a public garden. First planted in 1594, it has been a public garden from the start, intended to show a collection of medicinal plants; it was planted as a garden for education, research, and for the enjoyment of plants as well.

Almost 50 years later, in 1638, the *Hortus Botanicus Amsterdam* was established, not as part of a university, but as an early municipal act of public health care. The garden and its plants were intended to instruct and test local pharmacists, so that the quality of their work would meet the standards of the Amsterdam Pharmacopoeia as laid down by the Town of Amsterdam.

Both the Leiden Hortus and the Amsterdam Hortus recently decided to recreate these early gardens. Present day importance of the heritage of the respective gardens, rich source material and the public interest in plants lead to a wide scope of interesting botanical and historical stories to tell. These are stories about early renaissance science, about people and their passion for plants, about local or international plant networks, about human interaction with nature and about the plants themselves. In many ways these stories relate to present day issues concerning plants, nature and biodiversity.

Stories to tell

In both the early Hortus Leiden and the Hortus Amsterdam the quality of the garden and its collection greatly depended upon a few individuals with a strong passion for plants.

In Leiden it was several years after the foundation of the University that the Board of Leiden University was able to attract one of the most renowned botanists of the day, Charles de l'Écluse or Carolus Clusius (Arras, 1526 – Leiden, 1609 - fig. 1). He was the first Prefect of the garden, and as such responsible for assembling extensive plant collections in Leiden. He was assisted by a well-known pharmacist, Dirck Outgaertsz. Cluyt or Theodorus Clutius (? – Leiden, 1598), who at one time owned a pharmacy in Delft, which provided the herbs employed in the embalming of William of Orange, who was murdered in 1584. Together they established a garden with a collection of 1,585 records (ca. 700 species), of which a precise plan and plant list was presented to the Board of the University in February 1595. The collection consisted of many Dutch wild plants, European wild plants, garden plants and exotic plants. The collection distinctly marked the transition from a medicinal collection to a botanical collection.

A few decades later, a similar transition is evident in Amsterdam. Here it was Johannes Snippendaal (Amsterdam, 1616 – 1670) who was appointed Prefect of the *Hortus Botanicus Amsterdam* in 1646. In his first year he managed to publish two catalogues, the first one in the spring of 1646, with a total of 330 plants. In the fall of that same year a second catalogue was printed, containing 796 names, about 700 species. Of these 700 species only 280 were used for instructing and testing the local pharmacists. They are mentioned in the *Pharmacopoea Amstelredamensis*, which in 1636 was initiated by the renowned (Leiden-trained) Amsterdam physician Nicolaes Tulp (Amsterdam, 1593 – 1674). Tulp is better known nowadays as the central figure in one of the most famous pictures by Rembrandt, *Anatomy Lesson of Dr. Nicolaes Tulp* (1632). As the pharmacopoeia defined the first (medicinal) plant collection of the Hortus, it looks like Snippendaal immediately started collecting everything he could put his hand on: Dutch wild plants, European wild plants, trees (both indigenous and exotic), decorative plants such as *flore pleno* and *flore duplo*, and species from North and South America. The presence of salt-tolerant, local plants indicates that Snippendaal, just like Clusius in Leiden, went out into nature to collect plants. Snippendaal was dismissed in 1656, possibly because he added too many non-medicinal plants to its collection.

Apart from numerous historic tales about these gardens and their position within 17th century local and international society, the collections also have relevance in present times. Today medicinal plants and wild plants are often found in the spotlight: many important plant issues, like plant utility and phytotherapy, red list species, and biodiversity relate to these plant groups. Also, they are among the most recognisable and therefore accessible plants for the public.

Finding new forms for original gardens

In recreating these original gardens, a main issue was the availability of source material (table 1), which in Leiden is abundant, and in Amsterdam relatively scarce. In Leiden, the richness of detailed information on the early garden, its plants and people, combined with the fact that the original location of the garden was available, led to the choice of a complete reconstruction. The reconstruction was named after Carolus Clusius (figure 1). In 2009 the new *Clusiustuin*, being a *hortus conclusus*, opened its gates and since then gives the public a full historical experience, with the feel of renaissance botany. The location is strongly embedded in the history of Leiden and its university. The garden itself shows many plants in their exact 1594 position, in a layout which is 2/3 of its original size. The garden is surrounded by *Fagus sylvatica* hedges and 16th-century-style fences; several 17th century style ornaments have been constructed from early drawings (figure 2).

As noted above, in Amsterdam there were fewer primary sources. The location is not the original one (in 1682 the Hortus moved to its present location), there is no known plant plan or a garden plan. Only the alphabetical list of plants (figure 3) and a short description of the garden exist (table 1).

Based on this material, a reconstruction was not obvious. However, there was another reason for not aiming at a reconstruction: more important was the consideration that this new garden, transformed as it were, needed to fit the world and the Hortus of today. This is expressed by the new layout which, however based on the 1646-description, is entirely contemporary, as are the materials that were used (figure 4). The open relation to the surrounding garden is reinforced by the absence of fences or hedges and in the continuity of gravel paving. As such this new garden is naturally embraced by the Hortus, in the same manner as the past is part of the present. The absence of an original plant plan gives opportunity for flexibility in plant order and temporary theme beds. The accessibility for the public is emphasised by raised plant beds, bringing the public in close contact with the plants.

In both cases the project was preceded by thorough research. In Leiden, the initiative provided by the complete original plant list and garden plan as applied will be further explored. Other contemporary plant lists pertaining to the Leiden botanic garden (1592-1611) are available for future study and enrichment of this one theme.

In Amsterdam the Snippendaal list was scientifically translated to current taxonomy and a relation was made to the *Pharmacopoea Amstelredamensis*. The richly documented relationship between the garden and municipal healthcare gives fascinating insights into early 17th century municipal struggles with public health care.

Both Leiden and Amsterdam keep strictly to the original plants list and prefer not to plant modern cultivars. They use – wherever possible - plants of known wild origin, as these probably look like the original plant material, and may also be used for research purposes. It will always be hard to get the complete set of plants mentioned in the lists, as much material is not easily available, and many old cultivars have disappeared.

The Snippendaal plant collection is part of the Dutch National Plant Collection (SNP).

Education and research

Both gardens were once erected as collecting and teaching facilities. Nowadays no medical or pharmaceutical students are found there. In the Clusius Garden and the Snippendaal garden the teaching of students gave way to general awareness and education; 17th century research of the natural world changed into research of historic sources.

The new Clusius garden and Snippendaal garden both aim at a general public: general information panels, individual plant labels, website information, and guided tours are available for both gardens, as are several publications.

Through their website the Leiden Hortus participates in social media and they momentarily explore the possibility of RFID-chips, in order to make digital plant information available on the spot. Future Clusius garden themes focus mainly on the detailed historic data; they vary from 17th century botanic science, to early garden architecture, a story about tulips, etc.

In the Snippendaal garden more attention will be given both to local 17th century health care (like recipes from the pharmacopoeia), and to non-medicinal plants and themes like forgotten vegetables, toxicity, and the use of wild plants. While Leiden continues to do more research (modern interpretation of other available sources), Amsterdam will focus on presenting their plant list in more and different contexts.

A comparison between both gardens learns that there are many possibilities to give space to heritage in our present time. Furthermore, through mutual knowledge of these recreations both gardens can learn from each other's choices and sharpen their own identity. The public and the gardens will benefit from further exchange.

Acknowledgements

We thank Michael Saywer for his assistance with the English language.

Table 1. Primary source material of the botanic gardens of Leiden and Amsterdam, as used for the new Clusius Garden (2009 - Leiden) en Snippendaal Garden (2007 - Amsterdam).

Hortus	Date	Primary source	Source information
Leiden	1594	*Index Stirpium terrae commissarum sub extremum Septembrem anni 1594 in Lugdunensi Academiae apud Batavos horto,* Clutius & Carolus Clusius, Leiden.	Detailed plant list together with a detailed plant plan. Some plant groups nowadays we still recognize as taxonomic groups, such as the genera *Rosa*, *Paeonia* and *Tulipa*, the families *Apiaceae* (Umbellifers), *Asteraceae*, *Malvaceae*, and the ferns, were planted together, as are the plants collected on Crete, and plants with similar names, such as *Heracleum sphondylium* (*Branca ursina vera*) and *Acanthus mollis* (*Branca ursina*).
	1601	*Hortus Publicus Academiae Lugduno-Batavae. Eius ichnographia, descriptio, usus* Pieter Pauw, Leiden.	Printed list of plants in the Hortus, plus a plan to be filled in by students – one of these copies is kept in Leiden.
Amsterdam	1646	*Horti Amstelodamensis Alphabetico ordine exhibens eas, quibus is instructus fuit, atque, quibus auctior factus est, stirpes*. Johannes Snippendaal, Amsterdam.	Plant list in alphabetical order. A general description of the layout is mentioned in the introduction, "*Also a plan of this public place is added, spatially divided in squares, beds and flower beds*" . No detailed plant plan, unknown plant order. No tulips.

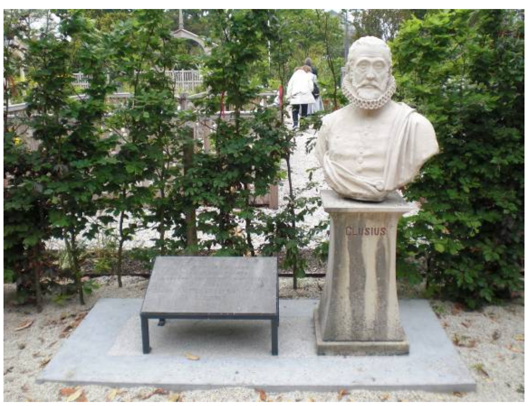


Figure 1: the bust of Clusius and a plaque commemorating Cluyt (present situation).

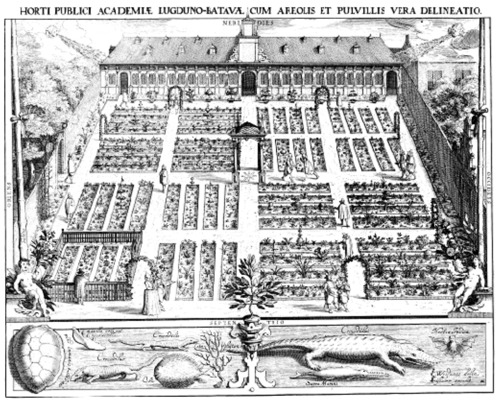
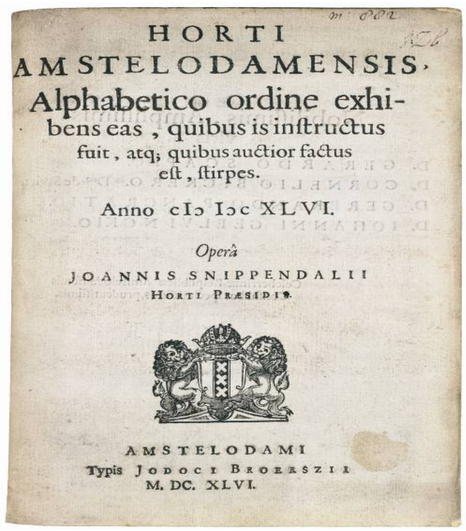


Figure 2: engraving of the *Hortus botanicus* Leiden by Woudanus (1610).



HORTI
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M. DC. XLVI.

Figure 3: frontispiece plant list Hortus Botanicus Amsterdam, J. Snippendaal, 1646, University of Amsterdam, University Library, Special Collections.

Figure 4: the public connects easily to the plants, Snippendaal garden, 2010.

Re-growth of vegetation, colour and landscape complexity: the role of design in the interpretation of natural systems in botanical gardens.

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Abstract

This paper addresses the question of how visitors' interpretation of ecosystems can be maximized based on the design of plant displays. Responses to natural landscapes were studied at the Royal Botanic Gardens Cranbourne, Australia, where fire is used to conserve remnants of indigenous ecosystems. People's preferences for, and verbal descriptions, of these landscapes were subjected to content and statistical analysis which found that three key features influence people's perceptions the most. These are the *re-growth of vegetation*, *colour* and *landscape complexity*. Results suggest a series of design strategies for improving visitors' interpretation of the processes associated with the various stages of ecological landscape change. Findings also suggest the need of integrating notions of scenic and ecological aesthetics into the display of natural systems displays.

Keywords

Botanical Gardens, Fire, Landscape design, Landscape Perception, Plant Displays

Introduction

This study was aimed at exploring visitors' experience of plant exhibits displayed in botanical gardens and their effects on environmental interpretation. A review of plant displays from over 25 botanical gardens around the world which focused on the conservation of biodiversity revealed that botanical gardens are exhibiting new types of plant displays (Villagra, in press). Plant displays were observed as being re-shaped due to a desire to improve the conservation of biodiversity and develop more positive educational experiences and people-plants relationships (Monem, 2007; Oldfield, 2007). While some botanical gardens are introducing artificial objects, such as local materials and features in their exhibits to increase people's familiarity and engagement with plants, others display plant communities in a more natural environment to assure habitat development. Indeed, more than 200 botanical gardens around the world are involved in the management of natural areas to conserve biodiversity (Oldfield, 2007).

However, unlike visitors to zoos, aquaria and other organizations with environmental education objectives, visitors to botanical gardens visit plant exhibits with an interest in recreational activities, such as reading, walking and the contemplation of nature (Neilson, 1985; Schroeder, 1991; Wringley, 2003). Enriching the understanding of the conservation of biodiversity seems not to be within visitors' aim (Ballantyne *et al.,* 2008) which raises the question of whether visitors feel attracted to botanical gardens with a conservation focus. Conservation practices maintain the health of ecosystems; however, in the process, they change the way landscapes look. Plant species grow, blossom, fruit, reseed, decay and die in a recurring cycle that shapes the landscape in ways that visitors might find either attractive or unsightly, creating misunderstanding (Davis, 1996). This type of more naturalistic exhibit is one in which plants are displayed in their natural habitat, either naturally or artificially made and are subjected to disturbances (e.g. fire, drought and strong winds) which are part of life cycles.

What are the landscape attributes that impact people's interest in these new exhibits? What are the meanings people ascribe to these more naturalistic displays? These enquiries were addressed in a PhD study undertaken by the author of this paper in the University of Melbourne, Australia, between 2006 and 2009. This study of people's responses to plant displays confirmed the findings of many previous perception studies. Specifically, three key variables - *vegetation regrowth*, *colour* and *landscape complexity* - were identified as being especially significant, and it is the effect of these variables on visitors' perceptions that is discussed in this paper in more depth.

The Study: Royal Botanic Gardens Cranbourne, Australia

The study was focused on the display of plants in the reserve area of the Royal Botanic Gardens Cranbourne (RBGC). The RBGC is located in southeast Australia, near the city of Melbourne and since 1995 fire management practices in the form of prescribed burns, have been introduced in the reserve with the aim of preserving 363 hectares of native bush, among other purposes. In Australia, like in many other areas of the world, fire effects (e.g. smoke and heat) are necessary for the sprouting of seeds and reshooting of dormant buds, among other aspects related to the conservation of natural habitats (Bradstock *et al.,* 2002).

Biodiversity has successfully increased after the use of fire in the RBGC; indeed, various orchids which had been unseen for years are today growing on site. However, the burns have also revealed to visitors new landscape scenes. Fire effects have created a mosaic of burnt, unburnt and semi-burnt landscapes which are in constant flux. How people perceive this type of display was explored by interviewing experts in fire management practice as well as visitors to botanical gardens in different cultural settings, such as Australia and Chile (Villagra-Islas, 2009). Fourteen different sites of the RBGC were burnt in autumn 2007 and were photographed monthly for a year. This photographic material (N=84) illustrated landscape change before and after the burns, including the scenes of burnt landscapes taken days after the fire and landscape scenes in the process of regrowth during the first, second, third, sixth and twelfth months after the fire. Photographs were used to ask people (N=187) about their preferences and the similarities they observed among the depicted landscapes. A mix-method approach was used to find relationships among landscape configurations, preferences and landscape meanings. Such relationships were illustrated in 'preceptual maps', or two and three dimensional graphs used to illustrate and interpret people's responses to landscapes, obtained after subjecting the data to multivariate analyses techniques available in the SPSS software version 15.

Figure 1 – Landscape changes observed over time at the Royal Botanic Gardens Cranbourne

Some of the photographs used in the study. The three lines of photographs show three types of landscape changes that occurred over time after the landscape was burnt. From left to right: before the fires, three days, six and 12 months after the fires. From top to bottom: the effects of high fire intensity, low fire intensity and moderate fire intensity.

The interpretation of the perceptual maps suggested nine key variables that impact people´s responses; one was associated with the intensity of the burns; two variables were associated with people's familiarity with the site and their knowledge of the effects of fire in fire-dependant environments; and six were linked to the characteristics of landscapes that change. In the following paragraphs three of these characteristics, the *regrowth of vegetation*, *colour* and *landscape complexity*, are further discussed.

Regrowth of Vegetation

This variable is associated with the amount of vegetation observed in landscape scenes, particularly that observed in the understorey. Most scenes which before the fire were closed due to overgrown vegetation which impeded the view of the background were least preferred by visitors, along with those scenes which after the fire depicted a bare ground. In contrast, landscape configurations which after fire and over time had a visible ground cover were highly preferred.

Previous studies have also observed that characteristics of the vegetation such as presence of undergrowth, age and growth rate are more influential on people's responses than other types of landscape elements (Anderson *et al.,* 1982; Daniel, 2006; Vining & Merrick, 2006). Similarly in this study, several landscape scenes received a different preference value over time due to visual changes in the undergrowth. Highly preferred scenes with artificial elements such as a fire track - most probably seen by people as reference to human presence within a natural setting – were least preferred over time. After the vegetation grew back and covered the middle and upper storey, the view of the background and of such artificial elements was obstructed; hence, these landscapes were less preferred. Such decrease in preference values most probably occurred because the track was not visible anymore; thus, landscape legibility, related to people's capacity of finding their way in the landscape, might have been lost. Legibility can highly increase preference for landscapes and arises when the landscape has distinctive elements, such as a track in this case, that allows people to create a memorable image and understand the environment (Kaplan *et al.,* 1998). The opposite situation occurred in this case after the vegetation grew over the track in large amounts.

Colour

Colour was a key variable in understanding people's responses, specifically in relation to its effects on the meanings landscapes convey. Previous studies have found that green, yellow and red colours, lighter over darker tones, and colour compositions without black colours can evoke positive feelings in people (Kaufman & Lohr, 2004; Da Pos & Green-Armytage, 2007). The same studies explain these results as being due to an evolutionary predisposition to prefer landscape aesthetics that are associated with productive seasons (Orians, 1980), and that was probably the case here.

Recently burnt landscapes which are achromatic, meaning that they depict only black and white colours associated with the ash and charcoal of the burns, were described as 'dead' and 'ugly'. In contrast, landscapes with a diversity of colours including a predominant amount of green and yellow colours of the vegetation and a light blue colour of the sky received a high preference value. Indeed, six to twelve months after the burns, in several scenes a large amount of dark and brown colours as well as the bright green and yellow colour of new leaves could be seen, and as a consequence, preference values increased dramatically. This type of effect suggests that the amount and type of colour as well as the distribution of colours needs to be of consideration in plant displays. Colourful types of landscape configurations, with predominant bright green colours conveyed 'pleasure' to most of the respondents. Landscapes with high sky visibility in a light blue colour additionally conveyed 'calmness' and 'peace' and scenes with predominant bright yellow colours in the understorey were also associated with 'happiness'.

Figure 2 - Colour Changes over One Year Time Frame.

This photograph was manipulated using the Photoshop software to illustrate changes in colour that occurred over one year in the most preferred landscape scene. The view at the centre depicts the characteristics of the most preferred colour configuration.

Landscape Complexity

In this particular study, landscape complexity was associated with the amount and distribution of elements observed in the scene and its effects on accessibility. Landscapes with overgrown vegetation and lack of openings were preferred the least. For those who had knowledge about fire practices these landscapes restricted the capacity to undertake management practices as well as increased fire danger. For those with less expertise, such as visitors from Australia, complex landscapes restricted the scenic view. For those who had less knowledge about fire ecology and less familiarity with the site, complex landscapes additionally restricted the development of recreational activities; for the Chileans, complex landscapes impeded the capacity to 'walk' through the gardens, to 'take photographs' and to 'lie down'. Overall, landscapes which over time showed a semi-open configuration, depth of view and at the same time a semi-enclosed space in the foreground area from where to observe the background scene were the most preferred of all.

High preferences for semi-open landscapes have been a recurrent finding in the literature on landscape perception (Gobster, 1994; Sommer & Summit, 1995; Kaplan *et al.,* 1998). Appleton's and Orians' theories suggest that characteristics of savannah-type environments, semi-open areas with scattered trees, such as those observed in this study, are highly preferred. Orians' (1980) habitat theory suggests that humans prefer these landscape types because they provided our ancestors advantages for survival, and several scholars support Orians' premise by explaining that landscape preferences for such type of landscapes have been maintained over time. Savannah landscape types seem to be preferred by contemporary humans due to an innate predisposition for life and life-like processes (Kellert & Wilson, 1993).

According to the prospect and refuge theory of Appleton (1996), people prefer savannah-lands which provided possibilities to see and to hide. The complexity of landscapes was also associated in the study discussed in this paper with the distribution of acacia-like trees, or trees with branches spreading from the bottom, observed in savannah-environments and used by our ancestors to hide from predators and guard their territory. Landscapes with acacia tree shapes placed on the side of the view were the most preferred regardless of respondent's personal values, cultural backgrounds and interests.

Key Findings

The study provides two key ideas that can extend our understanding of visitors' perceptions of plant displays in botanical gardens with a focus on habitat conservation. First of all, the study suggests that the characteristics of certain landscapes with vegetation on the ground cover, depth of view, brighter and contrasted colours (especially green and yellow) and semi-open areas are more preferred by people regardless of their previous knowledge and experiences of those landscapes. Second, visitors to botanical gardens include a wide range of people with different interests and experiences, therefore, their verbal responses to landscape vary according to their socio-cultural backgrounds. Visitors' descriptions of landscapes in the RBGC were found to vary with respect to aesthetic, ecological and utilitarian values. On the whole, although certain landscape configurations can be equally preferred by people with different personal values, both the most and less preferred settings convey different meanings, mostly depending on peoples' familiarity with landscapes and their expertise in landscape management practices.

A Dynamic Mosaic: Scenic and Ecological Aesthetics

The need of integrating both scenic and ecological aesthetics into natural systems displays is proposed here with the viewpoint of making botanical gardens more sustainable. According to Gobster (1999), scenic aesthetic is that which appeals to the pleasure of looking at nature and elicits positive emotions in people, in contrast, an ecological aesthetic reveals the dynamics and life stages associated with natural processes and arises from knowing the landscape is ecologically fit. The study discussed here suggests that plant displays within botanical gardens with a conservation focus sometimes look 'ugly', sad and unpleasant to the eyes of unexperienced visitors. These settings can be seen as 'messy', 'dull' and 'old' creating in visitors, aesthetics which are far from suggesting a scenic aesthetic. Hence, the experience in these landscapes can elicit negative responses in visitors with the possible subsequent effect of reducing their interest in the gardens and therefore limiting the interpretation process (Tilden, 1977).

To overcome this situation, a dynamic mosaic for botanical gardens which mixes a scenic and ecological aesthetic, is proposed. This mosaic derives from the skills and collaborative work of botanical garden managers and landscape designers. The layout of such dynamic mosaic should be defined with respect to the effects of ecological management practices and include a flexible pathway system. This scheme can provide a diverse circulation system which can vary while the gardens grow and change. This system will also have resting areas such as lookouts where colour diversity and high colour contrast can be assured. If it is not feasible to add colour by using natural elements, artificial colourful elements could be integrated into the display with the aim of making the landscape more attractive, less complex and more legible. A set of complementary and temporary displays can contribute in this case. These exhibits should also be considered throughout the garden with the objective of educating visitors about landscape change. Visitors should be aware, for example, that the process of making attractive landscapes includes the death and decay of plants as well as the blossoming of flowers and growth of fruits. Finally, it is relevant to include in the gardens a series of environmental education tools. Signs, workshops and guided tours should be incorporated with the aim of increasing familiarity and knowledge with both the management activities taken on site and the life cycle of natural systems under exhibit.

Conclusion

The approach to understand people's perceptions of plant displays which was presented here can provide useful information about the physical attributes of landscapes that impact people's responses positively or otherwise. These can be used in the landscape design of plant displays with a conservation focus and with the aim of making landscapes more appealing. Creating attractive and interesting displays can be seen as the first step in achieving the environmental education goals of botanical gardens. Plant displays which elicit a positive response from visitors can assure attracting visitors to the gardens and thereon, further strategies can be explored to educate them about plant-people relationships and the process involved in ecological landscape change.

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The Mexican living cycad collection at the Jardín Botánico Francisco Javier Clavijero, Xalapa.

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Abstract

Over the last 30 years Mexico has increased its cycad flora by over 300%, from 12 species known in the late 1970's to over 50, due to botanical explorations into previously unexplored areas and has positioned Mexico as second worldwide for cycad diversity. Parallel to field explorations a living collection was built up at the Francisco Javier Clavijero Botanic Garden known as the National Cycad Collection now completing its 30th anniversary. It is the most comprehensive documented living cycad collection in Latin America and includes some species from old world genera. Research has been largely systematic with recent molecular phylogenies based on the collection in the genera *Ceratozamia* and *Dioon* as well as DNA bar-coding. Improvement in cultivation techniques such as use of native *arbuscular mycorrhizal* fungi and root pruning experiments aimed at sustainable management projects promoted and assessed by the Garden.

Key words

Botanic Gardens, Cycadales, DNA-Barcoding, Mexico, Meso-America, Systematics, Zamiaceae,

Introduction

The cycad collection began before the Jardín Botánico Francisco Javier Clavijero (JBC) was established with *Dioon edule* accession 1975-002 being the second plant accessioned at the Garden collected by the author. The decision to build a living cycad collection was mainly to complete the Flora of Veracruz fascicle on the cycad family Zamiaceae owing to the scarcity of reproductive structures on plants in the field (Vovides *et al*., 1983). The cycads were cultivated in a makeshift backyard greenhouse (Fig. 1.) and when coning occurred the descriptions could be completed. Plants were later transferred into better greenhouses at the JBC that were inaugurated in February of 1977. Since 1980 the collection grew into what is now the National Cycad Collection and is registered with the Mexican Botanic Gardens Association. The Collection holds representatives of the known species of Mexico and also at least one species of the remaining world genera (Table 1, Fig. 2.).

Aims and objectives

The principal aims of the Collection are to supply living material for research and *ex situ* conservation, for botanic garden extension and outreach to schools, the general public and conservation authorities. Also for assessment to rural communities engaged in propagation of cycads aimed at sustainable management. These activities cover Articles of the Convention on Biological Diversity (Given, 1997), *ex situ* conservation in country of origin (Article 9), education and awareness (Article 13) and technical and scientific collaboration (Article 18). Many plants previously held in greenhouses are now established in outside plantings of the JBC (Fig. 3.).

Conservation through propagation

Based on ecological studies (Vovides, 1990), as well as germination trials at the Garden, the first rural cycad nursery at Monte Oscuro, Veracruz, was established for the propagation of *Dioon edule* in 1990. The farmers who own cycad habitat were given talks and invited to take part in a sustainable management project where hands-on basic horticultural training was given. The nursery is the forerunner of similar nurseries established in other Mexican states under the auspices of the national conservation authorities that license them (Vovides *et al*., 2002). Though much has to be solved, especially marketing, we have noticed a growing interest in cycads among landscape architects and it is becoming fashionable to use native plants in residential estates, hotels and municipal landscaping (Fig. 4).

New cultivation techniques

Pruning of principal root

The pruning of primary roots of *D. angustifolium* seedlings encouraged development of multiple primary roots and more fibrous roots. This method, developed by Dehgan & Johnson (1987) who used growth regulators was found to be successful with *Zamia floridana.* We varied this technique by inoculating with native arbuscular mycorrhizal fungi on previously root-pruned *D. angustifolium* seedlings.

Inoculation with native arbuscular mycorrhizal fungi (AMF)

When *D. angustifolium* seedlings were inoculated with AMF two years after principal root pruning a faster growth rate was noted compared to the control plants ($P = 0.019$). This technique encourages faster growth and better container handling of plants. Though still experimental, it is being adopted in the Monte Oscuro nursery (Vovides *et al*., in press).

Identification of AMF in cycads

Knowing that AMF is beneficial to cycad growth (Vovides, 1991: Fisher & Vovides, 2004) we isolated AMF in cycad species covering the three genera, *Ceratozamia mirandae*, *C. matudae*, *Dioon merolae* and *Zamia soconuscensis* grown in native soil. Multiple AMF species were found on the cycads that ruled out AMF specificity in cycads, which is in agreement with the literature for other plant groups. The following six AMF species were identified; *Acaulospora denticulata*, *A. scrobiculata*, *A.* aff. *delicata*, *Glomus claroideum, G. fulvum* and *G. microaggregatum* (Hernández et al., in press).

Systematics

There has been an unprecedented increase in cycad species in Mexico since the 1970s when only about 12 species were known to 54 species described to date. This is an increase of over 300%. This is due to the renewed interest in cycad biology and taxonomy by national and international botanists coupled with extensive field explorations and collections to enrich the living cycad collection at the JBC. Nineteen of these new species descriptions were based on specimens in the National Cycad Collection (Table 2.). For species described up to 2002 see Whitelock (2002) thereafter see (Avendaño *et al*., 2003; Gregory *et al*., 2003; Pérez-Farrera *et al*., 2007; Vovides *et al*., 2008a,b; Nicolalde *et al*., 2009).

Historic collection at National Botanic Garden, Glasnevin, Ireland

David Moore, curator of the National Botanic Gardens 1838-1879 acquired a *Ceratozamia* from Cuba that he tentatively named *C. fusca-viridis* in 1878 a year before his death. The origin of this species has since remained a mystery (no ceratozamias are native to Cuba) however Dr. Dennis Stevenson found a voucher at Kew that connected this name to a plant at Glasnevin. This plant is still in cultivation at the Garden and has been so for over 130 years, which speaks very highly of generations of horticulturists at the National Botanic Garden for keeping alive a specimen for so long. This plant was compared to living specimens collected recently in Mexico and has cleared up a vexing taxonomic problem on the identity of *C. fuscoviridis* (Osborne *et al*., 2006).

Cytotaxonomy

The living collection at the JBC has been used for research into chromosome numbers and karyotypes in cycads. Many of the Mexican species have been karyotyped based on the collection and the entire genus *Ceratozamia* is currently undergoing karyotipification. Somatic chromosome number and overall karyotype morphology in *Ceratozamia* is very stable typically 2n = 16, but in *Zamia* chromosome number and morphology is very variable mainly due to fusions and or fissions known as Robertsonian changes see (Vovides, 1983; Moretti & Sabato, 1984; Vovides & Olivares, 1996; Jones, 1977, 1998).

Anatomy

Old techniques and traditional tools that can still provide new information are useful to complement modern techniques in systematics. The Collection is used to explore potential anatomical characters that can help resolve problems of species relationships in cycads. Techniques such as histochemical staining, bright field microscopy, epiflourescence microscopy, Nomarsky differential interference microscopy and scanning electron microscopy are being used.

An example of this is the separation of *Ceratozamia brevifrons* from synonymy with *C. mexicana.* Only the description by Miquel exists of *C. brevifrons* and no type has so far been found. A small population of ceratozamias that fit the Miquel description have been found in central Veracruz. These were compared with *C. mexicana* and several morphological differences have been noted as well as a distinct leaflet anatomy that differs from that of *C. mexicana*. A neotype for *C. brevifrons* is being assigned.

Phylogenies

A molecular phylogeny hypothesis on the genus *Ceratozamia* using nuclear ribosomal DNA ITS and chloroplast *trnL-F* DNA non-coding region have generated a tree with a topology that agrees with the Pleistocene floristic refugia hypothesis as well as with species complexes based on gross morphology. Two main branches, one above or north and another below or south of Mexican Transition Zone divided taxa. Though resolution for all species was not obtained a deeper understanding of the biogeography of *Ceratozamia* was obtained (González & Vovides, 2002).

A molecular phylogeny of *Dioon* also reflected biogeography and morphology where the tree consists of three clades, two of which separated species from the Atlantic seaboard, the *Dioon edule/angustifolium* group from eastern and northeastern Mexico and the larger *Dioon spinulosum/rzedowski/mejia* group from southeastern Mexico and

Honduras. A third clade contained species from the Pacific seaboard and central Mexico. Species from both seaboards in their northerly distributions mirror each other by presenting narrow leaflets and small seeds (González *et al*., 2008).

DNA Barcoding

A promising and novel technique for species identification that has potential for use in law enforcement to control traffic of endangered and threatened species. However identification at 100% certainty has not yet been achieved for plants including cycads. The National Cycad Collection at the JBC has been barcoded using the recommended loci for plants. No unique loci exists for species identification, however using a combination of two to four loci up to 79% certainty has been achieved for *Dioon*, 78% for *Ceratozamia* and 75% for *Zamia* (Table 3). Much work is still needed to improve on this largely searching for new loci. Not withstanding, for CITES purposes that only require genus identification for most cycads, this technique appears to be very promising (Nicolalde *et al*., 2010).

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Table 1. The Mexican National Cycad Collection at the Jardín Botánico Clavijero

Families	**Genera**	**Species**	**Plants**
3	**10**	**96**	**1805**

Table 2. New Species Descriptions Based on Material in the National Cycad Collection since 1980

GENUS	**No. Species**
Ceratozamia	**12**
Dioon	**2**
Zamia	**5**

Over 300% increase in cycad flora since late 1970s

Table 3. Comparative performance of number of species uniquely identified of the various combinations of loci used, after character-based DNA barcoding analyses with the CAOS software (Sarkar et al., 2008).

Combination of loci	***Ceratozamia***	***Dioon***	***Zamia***
psbK-psbI	4/23 (17%)	8/14 (57%)	12/24 (50%)
psbK-psbI + atpF-atpH	9/23 (39%)	11/14 (79%)	15/24 (63%)
psbK-psbI + atpF-atpH + rpoC1	9/23 (39%)	11/14 (79%)	16/24 (67%)
psbK-psbI + atpF-atpH + rpoC1+ rpoB		1/14 (79%)	
psbK-psbI + atpF-atpH + rpoC1+ matK	12/23 (52%)		
psbK-psbI + atpF-atpH + rpoC1+ matK+ITS	18/23 (78%)		
psbK-psbI + atpF-atpH + rpoC1+ ITS2			18/24 (75%)

From Nicolalde et al. (2010) *Cladistics* **26** (on-line)

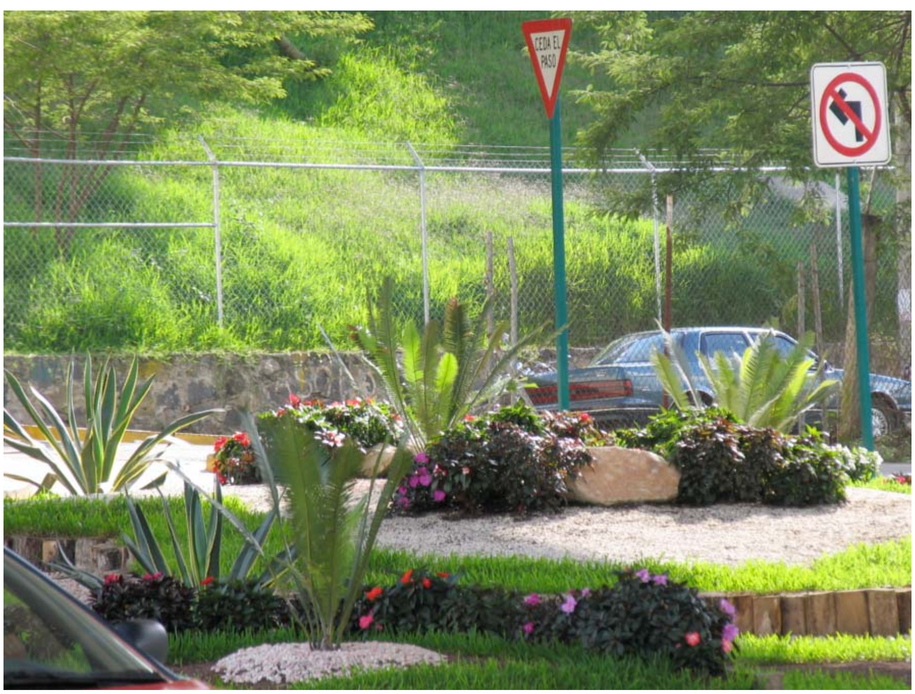
FIGURES

Fig 1. Makeshift greenhouse housing the first cycad collections prior establishment of the Botanic Garden.

Fig. 2. Present day greenhouse for the national cycad collection at the Botanic Garden.

Fig. 3. Outside plantings of the cycad collection at the Botanic Garden.

Fig. 4. Roadside municipal landscaping in Xalapa with *Dioon edule* produced at the Monte Oscuro nursery.



Safeguarding China's botanical heritage: BGCI's integrated conservation programme in China

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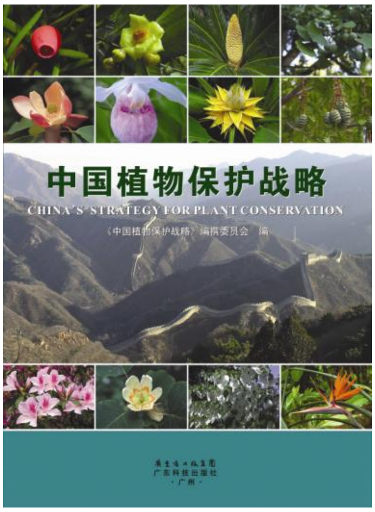
Abstract
China's rich floral diversity includes more than 31,000 vascular plant species, representing 10% of all known plant species. Over half of these species are endemic to China. However, China's rapid economic development in the last 30 years and continuous population growth has seriously damaged plant resources and the ecological environment, resulting in over-exploitation of plant resources and a dramatic increase in the number of endangered species. There are nearly 4,000 to 5,000 higher plants that are now threatened or on the verge of extinction. To help halt the loss of Chinese plant diversity, BGCI opened its first office based in Guangzhou in 2007. This office works along with Chinese partners securing Chinese plant diversity through integrated conservation approach, reintroduction/population reinforcement, engagement of local communities to conservation activities, capacity building in horticulture and environmental education and public outreach.

Key words

Capacity building; Integrated conservation; Local community; Reinforcement; Reintroduction

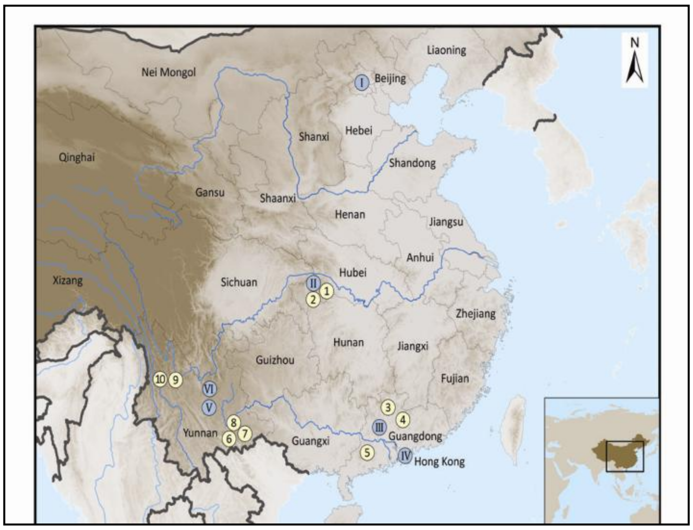
Introduction

China's rich floral diversity includes more than 31,000 vascular plant species, representing 10% of all known plant species. Over half of these species are endemic to China. However, China's rapid economic development in the last 30 years and continuous population growth has seriously damaged plant resources and the ecological environment, resulting in over-exploitation of plant resources and a dramatic increase in the number of endangered species. There are nearly 4,000 to 5,000 higher plants that are now threatened or on the verge of extinction.



BGCI was instrumental in bringing together three state agencies to create the China's Strategy for Plant Conservation (CSPC) which balances the development needs of China with its conservation imperatives. To assist in the implementation of CSPC, BGCI opened its first ever office in China in 2007. This office working along with Chinese partners are implementing the CSPC especially focusing on the targets 7 and 8, securing *ex situ* collections and restoring wild populations of critically endangered and endangered trees in China.

BGCI's work in China



BGCI China projects location map

BGCI's integrated conservation projects in China currently comprise as many as 30 rare and/or highly endangered species, such as *Bretschneidera sinensis*, *Dipteronia dyeriana*, *Davidia involucrata* or *Euryodendron excelsum*, as well as a number of other species, including magnolias, oaks, maples, and rhododendrons.

In situ conservation in Zhi-ben-shan Mountain, Yunnan province

Ex situ conservation of Davidia involucrata

BGCI seeks to promote the active involvement of all relevant stakeholders in its conservation programmes enabling them to voice their needs. Fostering dialogue among local communities, and authorities from local to national levels is significant to define locally appropriate conservation and management approaches. Local level stakeholder workshops form the basis to decide on and sanction conservation action such as species reintroduction and population reinforcement programmes.

Through attending BGCI's local level workshop, local people realized the importance of protecting plants and established their own threatened plants nursery and applied grants from other funding resources successfully with the help of BGCI project leaders.

	
Consultation with local community	Local people established their own nursery with the help of BGCI project leaders

Building a comprehensive collection of Ash germplasm

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Abstract

This paper summarizes a presentation from the Congress Symposium, "The Introduction of the Emerald Ash Borer in North America, A Case Study of Invasive Species Epidemiology and Conservation of the Host Species." It briefly discusses the state of *Fraxinus* (ash) taxonomy, ash as a landscape and forest tree, some of its specialized uses, including those by Native Americans, and its role in supporting other organisms. The devastation caused to native, North American ash populations by the introduction of *Agrilus planipennis* (emerald ash borer; EAB) to the Detroit, Michigan area has already led to the loss of tens of millions of trees. Diverse efforts are underway to document and slow EAB's spread and develop appropriate biological controls. Scientific research on ash-EAB interactions, including the study of potential tolerance or resistance mechanisms, breeding and genetic-diversity analyses, and ash systematics, would all benefit from access to well-documented, diverse ash germplasm. To help redress this unfolding biological tragedy, a collaborative, international effort to conserve these important genetic resources has been organized. Fortunately, ash is amenable to *ex situ* conservation through seed storage and cryogenic storage of dormant winter buds. Key partners in this effort are described herein, with a focus on the coordinating organization, the USDA-Agricultural Research Service's National Plant Germplasm System, along with a summary of progress to date and future plans.

Keywords

Agrilus, Emerald ash borer, *Ex situ* conservation, *Fraxinus*, Invasive species, Seed collection

An introduction to Ash, its value, and Emerald Ash Borer

Fraxinus is a member of the Oleaceae with winged fruits, consisting primarily of temperate, deciduous trees and shrubs, including ±60 species native to the Northern Hemisphere. Ash diversity is highest in China (22 species; Wei & Green, 1996) and the United States (16 species; USDA-ARS, 2010a). In the absence of a modern monograph for *Fraxinus*, however, such information can only be gleaned from floras. Fortunately, future efforts to develop a modern monograph should benefit from the recent phylogenetic analyses of Wallander (2008), who used nuclear ribosomal ITS sequences to study 40 *Fraxinus* taxa, and the work of Guy Neson, who is preparing a treatment of *Fraxinus* for Flora of North America.

In eastern North America, there are six native *Fraxinus* species (Fernald, 1950) under threat of functional extinction by the exotic insect pest, *Agrilus planipennis* (emerald ash borer or EAB), introduced from Asia to southeastern Michigan, probably in the 1990s (Siegert *et al.*, 2007). EAB adults feed on ash leaves, with larvae feeding on cambial tissue in ash stems and trunks. Female EABs oviposit on both healthy and stressed ash trees (Poland & McCullough, 2006), and there is no documented resistance among these six ash species to larval feeding, which ultimately leads to the death of the infested trees. Larvae commonly infest and kill both mature trees and juvenile saplings (Hermes *et al.*, 2009a). This phenomenon severely reduces opportunities for the evolution of increased tolerance to EAB and may hasten these species' extinction.

Two native *Fraxinus* species, *F. americana* (white ash) and *F. pennsylvanica* (green ash), are extensively cultivated and widely appreciated as stress-tolerant landscape trees (MacFarlane & Meyer, 2005). Many communities in the north central U.S. have overused green ash along their streets, leading to situations where it forms a significant proportion of the urban forest (Raupp *et al.*, 2006). Green ash also has a long and extensive history of cultivation as one the most commonly used trees for windbreaks in the Great Plains (Hoag, 1965). In garden settings, only a few selected staminate clones of white and green ash have generally been planted, which presents special challenges for the *ex situ* conservation of these species as noted below.

In addition to white ash and green ash, *F. quadrangulata* (blue ash) and *F. profunda* (pumpkin ash) also grow to sufficient size in forests to facilitate commercial harvest for timber and wood products. But beyond ash as a general timber commodity, ash wood has a diverse range of specialized uses. White ash wood exhibits a combination of strength and flexibility that makes it especially well suited for tool handles and as the first choice for professional baseball bats (Gasner & Widmann, 1990). Ash wood is also being crafted into artistic furniture and bowls.

Ash wood has also traditionally been employed by Native American communities in the north central and northeastern U.S. and eastern Canada (Schmidt, 1990). *Fraxinus nigra* (black ash) logs are laboriously pounded, and long thin strips of wood, known as splints, are removed layer-by-layer and trimmed. The splints are then woven to make a wide range of both utilitarian and decorative baskets.

These ash species occupy a wide range of ecological niches in eastern North American forests. Green ash has an especially wide geographic range from the Atlantic Coast west to the foothills of the Rocky Mountains and from the Gulf of Mexico north to the Canadian Prairie Provinces. Its wide distribution is mirrored by its broad ecological amplitude, occurring in seasonally flooded, floodplain and lakeside habitats, all the way to dry upland forests. White ash has nearly as wide a native range, but is generally restricted to fairly well-drained, mesic forests. Black ash is found in northern wet or boggy forests, often associated with *Picea* (spruce) and *Larix* (larch). Blue ash is associated with alkaline or calcareous soils, in a more limited geographic range in the central United States with outliers in Ontario, typically occurring in rocky, limestone woodlands. Pumpkin ash and *F. caroliniana* (Carolina ash) are typically found in or near standing water in the southern United States, growing with *Taxodium* (bald cypress) and *Nyssa* (tupelo).

In addition to the general ecological services that native ash trees contribute by providing food and shelter for wildlife, they also support a suite of at least 70 native specialist arthropods (Gandhi & Herms, 2010). Such species include *Tethidia barda* (brown-headed ash sawfly), *Lignyodes* sp. (ash seed weevil), *Aceria fraxinifolia* (flower gall mite), and 21 species of North American butterflies and moths (Wagner, 2007) affected by EAB's spread and the resulting death of millions of trees.

The spread of Emerald Ash Borer and potential controls

Since its North American introduction, EAB has been expanding via both natural dispersal and human assistance. Of the two, human-mediated dispersal is the more serious, in that it facilitates long-distance movement and the establishment of new infestations beyond the primary detection network (Poland & McCullough, 2006). This initially happened via the transport of nursery stock, wood products, and firewood. Today, firewood movement remains the most serious concern, as it is difficult to control through regulation. The spread of EAB is being diligently tracked by an extensive network of traps and regularly documented through the online publication of maps (Emerald Ash Borer, 2010).

In the wake of EAB, tens of millions of ash trees have already been lost (Smith *et al.*, 2009), with billions of dollars invested in tree removal, disposal (to prevent EAB reproduction), and replanting. But potential future economic losses are even greater, considering that the estimated number of remaining ash trees is as high as 8 billion (USDA-APHIS, 2010). When facing these huge costs, it is clear that investments to slow the spread of EAB serve two functions. First, they limit the annual economic burden to landowners and governmental agencies (Sharov, 2004; Poland & McCullough, 2010). Second, they buy time towards the effective deployment of biological control strategies, new treatments, and the potential development of resistant/tolerant ash trees.

There are many EAB-response strategies being implemented; a detailed enumeration is well beyond this paper's scope. Some of the most important, especially for the near-term, include the refinement of effective EAB trapping (Francese *et al.*, 2009; Marshall *et al.*, 2009) and monitoring systems (Careless *et al.*, 2009), the use of quarantines (USDA-APHIS, 2006) on the movement of ash nursery stock, timber products and firewood, accompanied by extensive public-education campaigns such as Don't Move Firewood (2010), the development of insecticide treatments to protect high-value trees (Herms *et al.*, 2009b), and research to identify, test, and introduce biological control agents (Bauer *et al.*, 2009; Gould *et al.*, 2009; USDA-APHIS, 2010). From a more long-term perspective, studies on the evaluation, mechanisms, and genetic control of host-plant resistance in Asian ash (Eyles *et al.*, 2007; Rebek *et al.*, 2008; Mason *et al.*, 2009), and on the potential tolerance of surviving native ash in highly infested zones (Koch *et al.*, 2010) are critical, as are tests of interspecific ash hybridization (Koch *et al.*, 2009), genetic transformation in ash (Pijut *et al.*, 2010), and investigations of genetic diversity, breeding systems and structure in extant populations (Hausman *et al.*, 2010). These efforts hold the promise of an eventual revival in planting ash as a landscape tree and of the re-introduction of ash populations to native forests.

The need for Ash germplasm

Research is focused on the host plant should advance more quickly with reliable access to well-characterized ash germplasm. *Ex situ* germplasm collections, if well designed, can provide a wealth of genetic diversity for economically and ecologically important traits, and supply known sources of clones and populations to serve as scientific controls or checks. But as we entered this crisis, *ex situ* ash germplasm collections in the U.S. were poorly developed. In 2002, there were no recognized ash collections among North American botanic gardens in the North American Plant Collections Consortium; ash provenance collections previously assembled by foresters were neglected or entirely abandoned (Steiner & Lupo, 2010); and the U.S. National Plant Germplasm System (NPGS) conserved only a few ash collections.

At that time, among other curatorial functions, I served as the NPGS curator for *Fraxinus*. As EAB spread and losses mounted, I began to consult other researchers and agencies concerned about this gap in *ex situ* conservation. At that time, the USDA-Natural Resources Conservation Service's Rose Lake Plant Materials Center began to mobilize volunteers to collect ash seeds in Michigan (USDA-NRCS, 2010). The U.S. Forest Service National Seed Laboratory initiated seed collections within its agency and with numerous partners (USDA Forest Service, 2010). The Canadian Forestry Service expanded efforts to collect native ash seeds for the National Tree Seed Centre (Natural Resources Canada, 2010). And within the NPGS, I began planning a series of domestic seed-collection expeditions and established contacts with the Morton

Arboretum and Beijing Botanic Garden to plan Chinese collection trips, designed to sample potentially EAB-resistant ash populations. In addition to the parties noted above, other botanic gardens, state forestry and natural resource agencies, and Native American communities became involved in the collection effort. It was quickly apparent that clear communications and interagency coordination were needed. At a 2009 meeting of interested parties held in Annapolis, Maryland, I agreed to serve as coordinator. In March 2010, I chaired a second meeting at "The Symposium on Ash in North America" in West Lafayette, Indiana, to prepare for the 2010 field season.

Taking on this role was a logical move in that the NPGS is the lead organization within the U.S. for the *ex situ* conservation of genetic diversity of economically important plants and their wild and weedy relatives (Widrlechner, 2009). It has extensive collections and supports considerable research on germplasm conservation protocols. NPGS collections are freely available for research and educational purposes world-wide, and information about the collections is widely disseminated online through the Germplasm Resources Information Network (GRIN) database (USDA-ARS, 2010a).

Assembling and conserving Ash germplasm collections

Fortunately, ash populations can be effectively conserved as seeds with orthodox storage characteristics (UK Forestry Commission, 2010), and clones cryogenically preserved as dormant buds (Volk *et al.*, 2009). Field plantings can also be maintained, if sufficient land is available and trees can be protected from EAB by geographic isolation and/or the effective use of systemic insecticides. Our initial focus has been on the assembly of comprehensive seed collections. To accomplish this, we must ensure good initial seed quality (embryo development and weevil infestation are important limitations, see seed-collection guidelines by Knight *et al.* (2010)), proper taxonomic identity (supplemented with herbarium vouchers), complete passport data, and effective sampling strategies. Ideally, samples should be diverse enough to allow us to preserve genetic profiles over future generations without inbreeding depression. To maximize overall diversity and the capture of genes conferring local adaptation, it is crucial to avoid areas with significant numbers of cultivated, staminate ash trees that can bias local pollen deposition and focus on sites with established natural populations.

On a broad scale, our sampling strategy is conducted on an individual-species basis, focusing on regions that are being colonized by EAB, stratified by plant-community diversity as reflected in Omernik Level III Ecoregions (Omernik, 1987; US Environmental Protection Agency, 2010). A new website for this conservation project has recently been developed (USDA-ARS, 2010b), which details the sampling strategy and presents current protocols.

Beginning in 2007, the USDA-ARS Plant Exchange Office has supported yearly ash seed-collection trips. Successful trips were conducted in New England in 2007, Missouri and southern Illinois in 2008, and Wisconsin and northern Illinois in 2009. Trips to Minnesota and Wisconsin and to Kansas, southern Missouri, and northern Arkansas are planned for 2010. Because of wide year-to-year fluctuations, summer reconnaissance trips to assess variation in local ash seed production and identify optimal populations for fall collection have proven quite helpful.

These collections and those of many collaborators are being incorporated into the NPGS. All these collections are being conserved at the National Center for Genetic Resources Preservation in Fort Collins, Colorado, with many of the best documented and representative samples being incorporated into the active collection at the North Central Regional Plant

Introduction Station in Ames, Iowa, which I curate. Table 1 lists the number of *Fraxinus* accessions in the active collection by species and continent.

Acknowledgments

I'd like to thank Frank Telewski for organizing this Congress Symposium, Jeffrey Carstens for his enthusiastic help with ash conservation and for map preparation, David Ellis and Chris Carley for images, Andrew Gapinski, Kathleen Knight, and Frank Telewski for their useful critiques, and Mack Shen for technical assistance with my PowerPoint presentation.

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Table 1. Current *Fraxinus* accessions (by species and continent) conserved at the North Central Regional Plant Introduction Station, Ames, Iowa, USA, as of 1 July 2010.

Species	North America	Asia	Europe	Africa
F. americana	61			
F. angustifolia		1	7	
F. anomala	6			
F. bungeana	1	7		
F. chinensis		23		
F. excelsior			14	
F. "hybrid"	2			
F. insularis		1		
F. latifolia	1			
F. mandshurica		10		
F. nigra	15			
F. ornus	1		10	
F. paxiana		3		
F. pennsylvanica	77			
F. profunda	6			
F. quadrangulata	12			
F. raibocarpa		1		
F. sieboldiana		2		
F. "sp."	6			1
F. stylosa		2		
F. xanthoxyloides		1		
Total	188	51	31	1

On the rocky road towards sustainability: aspiring towards the Kirstenbosch Model.

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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 Kirstenbosch, situated in the heart of the Cape Floristic Region, one of the world's six floral kingdoms. After a period of significant, sustained and strategic investment made through the 1990s, Kirstenbosch became one of the few self-sustaining botanical gardens globally in 2005 and has retained this status every year since. This paper looks at the reasons for Kirstenbosch's success and the significant capital investment made into the other South African national botanical gardens since 2001. It describes interventions that have been made to penetrate new markets opportunistically with a dynamic range of diverse products and services offered, and 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 the country's broad biodiversity mandate created through the National Environmental Management: Biodiversity Act. Innovative approaches to challenges and ways to improve (and once achieved, maintain), sustainability of South Africa's national botanical gardens will require careful analysis of the foreign and domestic market trends, resources required as well as opportunities that can be taken.

Keywords

Cape Floral Kingdom, Cape Floristic Region, Kirstenbosch, national botanical gardens, SANBI, South Africa, sustainability.

Introduction

South Africa is one of a few countries in the world where a single institution manages a network of national botanical gardens (NBGs). Kirstenbosch National Botanical Garden (est. 1913), located on the eastern slopes of Table Mountain, was the first national botanical garden to be established in South Africa. It focused entirely on the conservation of South Africa's wealth of indigenous plants and the network has subsequently grown to incorporate nine national botanical gardens, spread across six of South Africa's nine provinces (Willis 2005). As embassies of biodiversity and culture, South Africa's NBGs attract over 1.2 million visitors per annum, with Kirstenbosch receiving over 750,000 visitors annually.

The NBGs are situated in climatically different parts of the country, including predominantly winter-rainfall mediterranean climates (Kirstenbosch and Harold Porter NBG); semi-arid climates (the Karoo Desert NBG, situated in Worcester, with an annual rainfall of 250 mm, is the only truly succulent garden on the African continent as well as in the southern hemisphere); summer rainfall subtropical to tropical climates (Lowveld and KwaZulu-Natal NBG) and South Africa's interior plateau areas that can receive frost during the dry, cold winter months between May and August (Free State, Pretoria and Walter Sisulu NBGs). This range of climatic conditions means that different gardens are able to grow plants that might not be grown as successfully in other gardens without artificial structures having to be built. The national botanical gardens include natural vegetation representative of six of southern Africa's seven biome units, namely forest, fynbos (characterized by the presence of *ericas*, *restios* and *proteas*), grassland, savanna, Nama Karoo, and Succulent Karoo. The only biome not represented is the desert biome of the Namib Desert, which occurs almost exclusively in Namibia.

Apart from the Hantam Garden (Willis *et al*. 2010), all SANBI's national botanical gardens are situated in densely populated urban areas and are therefore relatively easily accessible to a broad and diverse audience. Since the inception of Kirstenbosch in 1913, the gardens have been supported by the Botanical Society of South Africa (BotSoc), a non-governmental organisation whose local branch members act as the 'friends' of the gardens and support both garden-based and *in situ* conservation efforts. The Botanical Society, the biggest Public Benefit Organisation (PBO) in South Africa, has also contributed significantly to the infrastructural development of South Africa's national botanical gardens, particularly in Kirstenbosch, where the largest branch of the society and its Head Office is based.

Whilst the 1990s was the decade for the development of Kirstenbosch, assisted through the Kirstenbosch Development Campaign (which raised over R50 million between 1991 and 2003) (Huntley 1993, 1998a, 1998b, 2003) and a range of sponsorships including private and corporate donors and the Botanical Society of South Africa, the first ten years of the new millennium have shown a shift in allocation of resources and the completion of new infrastructural developments in the various northern gardens (Willis & Huntley 2007).

This paper attempts to analyse the Kirstenbosch Model, reasons for its success, and what lessons can be learned by other South African national botanical gardens.

Kirstenbosch's Competitive Edge

Participants at the International Botanical Congress of 1999 voted Kirstenbosch as one of the 'Magnificent Seven' top gardens in the world. It forms part of the Cape Floristic Kingdom World Heritage Site and borders on the Table Mountain National Park. It is surrounded by the suburbs of Cape Town with a population of over 3 million people. It also forms part of Cape Town's 'Big 6' tourist destinations and only grows indigenous South African plants.

Kirstenbosch Model

Kirstenbosch became sustainable in 2006/7, when self-generated income covered all personnel and operational costs of the Garden. The Garden incorporates a range of outsourced tenants and income sources, such as restaurants, shops, plant sales nursery and sculpture sales. The Garden is used for recreation, private functions and events. The Garden generated R29 million in the 2009/10 financial year, and hosts a range of sponsored events and concerts through the year.

Critical Success Factors

Critical success factors for Kirstenbosch include the following:

- Unique setting, on the eastern slopes of Table Mountain in the heart of the Cape Floral Kingdom

- 150 volunteers
- Destination integrity, through its products and services
- Passionate, skilled and experienced staff
- Sound financial management
- Cost reduction
- Support from the Botanical Society of South Africa
- Strategic marketing partnerships e.g. the Big 6 Partnership
- Kirstenbosch Development Campaign (1990s) – generated R50 million
- Strong and stable leadership
- Demonstration gardens
- Relevant to the needs of society
- Sustainable strategies – including irrigation, water use, electricity use and recycling
- Links with tour group organizers
- Horticultural expertise
- Experiential training opportunities.

In 1965, Prof. Robert Harold Compton, the second Director of Kirstenbosch (1919–1953), wrote the following:
"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 lay-out 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.*"

Operational improvements

Kirstenbosch has implemented the following operational improvements over the past 10 years:

a. A 20% reduction of staff from 170 to 130, complemented by horticultural skills training for unskilled staff.
b. Outsourcing of non-core functions, such as gate administration (cashiers), security and cleaning services.
c. Market-related gate admission fees resulting in an increase in gate income from R1.4 million in 1996 to R12.5 million in 2009.
d. All restaurants and shops are privately operated with an average rental of 10% of turnover. Commercial tenants employ 140 staff.
e. Local and international concert programme which generates R10 million income for the Garden per annum.

Table 1. Comparison of admission fees charged between Kirstenbosch and other competing tourist destinations in and around Cape Town between 2006 and 2010.

	March 2006			***March 2008***			***March 2010***		
Venue	***Adults***	***Students***	***Scholars***	***Adults***	***Students***	***Scholars***	***Adults***	***Students***	***Scholars***
Kirstenbosch	**R25**	**R15**	**R5**	**R30**	**R20**	**R5**	**R 35**	**R20**	**R10**
Cape Point (TMNP)	R45	R45	R10	R55	R55	R10	R 75	R 75	R10
Robben Island	R150	R150	R75	R150	R150	R75	R 200	R 200	R 100
Table Mountain Cableway	R 115	R 84	R 60	R 130	R 88	R 68	R 160	R 160	R 80
The Castle	R 20	R15	R10	R20	R20	R10	R 25	R 25	R10
Two Oceans Aquarium	R65	R50	R 30	R 76	R 60	R35	R 94	R 73	R 45
Drakenstein Lion Park	R30	R25	R15	R40	R20	R20	R 45	R 45	R 25
Tygerberg Zoo	R44	R44	R28	R 48	R 48	R32	R 60	R 60	R 40
World of Birds	R50	R 40	R32	R55	R45	R35	R 65	R 50	R 39
Ratanga Junction	R100	R 100	R 50	R110	R110	R55	R 132	R 132	R 65
Ster Kinekor Cinemas	R38	R38	R19	R42	R42	R 21	R 48	R 48	R 29
									Update 30/04/2010

Financial status

In the years 1914 to 1920, a third of Kirstenbosch's revenue was derived from the sale to the general public of wood and acorns. By 1984, the Government grant formed nearly 90% of the Garden's total income. In 1997/8 Kirstenbosch depended on a government grant for 70% of its budget. In 2009/10 the Garden generated 112% of its budget as own income, with no annual government grant allocated since 2006/7. This financial success was due to (a) political changes in the country which enabled international tourism to the Garden to grow from a zero base in 1994 to 140,000 in 2006. Due to the global recession, this number dropped down to 100,000 in 2008/9, and (b) vast improvements in visitor facilities with R60 million spent on capital developments in the past twelve years.

Commercialization opportunities in Kirstenbosch include the following:

- Admission fees
- Plant sales/Garden Centres
- Tea Gardens/Restaurants
- Hiring of Conference Halls & Exhibition Centres (hosting amongst others, the Kirstenbosch Art Biennale, Biodiversity Expo)
- Marquee lawn attracting high profile political and corporate functions
- Kirstenbosch Shop
- Book shops
- Chapungu Sculpture sales
- Concerts
- Guided tours/Audio Guide.

The local and international concert programme generates R8.6 million gate income and R1.4 million in sponsorship, and attracts 135,000 visitors per annum.

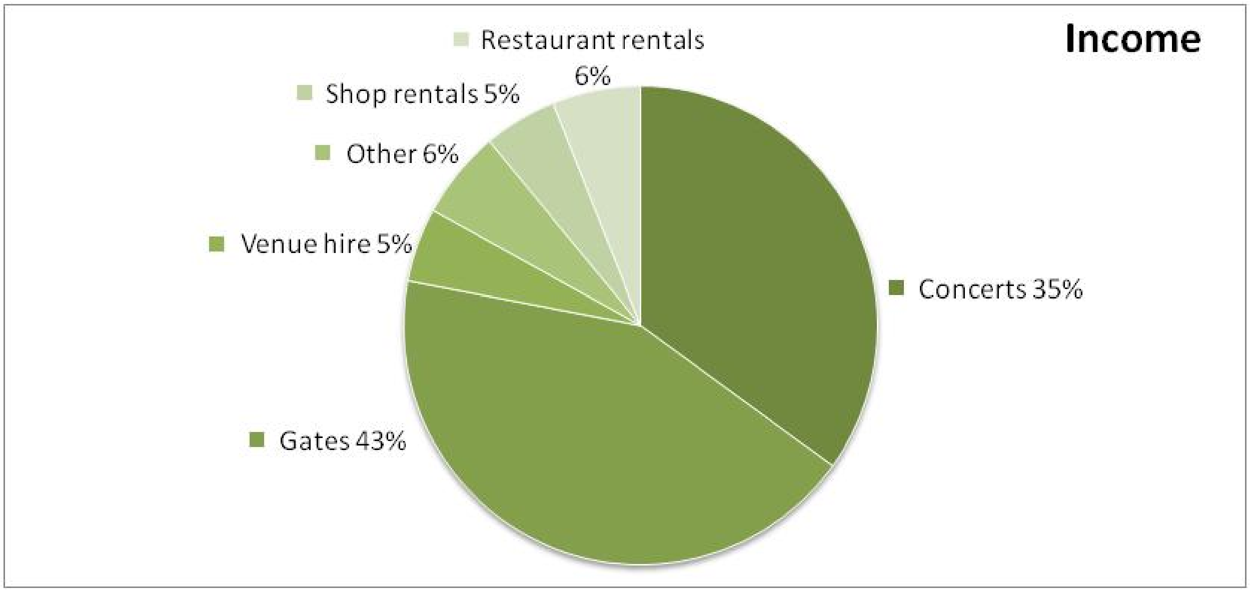

Figure 1. Breakdown of proportion of different sources of income to Kirstenbosch National Botanical Garden on an annual basis.

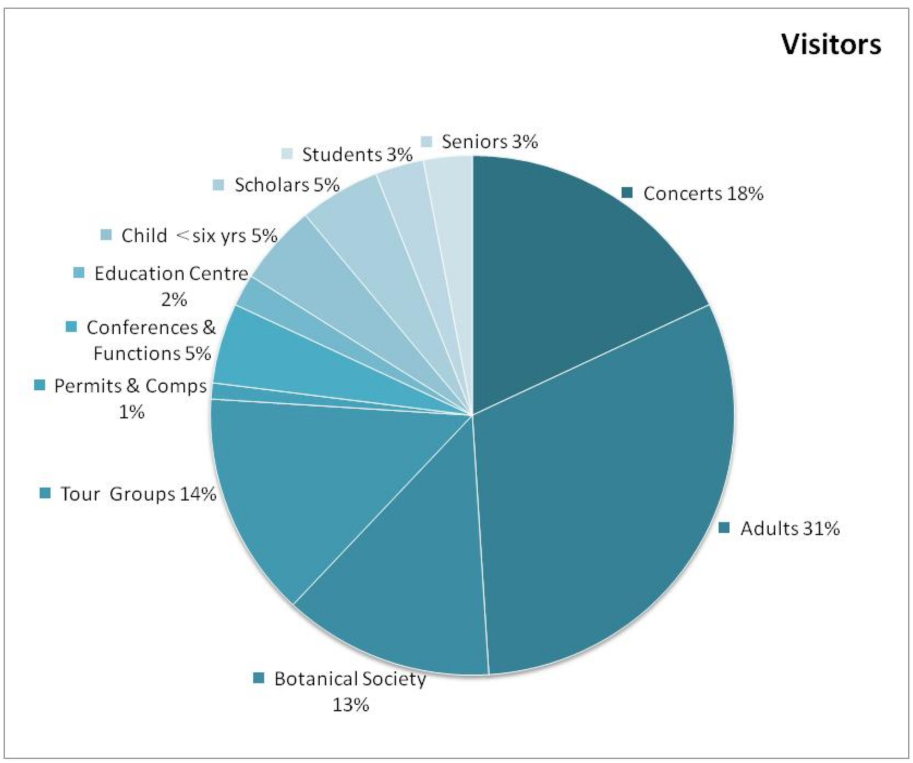

Figure 2. Breakdown of different categories of visitors using Kirstenbosch and its varied facilities on an annual basis.

> In 1965, Prof. Compton expressed the following:
> "To Kirstenbosch life means continuous growth and an ever-widening sphere of activity – Kirstenbosch should be as changeful and dynamic as the living plants which are its reason for existence".
> "It is perhaps difficult today [1965] to picture this embryonic institution, unbelievably ill-equipped, stricken by World War I and the untimely death of its first Director [Prof. Harold Pearson], national but stigmatised as "local", selling a few bags of acorns here and a few loads of firewood there in an effort to pay penurious salaries and wages, and yet conscious of the spark of greatness within itself which might one day burn with a noteworthy flame. Perhaps the true gardener's spirit pervaded the management – the spirit of hope and the unquenchable expectation of success despite repeated disappointments".

Achievements in regional gardens

Over R50 million has been invested in new capital infrastructure across SANBI's non-Kirstenbosch national botanical gardens since 2001, with significant support received from South Africa's Department of Environmental Affairs (DEA) (Willis & Huntley 2007). A large portion of this funding has been sourced from South Africa's Expanded Public Works Programme (EPWP). The Expanded Public Works Programme (EPWP) is one of the South African Government's short-to-medium term programmes aimed at alleviating and reducing unemployment.

Through these construction activities, 186,000 temporary job days have been worked and over 2,100 people employed. Projects completed in the various national botanical gardens include new restaurants, tea gardens, environmental education centres, visitors' centres, pathways and walkways. In addition, a range of new demonstration gardens have been developed, including useful plants gardens, geological garden, as well as threatened plant gardens.

Challenges and opportunities

In order for SANBI's national botanical gardens to achieve the Kirstenbosch Model of sustainability, the following aspects must been given the necessary resources and attention they deserve:

- Marketing/advertising
- Dedicated event organizers
- SANBI Brand and brand names for gardens
- Relevance to surrounding communities
- Improved directional road signage
- Sponsorships
- Effective management and operation of outsourced facilities
- Support from local, provincial and national tourism agencies.

Conclusions

Kirstenbosch's setting, history, support and investment is unique. Is it replicable in other areas? There is a need to review each garden in its unique context/setting. Community support is required, including for education and interpretation. It will require long term commitment and investment from SANBI and the South African Government. Partnerships and linkages with other tourism destinations in the same town or city are essential, and if developed, will reduce, for example, each garden's marketing and advertising costs. Each garden's product offering to the general public must be based on the principles of increased diversity, quality and consistency. Each garden must ensure that visits by the general public are value for money and relevant. Gardens must also be managed on cost effective principles, with the need in some cases to review and reduce staff and operational costs, and increasingly source sponsorships and organize events in the gardens.

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It takes a flower and a bee to make a meadow:* mutualistic plant-pollinator interactions are crucial for plant biodiversity conservation

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*title inspired by Ellis & Ellis-Adam's (1993) study

Abstract

Mutualistic plant-pollinator interactions play one of the crucial roles in generating and sustaining biodiversity of terrestrial ecosystems. They are even regarded as 'architecture of biodiversity'. Usually they connect dozens or even hundreds of species, forming complex networks of reciprocally beneficial interactions. The structure of such networks is highly heterogeneous and asymmetric: most of the species are rather weakly connected, while some of the taxa develop much stronger relationships than would be expected by chance. New mathematical tools allow us to analyse the network structure via designation of species playing structural roles in the studied ecosystem: *hubs* – organisms highly connected within their own module of the network, and *connectors* – species connecting several modules. This theoretical approach can be applied to indicate 'keystone' species which determine stability of the studied networks.

Key Words

biodiversity, conservation, ecological interactions, graph, network, pollination

How important is pollination?

In an encyclopaedic definition the process of pollination is quite simple and straightforward: it involves the transfer of a pollen grain from anthers to conspecific stigma. In nature this is usually done by wind, water and, most often, by animals. In zoogamous pollination the most important players from the animal side are insects (Proctor *et al*., 1996).

It is very difficult to say how many out of approximately 260,000 flowering plant species are animal-pollinated. The estimates based on suitably structured flowers indicate that up to 90 per cent of all flowering plants may depend upon animals (mostly insects) for their sexual reproduction (Buchmann & Nabhan, 1996). If we consider the ubiquity of this process, which takes place in all terrestrial ecosystems on all continents (excluding polar regions) we may regard pollination as a critical service, crucial for maintaining the stability of all terrestrial ecosystems where flowering plants are involved (Kearns *et al.,* 1998). It is also important for humans if we think of commercial plants that are animal-pollinated (Buchmann & Nabhan, 1996).

The value of pollinators

There are some 2,000 crop species cultivated around the world, but only about 120 are globally important (Klein *et al*., 2007). As shown by Klein and co-authors (2007) this number includes about 70 species for which animal pollination is crucial or important for a good crop; however, when we consider production volume this means about one third of global production comes from animal-pollinated plants. This voluntary service has quite substantial monetary value – according to various authors it fluctuated at around 120–200 billion US dollars a year in the 1990s (Richards, 1993; Constanza *et al.,* 1997). New estimates calculated solely for crop plants give the sum of 150 billion US dollars in the year 2005 (Gallai *et al*., 2009)! But the economic value of the process of pollination is not the most important aspect of these mutualistic plant-pollinator interactions: its biological significance is far greater. This is because of its crucial role in generating and sustaining biodiversity in terrestrial ecosystems (Kearns *et al.,* 1998).

Pollination networks

Plant-pollinator interactions form complex networks (Fig. 1) connecting dozens or even hundreds of species (Bascompte & Jordano, 2007). These kinds of networks can even be found in highly urbanized habitats and their properties are alike: for instance scientists from Warsaw University Botanic Garden studied two pollination networks from ruderal habitats in Warsaw city centre and, on the study sites that did not exceed 500 sq m, found complete networks built by over 50 species of plants and animals (Fig. 2).

To describe properties of a network ecologists use random graph theory developed in the late 1950s by the great Hungarian mathematicians Paul Erdös and Alfred Renyi. In the simplest network a random graph is defined by a set of nodes and a probability p that two such random nodes are connected by a link (Fig. 3). If we apply that to a biological system, nodes may represent species and the links are ecological interactions such as pollination (Bascompte & Jordano, 2007). However their structure may differ: Figure 1 shows a graphic representation of a pollination network in a lowland meadow in north-east Poland. Green dots represent plant species, empty dots are flower visitors. Connecting lines indicate a connection between a given pair of nodes (an insect visiting a flower). This network has the same number of nodes and mean node degree (i.e. the mean number of links) as the one from Figure 3. The architecture of interaction in these two graphs is however different, partly because the second one is a bipartite network with two different subclasses of nodes (i.e. plants and animals) that have no links within a subclass. This network's structure, similar to other mutualistic networks, resembles that of the Internet rather than the random Erdös-Renyi graph. Such biological networks are much more heterogeneous and asymmetric: most nodes (species in this case) are rather weakly connected, while a number develop much stronger links than would be expected by chance (Bascompte & Jordano, 2007). This is similar to the worldwide web, where we have many weakly linked web pages and highly linked portals such as Google or Wikipedia.

This is different to a random graph, where probability of node degree distribution fits the Poisson law (or exponential when the number of nodes keeps growing) and when we look at the Internet it seems to fit with power-law distribution. This kind of network is usually called scale-free as the relationship between number of links (k) and their probability cannot be defined on a particular scale. Biological networks usually fit in between these two kinds of degree distribution (Bascompte & Jordano, 2007).

There are few more interesting characteristics of mutualistic networks. One of the obvious things to be observed is that they contain link-dense and link-sparse regions. This creates compartments or modules, where species are more tightly connected together within their specific module than to other species in different modules. When we further look at specific nodes we can designate several classes of species: ones that have only one or very few connections usually within their own module – they are called peripherals. In biological terms these are usually specialists interacting with very few species. Species that are either highly connected within their module or with other modules are hubs or, biologically speaking, generalists. There may be module hubs – highly connected species linked to many species within their own module, connectors linking several modules, or species with many links both within a module and with other modules. They can be termed network hubs or super generalists, acting as both connectors and module hubs (Olesen *et al*., 2007).

What happens if we extract some nodes from a system? In real life this may happen, for example in species extinctions or if they shift their biogeographic ranges due to climate change. How does it affect the network? The answer depends on the topological role a particular node plays. If it is a peripheral the network structure does not change much, but if it happen to be module or network hub or connector, the whole system may be affected. In other words if we lose one of the structural species, be it plant or animal, other taxa which are linked to this node may be endangered. For highly connected species it usually results only in a decrease in node degree, but for peripherals it may mean exclusion from the network. And as a rule most of our endangered plants are specialists, which means peripherals. Therefore this kind of network approach may be very important in our conservation procedures, as the knowledge of a system structure may greatly enhance our chances of successful preservation or restoration of particular taxa. Thus, in any conservation efforts we must not forget that species are not separate entities and networks are everywhere – and some of them also include us humans.

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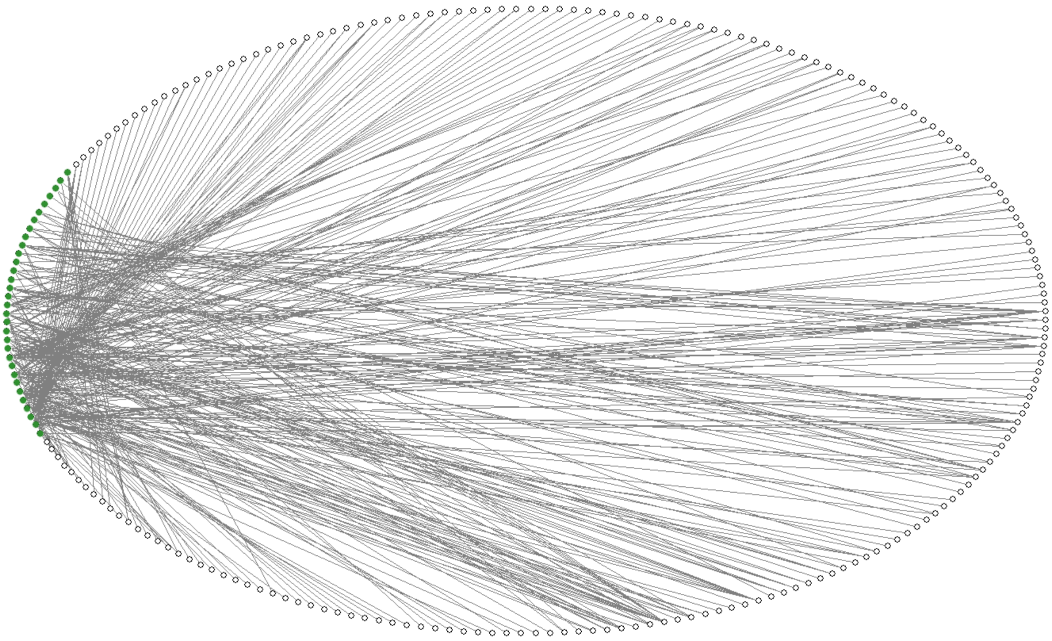

Fig. 1 Graphic representation of a pollination network in a lowland meadow in NE Poland (Zych et al., unpubl.). Green dots represent plant species, empty dots – flower visitors. Connecting lines indicate a connection between a given pair of nodes (an insect visiting a flower)

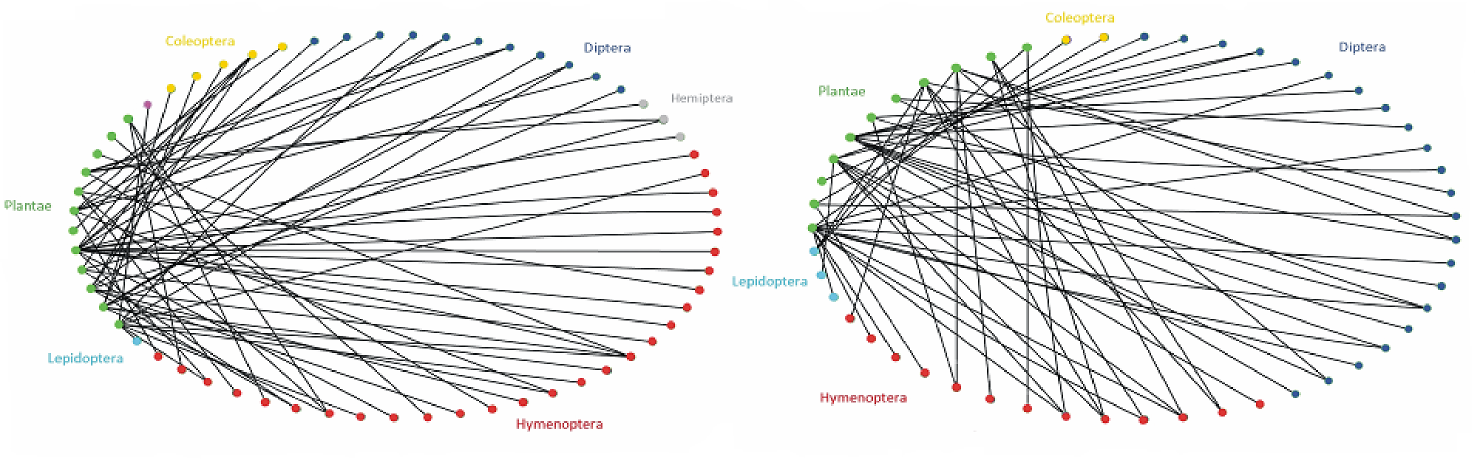

Fig. 2 Complete pollination networks from ruderal habitats in Warsaw city centre built by over 50 species of plants and animals. Green dots represent plants and other color dots insects from various taxonomic orders (Jędrzejewska-Szmek & Zych, unpubl.)

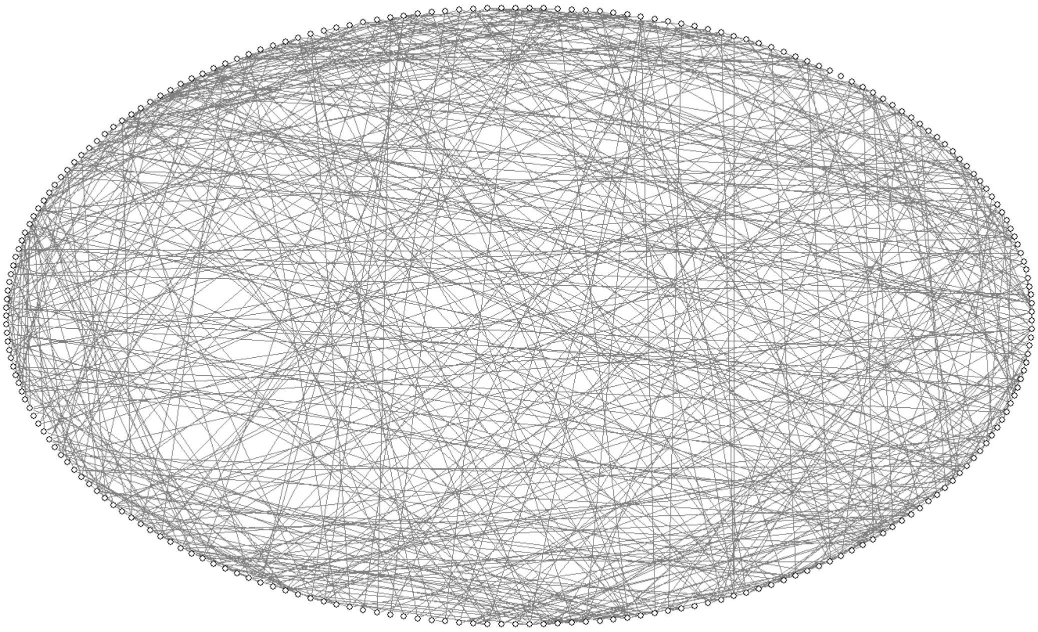

Fig. 3 A random network created by the Erdös-Rényi model. It has the same number of nodes and mean node degree as the graph in Fig. 1

At the start of the EFP in 1980, the publications of the various volumes were “indicated” to be completed in about 15-20 years. However, the completion of the Flora has taken about 29 years between 1980, when it was initiated and 2009, when it was completed, but 20 years since the publication of the first volume (Volume 3), in 1989 (Table 2). As shown in the table, volume 3 was published in 1989 (nine years after the initiation of the project, which meant, the first eight years of the project were devoted to the training of Ethiopians, which made possible the full participation of nationals in contributing to writing flora accounts of various families and participation in the editorial work. The completed flora volumes are shown in Fig. 1.

The contribution of scientists based in Ethiopia in writing family accounts grew over the years from about 4% in Volume 3, published in 1989 to almost 100% in Volume 4(2), in 2004. These include writing accounts of Families with about 440 species in Asteraceae in Volume 4(2) (Mesfin Tadesse, 2004); over 200 species in the Family Acanthaceae (Ensermu Kelbessa, 2006) and about 130 species in the Family Convolvulaceae (Sebsebe Demissew, 2006), both of the latter Families are in Volume 5 of the Flora of Ethiopia and Eritrea (FEE).

Opportunities, Challenges and achievements

Opportunities

Many outstanding professional botanists, Mr. Mike G. Gilbert and Dr Kaj Vollesen (employed by the FEE, based at the Royal Botanic Gardens, Kew, Prof. Ib Friis, University of Copenhagen, Denmark, Prof. Christian Puff, University of Vienna, Austria, Prof. Mats Thulin, University of Uppsala, Sweden, and Prof. Inger Nordal, University of Oslo, Norway, participated actively in contributing accounts of various families and also contributed to increasing the number of collections at the National Herbarium. In so doing they shared their knowledge and expertise with botanists based at the National Herbarium.

A number of national botanists have increased the number of plant specimen collections at the National Herbarium. The major collectors include: Profs. Ensermu Kelbessa, Sebsebe Demissew, Sileshi Nemomissa, Sue Edwards, Tamirat Bekele Tewolde Berhan GebrEgziabher, Zemede Asfaw, Zerihun Woldu, PhD and MSc students. Many individuals at the Institute of Biodiversity Conservation (IBC) and Ethiopian Institute of Agricultural Research (EIAR) and various institutions under the Ministry of Agriculture and Rural Development have also contributed to the increase in the number of plant specimen collections.

Challenges

One of the major challenges of the Flora Project was caused by the death of Prof. Pichi Sermolli in 2005. He had promised to deliver the Fern accounts, based on his wide experience and knowledge of the Ferns. Thus accounts of the families had to be started as new. The contributors of this challenging volume are shown in Table 3 and the national botanists also responded to the challenge.

Achievements

The publications of the eight volumes resulted in the documentation of about 6,000 plant species (angiosperms, gymnosperms, ferns and fern allies) with ca. 10% endemism. In addition to completing the documenting of the botanical resources, all the volumes were published locally. This made the cost of the publication cheaper and also availed the published volumes locally to the benefit of students, teachers, agronomists, foresters, other researchers etc. in the country.

Strengthening the National Herbarium

One of the three objectives was to strengthen the National Herbarium (ETH). The National Herbarium in Addis Ababa University was established in 1959 with the donation of about 6,000 species by an Irish Forester, H.F. Mooney. Mooney was keen to send to Kew for identification and receive the properly identified plant specimens. Between 1959 and 1980, the number of collections were about 16,000. Between 1980 to date, the number has increased to over 80,000. One of the outstanding contributors to the collection is Prof. Ib Friis who together with others have collected a series with over 10,000 specimens.

Promotion of scientific activities in taxonomic botany, economic botany, forestry, plant ecology, plant physiology

The project leaders who initiated the project had thought of this objective right from the initial stage of the Ethiopian Flora Project. The training of Prof. Legesse Negash in Plant Physiology, Prof. Zemede Asfaw in Ethnobotany, and Prof. Zerihun Woldu is testimony to this.

Plant identification services to many institutions and individuals are being provided by staff of the National Herbarium from the beginning of the project, and will continue for the foreseeable future.

Conclusions

The Ethiopian Flora Project has achieved its objectives by completing the Flora of Ethiopia and Eritrea with about 6,000 species and ca. 12% endemism. In so doing the accomplishment of the FEE has contributed to addressing the Ethiopian contribution towards achieving Target 1 of the GSPC targets; strengthened the National Herbarium with the collection increased from 6,000 to over 80,000 (at present), and is used by a number of professionals for identification of plant specimens and contribution to conservation activities in Ethiopia. The lessons to be learned from the Ethiopian Flora Project are the training of national botanists in documenting the national floras, and also the publication of the floras locally which would avail the resources to a wider participation locally.

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Table 1: **PhD training sponsored by the Ethiopian Flora project**

Name	**Year**	**Place of Study**	**Subject Specialization**	**Current Residence**
Mesfin Tadesse	1980-84	Systematic Botany, Uppsala	Systematics: Asteraceae	USA
Sebsebe Demissew	1981-85	Systematic Botany, Uppsala	Systematics: Celastraceae	Ethiopia
Zemede Asfaw	1983-89	Systematic Botany, Uppsala	Ethnobotany: Barley	Ethiopia
Ensermu Kelbessa	1984-90	Systematic Botany, Uppsala	Systematics: Acanthaceae	Ethiopia
Legesse Negash	1984-88	Physiological Botany, Lund	Physiology	Ethiopia
Elizabeth Kebede	1989-95	Limnology Institute, Uppsala	Limnology	UK
Damtew Teferra	1986-87	Illustrator, Copenhgen	Illustration	USA
Damtew Teferra	1993-94	Publishing studies, Stirling, UK	Publishing	USA

Table 2. Publication and editorship of the Flora Volumes by botanists based in Ethiopia

Volume	Families Covered	Year of Publication	Editors
Vol. 3	Pittosporaceae-Araliaceae	1989	I. Hedberg & S. Edwards*
Vol. 7	Poaceae	1995	I. Hedberg & S. Edwards*
Vol. 2:2	Canellaceae-Euphorbiaceae	1995	S. Edwards*, Mesfin Tadesse* & I. Hedberg
Vol. 6	Hydrocharitaceae-Arecaceae	1997	S. Edwards*, Sebsebe Demissew* & I. Hedberg
Vol. 2:1	Magnoliaceae-Flacourtiaceae	2000	S. Edwards*, Mesfin Tadesse*, Sebsebe Demissew* & I. Hedberg
Vol. 4:1	Apiaceae-Dipsacaceae	2003	I. Hedberg, S. Edwards* & Sileshi Nemomissa*
Vol. 4:2	Asteraceae	2004	I. Hedberg, I. Friis & S. Edwards*
Vol. 5	Gentianaceae-Cyclocheilaceae	2006	I. Hedberg, Ensermu Kelbessa*, Sebsebe Demissew*, Sue Edwards* & E. Persson
Vol. 1	Lycopodiaceae-Pinaceae	2009	I. Hedberg, I. Friis & E. Persson
Vol. 8	General part & Index	2009	I. Hedberg, I. Friis & E. Persson

*Scientists based in Ethiopia.

Table 3: Contributions of number of Families by authors

Contributor/s	Number of Families
Ensermu Kelbessa	7
Ensermu Kelbessa & Henk Beentje	1
Ensermu Kelbessa & Kous Roux	1
Sebsebe Demissew	8
Sebsebe Demissew & Ib Friis	1
Ib Friis	7
J.P. Roux	16

Figure 1: Completed flora volumes 1-8.

most related to taxa from distant geographical regions (especially East Africa, South Africa or the New World), and finally 18% of the flora derives from Macaronesian ancestors. Thus, founder events from mainly Mediterranean Europe and NW Africa plus a substantial contribution from Macaronesia, have shaped the rich and distinctive flora in the Canaries. With different proportions (but with less published molecular phylogenetic evidence), these geographic links may be generalized to the remaining Macaronesian archipelagos save for Cape Verde, where the principal mainland African founder stock is not associated with the same region.

Macaronesia is thus a geographically highly diverse oceanic insular region where (i) different island ages and biogeographic histories, (ii) variable distances among the archipelagos and with the mainland, and (iii) lack of substantial effects of glaciations on the floras, have created an extremely diverse landscape that has generated a high number of plant endemics (Figure 1). At present, the Macaronesian endemic flora is estimated to host 30 endemic genera that contain 68 species, and a total of about 850 endemic terrestrial plant species overall (Caujapé-Castells et al., 2010, and references therein). The archipelago with the highest species density is Madeira, and the small Canarian island of La Gomera features the greatest number of endemics per unit area in Europe and the northern quarter of Africa (Martín-Esquivel et al., 2005).

As the authorship of this contribution clearly demonstrates, the five botanic gardens of this multi-national oceanic insular hotspot do play a most distinctive and strategic role in the identification, research and conservation of the endemic terrestrial Macaronesian floras, and they are home to some of the most relevant researchers of the Macaronesian endemic plant diversity. These five institutions host four herbaria, five seed banks and three DNA banks that are both the causes and effects of most significant research on the conservation of plant biodiversity in this oceanic hotspot. There are also five universities in Macaronesia, though only three of them (in Tenerife, Azores and Madeira) feature thorough educational and research programmes on terrestrial floras. Furthermore, a comprehensive network of nature preserves and Natural Parks exists in all archipelagos, whose staff are extremely dedicated and knowledgeable about the plant diversity in their respective islands, and who offer strong support for investigation.

All these research and management assets are devoted to cope with the five threat factors that most affect the decline in plant biodiversity in Macaronesia according to a recently published review (Caujapé-Castells *et al*., 2010). Namely small population sizes and fragmentation, habitat alteration and destruction, invasive alien vertebrates and plants, and demographic and economic growth (Figure 2). Perhaps the Asteraceae *Atractylis preauxiana* is one of the cases that best illustrates the added effects of the threat factors highlighted (Figure 4). According to recent population genetic results (Caujapé-Castells *et al*., 2008), geographic isolation between Tenerife and Gran Canaria is an effective barrier to gene flow, and genetic heterogeneity within islands is also substantial, plausibly due to the negative impacts of fragmentation on genetic variation. Moreover, the population at Granadilla de Abona in Tenerife is threatened by the imminent construction of a port in that area (see Fig. 3). Low genetic variation and scarce gene flow within the islands, together with declining population sizes, poor seedling survival, and both recent and foreseeable population extinctions, compellingly indicate that *A. preauxiana* is undergoing an extinction ratchet, whereby every further local extinction will irreversibly add up to the probability of total species' extinction. Recent surveys of the populations in Gran Canaria revealed a very high number of dead individuals.

The survival plight that this plant is undergoing is probably not the general rule at present in the Macaronesian floras, although many endemics are indeed likely to undergo similarly dramatic situations if we do not react immediately and adamantly to counter the threats posed by unsustainable development and, increasingly, climate change. Taking into account the impacts of thirteen drivers of biodiversity decline on the four Macaronesian archipelagos (Figure 2), it is evident that the threats to each archipelago´s biodiversity are not related to geographical proximity, except for the cases of Madeira and the Canaries, whose numerous floristic links partly explain the similar response of their plant biodiversity to these threats.

The rapidly growing human population and the high impact of tourism as the major source of income in all Macaronesian archipelagos (except for the Selvagens) makes it impossible to protect all habitats, and imposes at least two priorities. First, to complement habitat protection with *ex situ* conservation measures that use the information contained in hyper variable DNA regions to guide seed collections that represent natural genetic diversity in seed banks. Second, to foresee the impacts of climate change at least in the endemics that are most directly threatened, like those in mountain summits or coastal environments. Project BIOCLIMAC (Table 1) brings together three of the five Macaronesian botanic gardens to address specifically this important threat. To fulfill these needs, a stronger coordination among at least taxonomists in herbaria, seed banks, reproductive biologists and population geneticists is mandatory.

In the Azores, we find some other paradigmatic examples of plants endangered by the factors that affect the Macaronesian archipelagos. One of the most dramatic cases is the Scrophulariaceae *Veronica dabneyi*, considered extinct in the Azores in 1938, and rediscovered (only in Flores) in 2000. One of the major threats to this species (i.e., the action of road builders, who were unaware of its occurrence and cut it during maintenance works) was already eliminated by appropriate training actions. However, the impact of alien invasive flora and rabbit herbivory in Flores now make up the highest threats for this and other species. Project BASEMAC (Roca-Salinas *et al*., 2005; Table 1), is allowed to stock the seeds of this Scrophulariaceae and of 23 other Azorean rare plants (representing 1/3 of the archipelago's endemic flora) on Faial's Botanic Garden seed bank. Targets of new surveys have already been selected, like the Caldeira do Faial, where ca. 50 of the 75 Azorean endemic species concentrate in only 313 ha.

Moreover, the Azorean government is adopting a more focused approach to nature conservation; the current implementation of Nature Parks in all islands is aimed at protecting sensitive areas with a rich genetic heritage, and at the definition of strategic plans to (i) control and eradicate alien plant species, (ii) reduce cattle's impact on flora, and (iii) raise public awareness of the need to preserve the archipelagos' biodiversity.

Other necessary requirements in Macaronesia concentrate in four basic areas: first, consistent funding is needed to develop strategic research on biodiversity and to apply the emerging knowledge to its management and conservation. Second, sensible laws need to be passed, and other ones that already exist require proper enforcement. Third, field exploration and taxonomy have to be urgently promoted: many new species are still discovered on Macaronesia and others that were considered scarce or feared extinct reappear, yet young taxonomists are in short supply. And fourth, we need to increase scientific coordination both within and among archipelagos and with institutions from other areas that are interested in the Macaronesian plant diversity or may give complementary approaches to its investigation and conservation.

Our botanic gardens have been collaborating in a number of research projects that have significantly contributed to the cohesion of research on the floras of the Macaronesian oceanic hotspot and their conservation. Two of the agencies that funded these initiatives (see Table 1) have spent from 2002 till mid June 2010 more than €22m in projects devoted to some aspect of the Macaronesian biodiversity (full details available at <www.interreg-mac.org>). Even a cursory analysis of the institutions involved in these initiatives highlights that coordination among the European archipelagos has been considerable (especially between the Canaries and the Azores [90 projects] and the Canaries and Madeira & Selvagens [93 projects], but only 32 projects between Azores and Madeira & Selvagens), whereas Cape Verde has participated in only a minority of initiatives, with six projects with only Canarian stakeholders.

Biodiversity does not take notice of political borders, and it is quite apparent that not enough effort and resources have been used at the pan-Macaronesian level to address the urgent problems that it faces. A lot more stimulus and strategic funding is thus needed so that Macaronesia may act coordinately as a single biogeographical unit (including some relevant enclaves in the mainland), based on the floristic links among the different insular and continental areas, but also on their different conservation needs and priorities. Furthermore, the geographic isolation that contributes so much to beget the distinctive Macaronesian plant biodiversity is also a strong deterrent to proper botanical exploration, and we do need to invest a lot of funds on taxonomy and field prospection to gain proper understanding on the composition and distribution of the floras.

The evolutionary singularity of the endemic insular floras and their extreme sensitivity to external changes, derived from prolonged isolation, should suffice to the integral protection of the Macaronesian biodiversity. In an ideal world, all insular biodiversity should be legally protected. However, as highlighted above, some of the most important activities for the survival and development of the growing Macaronesian populations need space and generate fragmentation that impinges on the survival and genetic cohesion of biodiversity. Hence, it is necessary to enforce the right laws that foster sustainable development policies to preserve biodiversity; furthermore, education and awareness about the value of biodiversity have to be promoted among the non-specialist population, and increasingly politicians.

Despite research efforts, the wrong laws are sometimes proposed, passed and enforced by persons alien to biodiversity conservation, and it is equally important that specialists react against these. One such wrong law was passed on May 18th 2010 by the Canary Islands Parliament that deprives most of this archipelago's biodiversity of legal protection in a clear and unconcealed move to allow many projects associated with unsustainable development. Certainly, this new law represents a huge problem for every solution that conservation scientists from this archipelago may suggest to preserve its lush biodiversity, and it contains a potentially more awful consequence: it may be contagious, thereby imperiling the endemic biodiversity in the remaining Macaronesian archipelagos, for a start.

The radical threats faced by the insular endemic floras are not local, but global, and only an effort of the same magnitude may provide the critical mass of knowledge needed to help take the right course of scientific and political action. The impacts of major threat factors on insular endemic plant biodiversity are unrelated to geographical proximity, thereby emphasizing the need for enhanced contact among island conservation scientists.

Botanic gardens are among the centres that conduct the most relevant research on plant conservation in all countries of the world. Notably, in many islands, botanic gardens are simply the only institutions that implement effective conservation measures for the endemic flora, based on the knowledge that they generate and glean.

Therefore, this 4th Global Botanic Gardens meeting in Dublin is a superb arena to set the stage of a global island plant conservation network, which is already operative at <http://www.bgci.org/ourwork/islands/>.

Acknowledgements

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Roca Salinas A, Vilches Navarrete B, Jardím R, Carvalho JA, Fernandez F, Melo J (2005) BASEMAC: Banco de Semillas de Macaronesia. Conservando para el futuro. *Rincones del Atlántico* 2: 122-125.

Table 1. Projects co-funded by FEDER through the INTERREG-IIIB 2002-2006 or the PCT-MAC 2007-2013 initiatives (85% of the total amount) where botanic gardens or other institutions interested in/devoted to the research and conservation of the Macaronesian endemic floras have contributed (15% of the total amount). Participating institution abbreviations correspond to (in alphabetical order), CHA: Complexe Horticole d'Agadir, Institut Agronomique Vétérinaire Hassan II (Morocco); INIDA: Instituto Nacional de Investigaçoes e Desenvolvimento Agràrio (Cape Verde) JBCVC: Jardín Botánico Canario "Viera y Clavijo"-CSIC, Gran Canaria (Spain); JBF: Jardim Botânico do Faial, Azores (Portugal); JBM: Jardim Botânico da Madeira (Portugal); UA: Universidade dos Açores at Ponta Delgada (Portugal); ULPGC: Universidad de Las Palmas de Gran Canaria (Spain). In all these cases, the project leader was the JBCVC.

Acronym	Participating institutions	Total amount	Main objectives
BASEMAC	JBCVC, JBF, JBM	885,476.47 €	Improve seed banking facilities in three Macaronesian botanic gardens
BIOMABANC	JBCVC, UA, ULPGC	1,120,646.59 €	Generate new genetic diversity data (all) and create banks of DNA (JBCVC, UA), reproductive data (JBCVC), and ethnobotany (JBCVC)
CAVEGEN	INIDA, JBCVC	235,294.00 €	Create seed and DNA banks of the Cape Verdean endemic flora (JBCVC, as trust funds on behalf of the INIDA)
DEMIURGO	JBCVC, UA, ULPGC	814,377.87 €	Create public databases of genetic & biological information. Generate genetic diversity data on selected lineages
BIOCLIMAC	JBCVC, JBF, JBM	956,117.00 €	Design seed collection strategies based on genetic diversity data; study impact of climate change on selected taxa
ENCLAVE	CHA, JBCVC	519,315.00 €	Enhance multi-disciplinary knowledge and research collections on the floristic link Canaries-SW Morocco

FIGURE CAPTIONS

Figure 1. Examples of landscapes and Macaronesian endemic plants. Photo credits: João Melo, Nuno Rodrigues, Paulo Silva, Juli Caujapé-Castells, Águedo Marrero Rodríguez, Pepa Navarro, Felicia Oliva.

Figure 2. The five main drivers of endemic plant diversity decline on Macaronesia. The representation in the inset (below, left) is the relative position of the Macaronesian archipelagos relative to five other oceanic or para-oceanic archipelagos in the multivariate space defined by the 13 threat factors assessed in Caujapé-Castells et al. (2010). The five Macaronesian archipelagos are represented by different geometrical shapes that approximately correspond to their areas. G: Galápagos; H: Hawaii; J: Juan Fernández; M: Mascarenes; S: Seychelles.

Figure 3. Approximate present distribution of the extremely endangered endemic Canarian species *Atractylis preauxiana* (Asteraceae) in a few fragmented populations along the Eastern coasts of Tenerife and Gran Canaria. In Tenerife, eight populations have about 1600 censused individuals on the whole, but the size of many of these does not reach fifty specimens (the black circle pinpoints the population at Granadilla de Abona, see text). In Gran Canaria, only three populations are known, with roughly 4000 individuals overall. This species is in a critical situation because of the constant exposure of plants to intensive, uncontrolled anthropic action in the last few decades, that has generated demographic and habitat degradation.

Figure 1

Figure 2

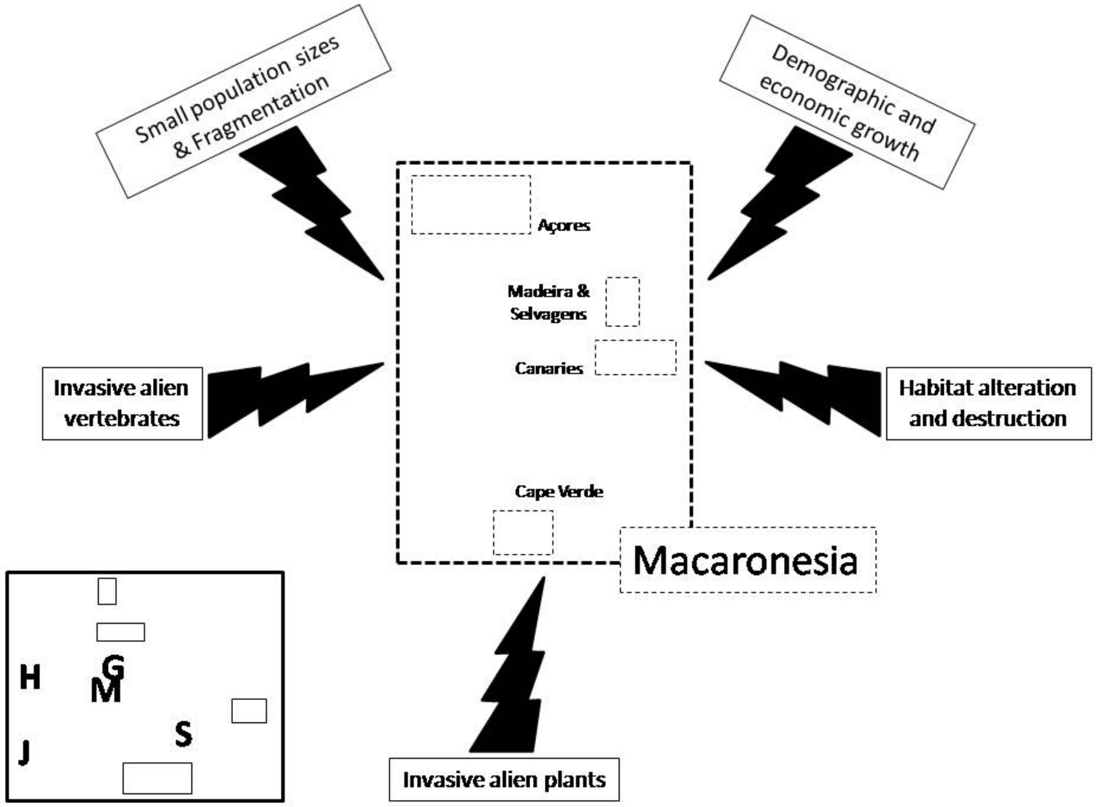
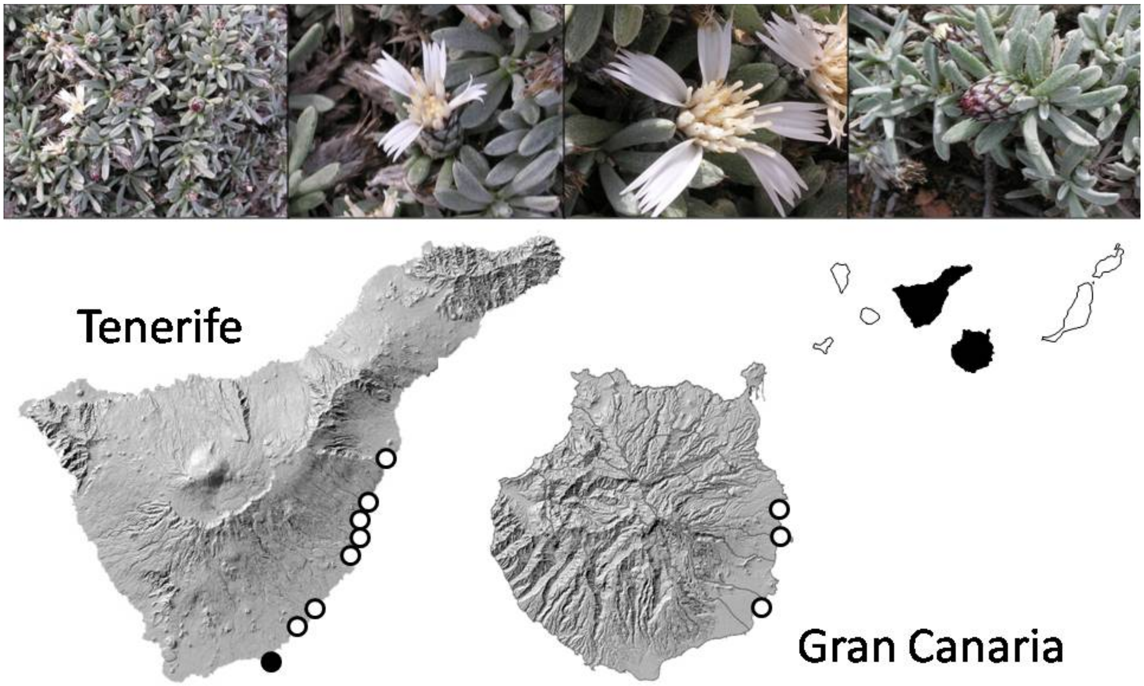

Small population sizes & Fragmentation
Demographic and economic growth
Açores
Madeira & Selvagens
Canaries
Invasive alien vertebrates
Habitat alteration and destruction
Cape Verde
Macaronesia
H
G
M
S
J
Invasive alien plants

Figure 3



Recognising that the network had much to offer in the development of 'processes' within educational programme development and implementation, BGEN opened its doors to engage with a slightly broader range of organizations. Members now include staff from museums, environmental education organizations, zoos and country/heritage estates, as well as free-lance educators and interpreters. Several members of staff from western European countries such as Austria and Italy have also joined, and attend BGEN training days and conferences in the UK.

The main offer of the network is capacity building and training. A minimum of four training days are offered annually. These training days are usually process led, pragmatic and participatory and sessions across 2009-2010 included such topics as 'Natural Play', 'Low Cost Interpretation', 'Effective Storytelling', 'The Secondary Curriculum', 'Current Research in Education' and 'Developing and writing audio trails'. Some introductory training sessions are provided in repeated format across a number of regions, so as to minimize travel costs for members. These sessions, called 'Back to Basics', are primarily for new staff in organizations and are focused on strategies for developing education in botanic gardens or similar organisations. Besides the training days, BGEN provides a three day annual conference, focusing on a topic that is current to education, or on a topic selected by members during a canvassing exercise. The most recent conference (November 2009) focused on Education for Climate Change, whilst the forthcoming conference will feature basic application for 'Taxonomy, Horticulture and Communication' – three strands essential to those working in education for plant diversity management.

Maintaining good communication with members and offering resource material to support education delivery in member organizations is also critical to BGEN's success. A new website, www.BGEN.org , has recently been launched offering quick and easy access to a range of good published articles, programme ideas and useful contacts.

BGEN's broad networking strength recently attracted the attention of the Department for Education in the UK, resulting in an offer of funding to both support and build the network and to manage a project focused on enhancing teacher recognition of gardens and gardening as stimulating educational resources – the *Growing Schools Garden Site Award Scheme*. BGEN has similarly been invited to participate in support for BGCI's educational material development on 'Climate Change' and data/reports for Target 14 of GSPC. Directors of BGEN have also been invited to sit on a number of national steering committees such as the Ministry of Education's initiatives on 'Learning Outside the Classroom (LOtC)' and the BBC's recent 'Breathing Places Campaign'. The network also feeds into national and international surveys related to environmental education programmes

The network is managed by a board of 16 directors/charitable trustees drawn from a range of establishments and elected for a 3 year period. This steering committee meets four times annually and additionally attends an Annual General Meeting; venues change for each meeting, with one of the committee members hosting the day. Three working groups exist, made up of directors/trustees working alongside invited non-board members. These working groups meet on the morning prior to the general committee meetings for efficiency and effective programme development; where feasible, phone conferencing may be used to save on travel costs. The three groups focus on development programmes for fundraising, training and communication.

Funding for the network comes from a number of strands including:

- Membership (3 levels – individuals, medium sized organizations, large organizations)
- Fees for training days (a target profit sum is set)
- Conference fees (a target profit sum is set)
- Donations
- Overheads for project work

The impacts that the network has had on UK plant based education and on capacity building within the field have been many and positive. Many botanic gardens, and similar organizations, have one individual who supports the education delivery on site, and they come from a range of backgrounds – horticulture, science and the formal education system. Having a good range of cheap and up-to-date training opportunities allows individuals to 'pick and mix' their own professional development and extends the range of teaching methodologies and content delivery that these individuals can offer in their own institution. It also offers a good benchmarking system.

A resource directory that can be accessed on-line provides an excellent way of keeping abreast of current research and knowledge in the field and the e-network provides opportunities for instant mentoring, advice or offers of resources. This helps reduce 're-inventing the wheel' in programme development or production of written activities and materials.

BGEN is linked externally to a number of other networks, with whom there is regular contact. This broadens the reach of BGEN and also provides other contacts and training opportunities for members. The network is now recognized nationally and this has helped increase the profile of plant based education, raised the status of education within botanic gardens and offered lobbying opportunities for better plant based education with the Government and other education providers. It has also opened up the possibility for BGEN to bid for and be awarded funding for regional and national projects.

Case study 2 - The Argentine Network of Botanic Gardens (RAJB)

The development of Argentine Botanic Gardens goes back to 1898, when the municipal garden of Buenos Aires, Jardin Botanico Carlos Thays, was opened. This was followed by the Lucien Hauman Botanic Garden (1910-22) and the Jardin Botanico Arturo Ragonese, (INTA) in Castellar, Buenos Aires in 1947. Many more have been opened since that time. The Argentine Network of Botanic Gardens (RAJB) originated in 1996 and was launched at the 25th Argentine Symposium of Botany when the first meeting of all the botanic gardens was hosted.

The objectives of RAJB are to:

- Co-ordinate activities and promote communication between botanic gardens using seminars, courses and publications
- Extend conservation programmes *in situ* to National Parks
- Promote the importance of natural resources to local communities through education programmes
- Organize environmental and research congresses, including the participation of invited national and international researchers
- Work together to obtain political recognition

Many of the network encounters were during national and international congresses, where members could share their experiences and look for potential joint collaborative projects. These ranged from participation in the BGCI International Congress in Ashville, USA (2000), the Australian Botanic Garden Congress (2001) and the Global Botanic Garden Congress in Barcelona (2004) to the Annual Meeting of the Botanical Society in Chile.

A huge boost was given to the network, when there was a collaborative project between BGCI and RAJB initiated in 2004 and sponsored by the Investing in Nature Programme. This provided funding to enhance and strengthen the network. A training programme was set up which has built capacity over the last few years, with seminars and workshops offered on Botanic Garden Management (2004), 'Environmental Education' (2005) and Conservation in Botanic Gardens (2006). Over these three years there has also been an additional annual workshop to explore 'Botanic Gardens in Argentina'. Since 2005, the network has managed and implemented the development of an annual 'World Botanic Garden Day' in Argentina, promoting the role and work of botanic gardens to the wider public.

These training sessions and regular network meetings supported the development of a national 'Action Plan for Botanic Gardens', where over 40 botanic gardens collaborated to build a strategic development plan for Argentina. Launched in 2006, this Action Plan has three elements – Conservation, Education and Research. The network has been able to monitor progress on the Action Plan and data has been collected on the work to date. 13 botanic gardens were surveyed to evaluate how internal and external issues had impacted on the delivery of the Action Plan and to what extent the objectives had been successfully completed. 77% of botanic gardens had fulfilled their Action Plan targets; however there were some weaknesses in the overall delivery of conservation initiatives into national parks, public education programmes and human resources development.

The evaluation did however show clear benefits of networking across the gardens including:

- The development of joint project activities
- Good collaboration on database and living collection information
- Development of joint protocols
- An enhancement of *in* and *ex situ* conservation work
- More sustainable use of resources.

Overall there was an improved efficiency in the work and development of the botanic gardens

In summary, networks offer exciting and effective possibilities for personnel working in botanic gardens; they are also highlighted as a target within the Global Strategy for Plant Conservation. In an economic climate of diminishing funds and loss of resources, it is even more important that we find efficient ways of working together to reach our ultimate goal of plant conservation and the sustainable use of our resources. Networks are a critical tool to accomplish this.

Specifically, they will enhance data representation in regions where botanic garden representation in the databases is lower than in other regions. They will add information on where expertise in horticulture, taxonomy, mycology and entomology can be found in the world's botanic gardens. Finally, they will add information on which plant species demonstrate weediness in their new climate or location. This information will be useful for all countries.

The American Public Gardens Association (APGA) received funding to develop a training and outreach campaign for botanic gardens. APGA will work with the USDA National Institute for Food and Agriculture to develop training modules to teach garden staff to identify and report plant pests. This will help gardens to protect their collections, and to get better diagnostic support and control recommendations. The grant will also help gardens enhance their outreach programmes, with the goal of enlisting plant lovers everywhere in the effort to detect new pests as soon as they arrive. Once these training modules are developed they will be made available to botanic gardens worldwide.

Pilot Projects

Several pilot projects by other researchers have demonstrated the feasibility and value of a sentinel plant network. The most advanced of these was a five year pilot by the Ministry of Agriculture and Forestry of New Zealand. Fagan *et al*. (2008) first analyzed collection information to select gardens with strong representation of New Zealand plants. Then they performed a climate analysis to find gardens with climates most similar to that of New Zealand. The most suitable sites were in Australia, north-eastern Europe and parts of the western USA. They developed a standard symptom-based survey protocol that could be used by non-specialists. Fourteen gardens were visited and 91 attacks of pests on New Zealand's native plants were observed. Of the 32 pest taxa they diagnosed, 22 were pests already present in New Zealand. Thus ten new pests of concern were identified. An analysis of the costs and benefits of various approaches to collecting such data was conducted (Fagan, *et al*., 2008). However, to date the program has not been fully implemented.

French and Chinese entomologists are collaborating to establish plantations of European tree species in China. Two of four planned plantings, containing over 500 trees, have been established. Monitoring studies have detected a number of insect pests and diseases (Alain Roques, pers.comm.).

Conclusions

The National Research Council recommended monitoring native plants growing abroad to inform invasive pest prevention efforts. The above examples demonstrate that sentinel plant monitoring approach can help identify potential pests. BGCI member gardens are invited to participate in helping to develop an international network of gardens to help preserve species diversity by preventing the spread of invasive insect pests and diseases.

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This is how the Botanic Garden, Natural History Museum, in Oslo has started to take this topic seriously, listed by the five above mentioned pathways:

1. Regarding the information aspects, the Botanic Garden in Oslo has built a demonstration area of alien as well as threatened Norwegian plant species. Alien species have black labels; threatened species have red labels, according to our Norwegian Black and Red List. The area was officially opened by our Minister of Environment at the Biodiversity Day in 2010. The alien plants grow in circular cement holders so they don't spread vegetatively. All seeds are collected after flowering in order to prevent seed dispersal.

In cooperation with the Garden Society, the County Governor's Office and the Norwegian Food Safety Authority we have made a brochure with information about plants that escape from gardens and become a threat to the indigenous vegetation. It is widely distributed from our Botanic Garden, Garden Shops, museums and art galleries, as inserted in magazines etc.

2. Discussions during guided tours in the Botanic Garden at the demonstration area of alien and threatened species give awareness. We have had some courses for teachers and workers at the Municipality of Oslo in natural sites outside the Botanic Garden, where both invasive alien species and threatened indigenous vegetation have been highlighted.

3. In nature, in and near Oslo, the following plant species are regarded as a threat to biodiversity: *Solidago canadensis*, *Rosa rugosa*, *Heracleum mantegazzianum*, *Fallopia japonica*, *Impatiens glandulifera*, *Lupinus polyphyllus*, *Vincetoxicum rossicum*, *Vinca minor*, *Lysimachia punctata*, *Bunias orientalis*, *Acer pseudoplatanus*, *Syringa vulgaris*, *Cotoneaster lucidus* and several other *Cotoneaster* species, *Phedimus spurius*, *P. hybridus*, *Cerastium tomentosum*, *Laburnum alpinum* and *L. anagyroides.* The Municipality of Oslo and the County Governor now employ 4 people during the summer months to eradicate the majority of these species, especially in nature reserves and along the sea shores. The Natural History Museum provides courses each spring and supervises the job. During 2009-2010 we were in the working group, together with marine biologists, limnologists and the authorities, to make a Regional Action Plan for how to deal with alien species in our region of the country.

4. Six years ago we started the eradication of *V. rossicum* and marked on maps where it is growing. Each summer we have been involved in the combat against this plant. The Natural History Museum has made a TV film about one of the species rich islands just outside Oslo and there we demonstrate, among other topics, how *V. rossicum* is manually removed

5. Experiments with eradication: The two problematic alien species the Natural History museum have been working with are *V. rossicum* and *Phedimus spurius*, two introduced plant species growing on open habitats on calcareous soils near Oslo, where the biodiversity is very high and there are many rare and endangered species. These two alien species are not observed or considered as a severe problem in other parts of Europe and no manual for eradication was available for the authorities. The methods studied are: manual picking, burning, herbicides and covering with black plastic so no light reaches the earth surface.

Some botanic gardens have started demonstration areas and provide information about problematic alien species. I hope that the above mentioned list of our start projects can function as an inspiration for the botanic gardens around the world that still have not begun the combat against alien species. Each region has there own problematic species. Each botanic garden has thus different problematic species to inform about.

The big question is now how to handle our collections and how to prevent spreading from botanic as well as private gardens. In the gardens we have hundreds of species potentially capable of escape. The basic function for botanic gardens has been to highlight biodiversity and display as many species as possible from all parts of the world. In the Botanic Garden in Oslo we have started by having problematic plants that we want to show the public in this new special area for demonstration. At other places in the garden they are removed. But we have many species of *Cotoneaster* and *Sorbus*, whose fruits are spread by birds. How shall we deal with this fact, remove them all or close our eyes?

Our new function will be, in addition to highlighting worldwide biodiversity, to preserve the indigenous diversity, give information about alien species that are or have the possibility of becoming a threat, cooperate with the municipality in eradication work and participate in restoration projects.

What should be the features of programmes we offer to young children? First of all, as all age groups benefit from hands-on activities, programmes for this age group should also be hands-on. Learning by doing in nature is one of the most natural learning methods that help us to explore our surroundings and to understand the life on the earth. Lind (1996) supports this idea by stating that “Hands-on experiences, which emphasize the process skills of science, are essential if the child is to receive the maximum benefits from science instruction” (p.55). Hands-on activities are an essential part of all programmes of NGBB. Young children, participating in the educational programmes of the NGBB, plant, observe, classify, collect natural materials and create artistic works. Since 2005, 8,911, 3-6 year old children have participated in educational programmes of the NGBB. Sensory participatory engagement with the environment is the key of the success of these programmes for young children offered by NGBB because young children learn about the world through their senses. Lind (1996) suggests making children observe with their senses. As a second step, she stresses that scientific process skills such as classifying, predicting, measuring and communicating results will be taught to young children for the development of scientific concepts. Also Jenkinson (2006) says sensory engagement with the outdoors in the early years helps the development of ethical and environmentally friendly behaviours and attitudes.

Other than content, the pedagogy of the programmes is the other key for success of the NGBB educational programmes. However, Falk and Dierking (1992) state that museum like institutions such as botanic gardens generally aim to teach content rather than trying to increase interest and motivation of visitors or their affective potential. As Falk and Dierking stress it is one of the important points to maximize the affective domain of visitors and it can be said that it is the first step for further content learning.

If botanic gardens want to enhance learning opportunities for young children the other thing that should be considered are the properties of the landscape if it provides young children any chance to explore and to learn or not. Falk and Dierking (2000) mention the importance of physical setting in museum-like institutions like botanic gardens. Similary Orion (1993) emphasizes the importance of providing an environment in which children can construct information themselves. Danks (2006) confirms this by saying that “…we do not just want them to learn about nature, we want them to learn from it” (p.20). This kind of learning will be related to real life and hands-on and it is valued as long lasting and meaningful learning. Senses should be provoked by our educational facilities and also landscapes. Fortunately Willison (2006) states “… many gardens are increasingly conscious of the need to offer children opportunities to explore their surroundings freely” (pp.2-3). If so, botanic gardens need to consider the developmental characteristics of children in designing landscape and infrastructure, and providing nature play opportunities. As an additional part of landscape, many botanic gardens started to build themed playgrounds for plant-based learning for young children. Recently, NGBB opened the first of this kind of playground, “Discovery Garden”, in Turkey. It was opened on 23rd April 2009. This Garden has been designed for children ages 3 to 9 to teach children about nature and plants as they play. The theme of the garden is “*the importance of plants for other living organisms”* . The garden components, that were shaped by the theme, include a maze made from evergreen shrubs, a tree house, a spiral water feature, a sand box, tunnels made from willow (*Salix* sp.) branches, a balancing roller bridge, agility area, and an activity area for storytelling and art activities. There are some additional toys and equipments like a flower puzzle showing plant parts, musical instruments, a worm puzzle and interactive exhibits like the photosynthesis wall, cactus plant, and age rings of a tree. It will also support their physical activity, social development, and emotional wellbeing through outdoor experiences. On weekends, different educational activities are offered for the targeted group at the garden.

Furthermore, gardening projects can be applied with young children. NGBB started a Children’s Gardening Project in 2006. Although, the project is targeted at primary school students, the annual programme was adapted and applied with a group of preschool students in 2010. These programmes are valuable because they provide hands on experiences in the natural environment and help children to observe the life cycles of plants, ecological systems and human impact. Positive effects of gardening projects are proved by much research (e.g. Conlon 2005; Tims 2003). Capra (2001) states that developing a garden and using it as a source of food can help people to understand the principles of ecology. Also this kind of project can be helpful for the development of healthy eating habits, because early childhood is an important period for good health and nutrition habits (Lind, 1996). Further plans of the NGBB are to continue these programmes with various age groups and make valuable evaluations on these.

NGBB has already developed many programmes for preschool groups. However, there was a big demand from families whose children do not attend preschool. So, various weekend programmes and workshops that families can participate in are created for preschool groups. “Bird watching”, “Art inspired from the garden”, “My nature bag”, “Paper making”, “Art from rubbish”, “Experiments in nature”, “Maths in the garden”, “I am a child, I have rights” and “Nature and origami” are some examples of these programmes. These programmes are applied by experts who work in the environmental education area in Turkey.

Conclusıon

Taking everything into account, botanic gardens are important out-of-school science learning sites. By considering the importance of the early years, botanic gardens need to target young children. Young children explore their surroundings by their senses so it is one of the keys of provoking their senses by our programmes and landscape for plant based learning. Also, programmes and activities for young children must have some characteristics. Most importantly, young children learn by doing and active involvement is important. However to be effective other than content, pedagogy is important and we need to consider the affective domain of our programmes. Play is the business of children so it is important to provide enjoyable and playfull programmes for better learning. This may help us to increase plant interest and indirectly may help us to increase positive attitudes toward the environment and to conserve plant biodiversity. Gardening programmes with young children can be applied and this may help them to learn about ecological systems. Children develop scientific process skills such as observation, measurement and prediction at early stages. So, science is for young children as well. Lastly, the NGBB is one of the botanic gardens that try to provide good examples on educational strategies for young children.

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The Conservatoire Botanique National du Bassin Parisien has been observing the species since 1995 and the results clearly showed that: (1) there were a small number of remnant individuals (*Fig. 3*); (2) a majority of plants did not flower; (3) a few capsules were produced; (4) the seeds are very often aborted; (5) among the very rare germinations, we observed a very low survival rate.

Further investigations made us able to understand why the species became so scarce in the Fontainebleau forest: besides the modifications of forestry practices, we found a low genetic diversity in comparison with upland populations and we have reliable indices of an inbreeding depression inside the Fontainebleau populations (*Fig. 4*).

Therefore, it became obvious that, considering the low number of remnant individuals in 2000 (only one) and the genetic patterns, the reintroduction scenario will be based on the increasing of the effective size, a combination of a higher number of individuals and a higher genetic level inside the reintroduced population. Indeed, the increased number of individuals reduces the effects of the demographic stochasticity and protects against the Allee effect, while increasing the genetic diversity prevents the population from inbreeding depression and enhances adaptive capabilities, almost in the context of threatened populations facing climate changes.

To make the coercive laws progress: the contribution of applied research.

However, the specifications of the Conservatoires Botaniques Nationaux are very clear and correspond with those of the IUCN: for reinforcement or reintroduction programmes, prefer the local material.

In 1999, we decided to experiment with the creation of eight hybrid populations of *A. grandiflora*, to study the benefit of supplementing the local genotypes with new blood and, maybe, to improve the laws and to change scientific minds. We placed two enclosures of one hundred square metres each in four sites in the Fontainebleau forest. Of course, the enclosures are far enough from the original populations to avoid gene flows between the threatened populations and the artificial ones (*Fig. 5*). In each enclosure, we reintroduced two hundred and twenty five individuals: one third were cuttings from Chinon, and two thirds of them were cuttings from Fontainebleau. We set up a specific monitoring protocol thanks to permanent quadrats with twines that are attached to the enclosures in which all plants are labelled (*Fig. 6*). The annual monitoring is carried out by the staff of the Conservatoire and each summer includes: floristic inventories, the enumeration of all living individuals, the evaluation of the mortality and the morbidity, the recruitment level, the plant size, the numbers of flowers per individual, the number of fruits, their size and their weight. Meanwhile, we developed molecular markers that enabled us to identify the parents of each new plant.

Finally, the experience gave us three main results: (1) we found that the descendants of Chinon are well adapted to their new environment (*Fig. 7*); (2) the hybrids between the two origins are more vigorous than the autochthone ones; (3) and we did not observe any crossbreeding depression. Therefore, it became obvious that the fitness of populations increases when new blood is brought into Fontainebleau's genotypes and, if we want to restore populations with improved adaptive capabilities, we have to supplement the local genetic diversity of the threatened populations of *Arenaria grandiflora* in the Fontainebleau forest.

To promote the Common Good by working together.

This applied research started in 1999 and up to now, we have only discussed it between scientists, while conservation biodiversity is supposed to benefit all. Moreover, since the beginning of the project, we encountered some difficulties in making this reintroduction accepted by forest managers, users, associations, etc. We decided to involve more people in the reintroduction programme and we began with a discussion with the scientists and the land managers involved in biodiversity conservation, and at last, with the public at large.

It is very clear that everybody feels very concerned by biodiversity conservation and they seem motivated to participate in it. But when we address the issue of reinforcement or reintroduction, both the public at large and ecologists seem rather doubtful. Finally, when we address the issue of the benefit of mixed populations in reintroduction programmes, feelings turn to fear, almost like those about the issue of genetically modified organisms.

To whom will we bequeath the seeds we conserve?

Accordingly, because we generally encounter difficulties in changing adults ways of thinking, our goal was to involve young people in the reintroduction programme.

In 2008, we settled up an educational project with three Primary school classes, with a total of ninety students aged eight to ten years.

We chose two different schools : two classes were located in the city of Fontainebleau, thus in a very green environment, and the third one was located in the city of Thiais, very close to Paris, in a very urbanized environment and in a suburb where education was declared as a priority by the French Government.

We did not want the reintroduction programme to be only an operation about gardening, so we worked with the students in the framework of an educational project of which the aims were: (1) to involve them as soon as possible in the scientific process; (2) to make them understand what they do and why; (3) to make all of them participants and responsible for each aspect of the project; (4) and to establish it as a lasting experience in their minds.

Toward a wide community interest.

The construction of this project needed the support of many important partners, including: the National Center for Scientific Research, the Inspection of the Academy (a governmental structure in charge of the education in French regions), the councils, the early childhood services of the councils, the French Forestry Office, and the Ecology and Sustainable Development Ministry.

Preliminary works.

The first step of the educational project was a list of key words we gave to the teachers. Because of the complexity of scientific concepts needed for the reintroduction programme, like “inbreeding depression” or “*in vitro* micropropagation”, the teachers could introduce these terms, in order to avoid misunderstandings during the later stages of the programme.

A few months later, engineers, researchers and botanists gave them a three hour course to teach them: (1) about the importance of plants in our life; (2) to make them aware about scarcity, the disappearance of species and its consequences; (3) the threats that put the species on the verge of extinction; (4) the rule of citizens and their rule to prevent it; (5) their work on the field for *Arenaria grandiflora*; (5) the place this program has in the French history of conservation.

Two months later, we organized a tutorial session at the Museum and in our laboratory where each student had a stereo zoom microscope to observe seeds, with *A. grandiflora* ones. During the day, the students could isolate seeds of different species from soil samples thanks to an automatic sieve, and they sowed the seeds in plastic cups. Each student realized their own *in vitro* cuttings on *A. grandiflora* (*Fig. 8*) and they visited our seed bank and the conservatory garden where the plants to be reintroduced were cultivated. After this tutorial session, each student went home with two souvenirs: (1) the plastic cup in which they sowed the seeds (the goal was to ask them if they can identify the species which will grow in the cups); (2) the test tube in which they placed the cuttings of *A. grandiflora*. Thus they could observe the development or not of their sample.

The "reintroduction day".

The "reintroduction day" was organized two months later. The classes were divided into five student groups, and each group was responsible for the plantation of twenty-five plants, by using a quadrat. Then they placed a permanent survey marker at the centre of each quadrat to facilitate the monitoring during the following years.

Each group had a survey data paper where the students noted their own measurements of the three individuals they planted (*Fig. 9*): the places inside the quadrat, the sizes of the plants, did the plants produce flower buds and their number.

At the end, they labelled each individual they planted with a permanent label and they wrote their own name on it, in the framework of a real sponsorship of this reintroduced species (*Fig. 10*).

The project did not finish with the plantation and we organized another field session at the flowering period. During one day, the students came to measure the development of their own plants, so they could make a rapid comparison with the former two months stages. After the summer holidays, the city of Thiais organized each September a fair for non-professional gardeners, and the students managed a booth to present their experience to the public at large during the 2009 fair. Finally, during the same day, they received a diploma.

Their first diploma.

The diploma we gave the students looks like an official one (*Fig. 11*). It contains the name of the student, the numbers of the three individuals each student planted, a picture of the student during the event, and was signed by the student, the director of the Conservatoire Botanique National du Bassin Parisien and by the General Director of the French Forestry Office.

The implementation of the GSPC.

Thanks to the many aspects of this programme, the Conservatoire Botanique National du Bassin Parisien widely contributes to the implementation of the GPSC, especially for the nine following targets:

1. **<u>A widely accessible working list of known plant species, as a step towards a complete world flora.</u>**

Since the beginning of this programme, the Conservatoire has been accumulating thousands of data for species belonging to the calcareous grasslands flora.

2. **<u>A preliminary assessment of the conservation status of all known plant species at national, regional and international levels.</u>**

The result of the monitoring protocol carried out during the last decade is a good knowledge of the conservation status of this glacial relict, as well as the very rare species that grows with *A. grandiflora*.

3. **<u>Development of models with protocols for plant conservation and sustainable use, based on research and practical experience.</u>**

We made much progress in the field of reintroduction of populations, with the experimentation of hybrid populations carried out in nature.

4. **At least 10% of each of the world's ecological region effectively conserved.**
5. **Protection of 50% of the most important area for plant diversity assured:**

Besides the reintroduction of *A. grandiflora*, the ecological restoration of the sites before the program allowed the conservation of open habitats like calcareous grasslands.

7. **60% of the world's threatened species conserved *in situ*.**
8. **60% of threatened plant species in accessible *ex situ* collections, preferably in the country of origin, and 10% of them included in recovery and restoration programmes.**

The program of reintroduction of *A. grandiflora* in nature was only possible because the species was cultivated *ex situ* and propagated *in vitro*.

15. **The number of trained people working with appropriate facilities in plant conservation increased, according to national needs, to achieve the targets of this Strategy.**

16. **Networks for plant conservation activities established or strengthened at national, regional and international levels.**

The wide Community Interest which made this programme possible facilitates at the same time the emergence of the biodiversity conservation in the main society concerns. This programme was widely covered by the media that helped the public at large to realize that concrete actions can be conducted for the benefit of the Common Good.

Fig.1 *Arenaria grandiflora* L.

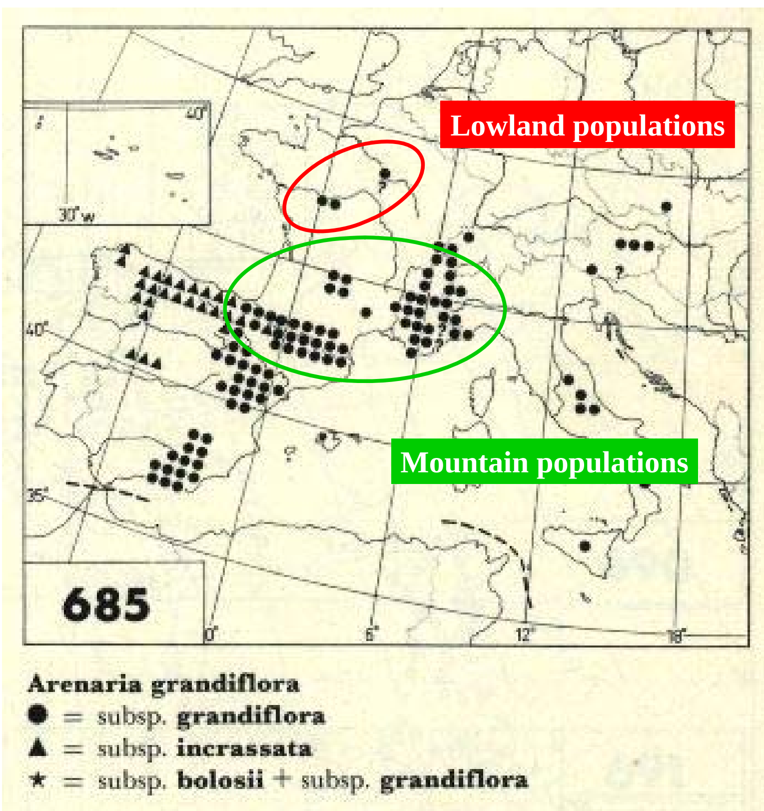


Fig. 2 Repartition area of *A. grandiflora*.

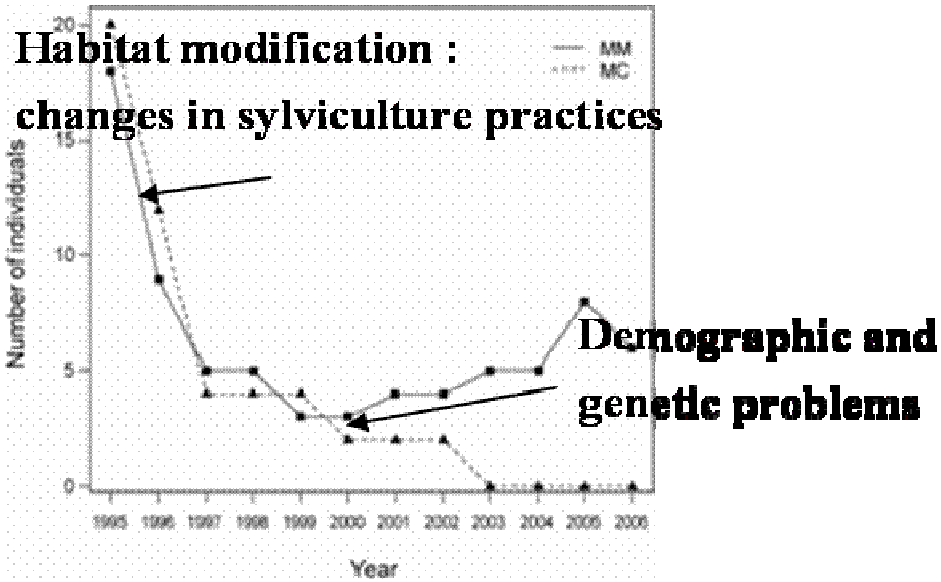
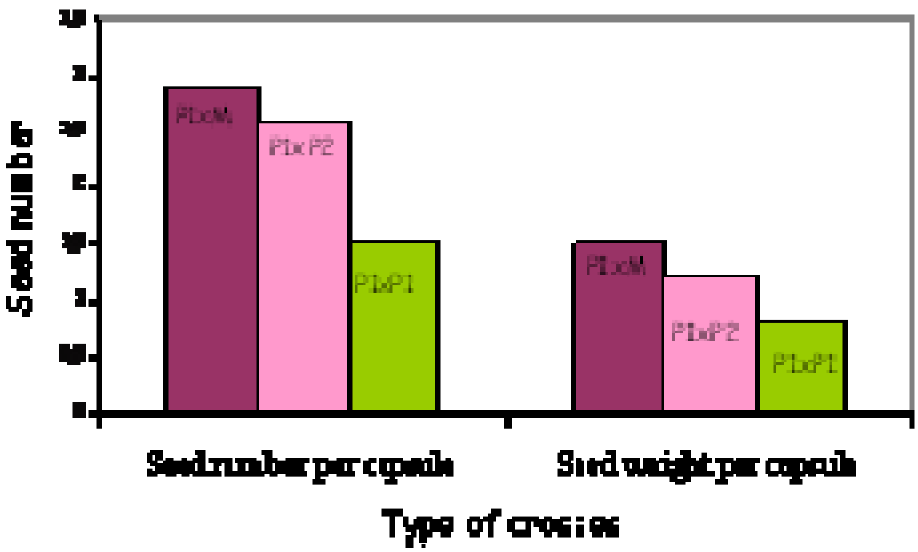


Fig. 3 Demography of the two populations of Fontainebleau forest over the last decade.



☆ Fontainebleau x Fontainebleau (lowland crosses)
☆ Fontainebleau x Chinon (lowland crosses)
★ Fontainebleau x Alpes (lowland/moutain crosses)

Fig. 4 Quality of the biology of the reproduction, according to the type of controlled crossing.

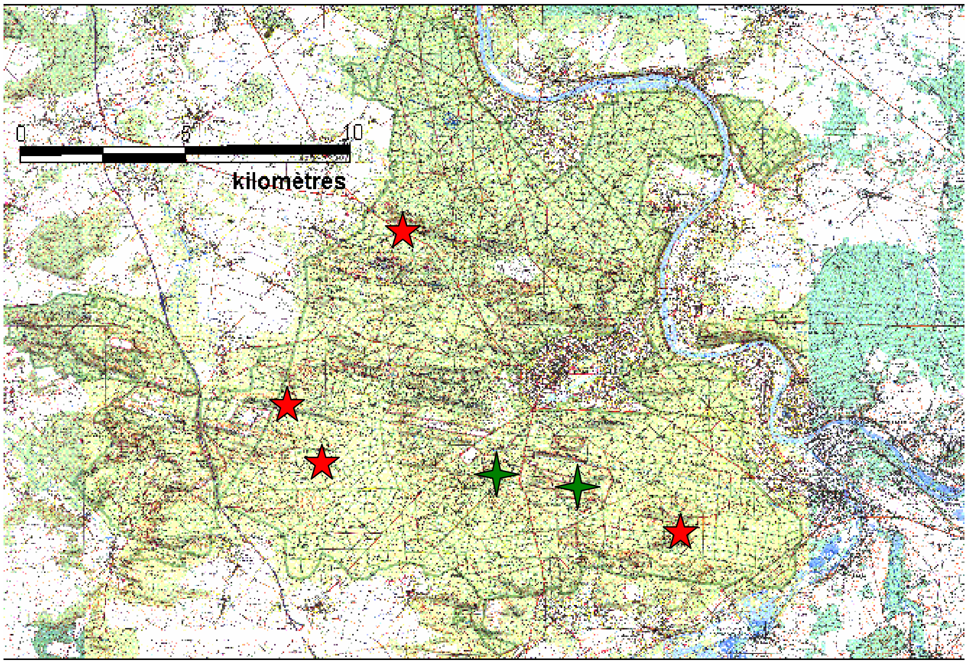


Fig. 5 Location of the experimental hybrid populations (in red) and of the original populations (in green).

Fig. 6 The monitoring protocol.

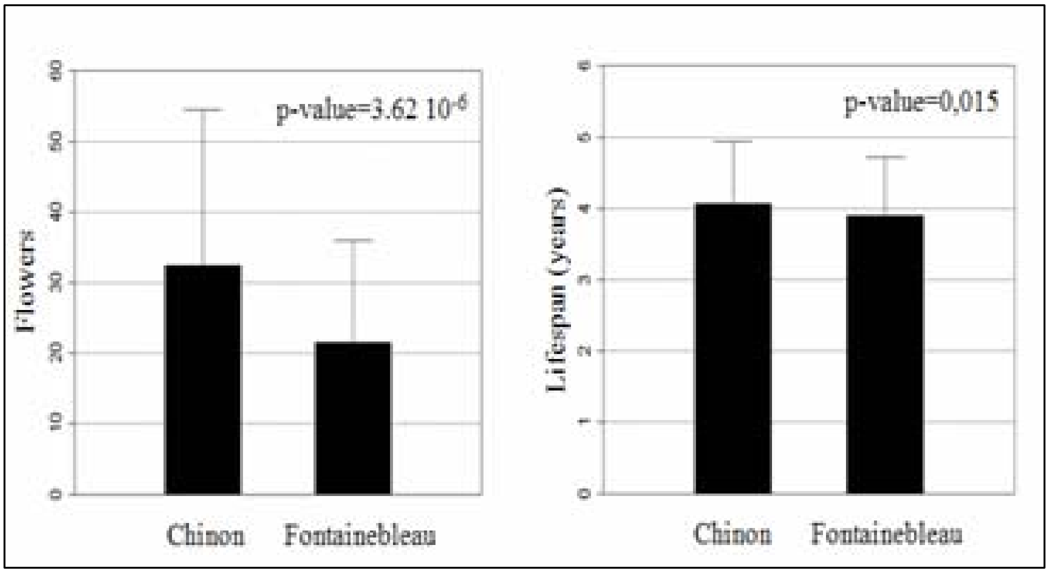


Fig. 7 One of the main results: the adaptation of the allochtonous genotypes to their new environment.

Fig. 8 Picture of the *in vitro* micropropagation experiment conducted by the students.

Fig. 9 Picture of one of the students during the plantation.

Fig. 10 A plant labelled with the name of its “Godfather”.

CERTIFICAT DE PLANTATION ET D'ECO-PARRAINAGE
D'UNE ESPECE VEGETALE
MENACEE DE DISPARITION

Ecole Buffon
- THIAIS -

M. Jacques MORET, directeur du Conservatoire botanique national du Bassin parisien,
M. Pierre-Olivier DREGE, directeur général de l'Office National des Forêts,

décernent à **Faiza DRIF** *le* ***Certificat de plantation***
et d'Eco-parrainage *de trois pieds de Sabline à grandes fleurs (****Arenaria grandiflora*** *L.).*

Certificat obtenu le 31 mars 2009 avec la plantation de **FAIZA 1 (n°18), FAIZA 2 (n°14) et FAIZA 3 (n°5)**
au Petit Mont-Chauvet, en forêt domaniale de Fontainebleau.

Le titulaire

Le Directeur du Conservatoire botanique national du Bassin parisien
M. Jacques MORET

Le Directeur général de l'Office National des Forêts
M. Pierre-Olivier DREGE

Fig. 11 The diploma each student received after the project.

Study islands and methods

The major physical characteristics of the islands of the Mascarenes and granitic Seychelles as they pertain to plant diversity and conservation along with their respective native angiosperm flora are summarized in Table 1. A relatively low diversity but high endemism is apparent as is indeed typically the case for isolated and high oceanic islands.

The Mascarenes and granitic Seychelles share a broadly similar human colonisation history which over the years came to strongly influence the islands' native habitats. All three Mascarene Islands started being settled in the 17th century, while the granitic Seychelles was colonised a little later around the mid 18th century. The Seychelles and the Republic of Mauritius (which includes Rodrigues) got their independence from British colonial administration about 40 years ago while Réunion has remained a French territory.

Overall the angiosperm flora of the region is generally well known. This is partly related to a long tradition of botanical studies particularly for the flora of Mauritius and Réunion which started to be systematically surveyed in the late 18th century with Commerson (1768). Botanical surveys of the flora of the granitic Seychelles started in earnest somewhat later in 1840 (Friedman, 1994) while that of Rodrigues was the last, in 1874, to draw the attention of botanists (Balfour, 1879), when unfortunately much of the native vegetation was already destroyed (Horne 1875; Balfour 1879) and a number of species doubtless had already gone extinct before being formally described as can be deducted from Leguat (1708).

Among the islands, Mauritius had its Flora published first (Bojer, 1837), followed by the Seychelles (Baker, 1877), Rodrigues (Balfour, 1879) and Réunion (Cordemoy, 1895). The flora of the Mascarenes is being thoroughly updated through the 'Flore des Mascareignes' project which started in the early 1970's and is about to be completed with only three families remaining to be published. The most updated Flora for the Seychelles is that of Friedmann (1994), who however flags a number of unresolved taxonomic problems with some groups, such as the Rubiaceae, Euphorbiaceae and Phyllanthaceae. Friedmann (1994) covers only dicotyledons, while for monocotyledons only a checklist exists (Robertson, 1989).

Despite the small sizes of the islands and their long history of botanical inventories (ranging between 135 and 240 years) new endemic species are still being discovered (e.g. Florens & Baider, 2006; Le Péchon, 2009) as are non-endemic natives (e.g. Roberts *et al*., 2004). Traditional morphological studies are also still leading to the splitting of single into several species (e.g. Bosser 2005), while other studies are sinking previously recognised species (e.g. *Gaertnera* in Mauritius, Malcomber & Taylor, 2009). A molecular approach to delimit species/genera is also being used (e.g. Le Péchon, 2009; Plunkett & Lowry, in press). All these works are leading to a constantly evolving knowledge and size of the flora of all the islands.

In this paper we review the native angiosperm flora sizes, endemism and their degree of threat, as well as the status of plant conservation in the Mascarene Islands and the granitic Seychelles. We based our review on the latest available documents and on contributions of experts from each island or island group.

Results and discussion

Diversity and endemism

The total native angiosperm flora of each island vary between 150 to 691 species, summing up to 555 single island endemic species (if the granitic Seychelles is counted as a single island), with an island endemism varying between 30-39.5% (Table 1). The Seychelles has an angiosperm flora estimated at 200 species, with c. 70 endemics. In the Mascarenes, Rodrigues has the smallest flora with 150 species, followed by Réunion (550) and Mauritius (691). For the Mascarenes, some of these species occur in 2 or all three islands of the archipelago. Such Mascarene endemics (ME) are distributed as follows: Rodrigues, 72; Réunion, 140; Mauritius, 150. An important percentage of the Mascarenes plants are single island endemics (SIE): Rodrigues, 47; Réunion, 165; Mauritius, 273 (Table 1).

Red List categories and threats

For all islands, the percentage of threatened species *sensu* IUCN (2001) is relatively well known though many species do not yet appear in the official IUCN Red List. In the granitic Seychelles, it is estimated that 2-5 (2-6%) species are extinct, with 70% of the endemic species considered threatened with extinction. For the Mascarenes, considering SIE only for example, Rodrigues has the highest rate of extinction (10 species or 21.3%), followed by Mauritius (30 species, 10.9%) and Réunion (2 species, 1.2%). The level of threatened SIE is high in all islands (Mauritius, 81.7%; Rodrigues, 77.8%; Réunion, 50.9%). These high levels of threatened species are largely the consequence of high rates of past habitat destruction for agriculture and other land uses. While less than 5% of the original habitat is left in each of the granitic Seychelles, Mauritius and Rodrigues, in Réunion which has the lowest rates of extinction and threatened species, native cover is still relatively high (30%) although some community types like the dry forest have all but disappeared (Strasberg *et al*., 2005). Past habitat destruction has generated two main and related threats currently affecting plant diversity in all the granitic Seychelles and the Mascarenes: small population sizes and fragmentation. However, the most important threat (on all islands) is posed by a variety of interactions with invasive alien species (both animals and plants). Socio-economic threats (e.g. demographic growth, tourism, etc.) are considered less severe than biological threats (Caujapé-Castells *et al.*, 2010).

Conservation achievements and gaps

All islands have recently greatly advanced some aspects of plant conservation, while certain gaps are however also apparent. Major advances include the production of conservation strategies for all the islands concerned (e.g. Beaver and Kueffer, 2005; Kueffer *et al*., 2007), although implementation of these strategies is sometimes weak like in Mauritius. Similarly *ex situ* conservation is undertaken in all the islands. The extent of area protected for biodiversity conservation remains small in Mauritius and Rodrigues but has recently slightly increased in Mauritius with the setting up of the National Park of islets in 2004. A greater improvement occurred recently in extent of protected areas for the granitic Seychelles, and particularly for Réunion with the creation of a large National Park (> 1,000 km^2). Creation of new conservation NGOs and improved outreach (e.g. the Seychelles plant conservation newsletter 'Kapisen', see http://www.plantecology.ethz.ch/publications/books/kapisen) have also been noted recently in the Seychelles and Réunion, while Mauritius and Rodrigues both already have strong and active NGOs.

Conservation of island biodiversity often necessitates active ecological restoration where invasive species are, if not eradicated, at least controlled (Simberloff, 2001). This situation applies well to the islands studied here where some well known success stories in saving animal species already exist, for example on Mauritius (Jones, 2008). Ecosystem restoration has however been generally slow to follow particularly on Réunion where prohibitive costs appear to be a sizeable obstacle. However, some degree of ecosystem restoration is being undertaken on all islands (e.g. Florens, 2008; Samways *et al*., 2010). Such work is particularly advanced on Mauritius for example with the so-called 'Conservation Management Areas' (comprising of forest patches weeded of alien plants and fenced against large hoofed alien mammals) which however remains to be extended beyond the currently tiny areas concerned.

Other gaps, applying particularly to the Seychelles, Mauritius and Rodrigues include a lack of human and financial resources in conservation research and management. The islands' local governments seem to recognise the importance of conservation, but do not follow up with meaningful support. In Réunion, such problems are less acute because the island typically benefits from a large pool of expertise from France. Establishment of regional networks to exchange expertise and experience could help decrease such weakness and improve plant conservation. Given the similarity in biogeography and past and current anthropogenic disturbances, it would be ideal to set up a strong regional plant conservation network (including Comoros and Madagascar) as well as envisage creating regional strategies on conservation and research.

Conclusions

The granitic Seychelles and the Mascarene Islands hold a globally important angiosperm flora with high level of endemism which however is currently highly threatened due mainly to extensive past habitat destruction and current impacts of invasive alien species. The tasks of conservationists are made more difficult by a general lack of human and financial resources as well as governmental commitment particularly in the case of the Seychelles and the Republic of Mauritius (includes Rodrigues), although some encouraging important development has been achieved recently. The management capacity on these islands is thus vulnerable and the long-term institutional and financial support of the few key persons per island is rarely secured. Finally, it appears that there is scope for networking and strengthening plant conservation on islands given the similarity of challenges and solutions facing them regarding the conservation of their plant diversity.

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Table 1: The islands studied, their geological origin, age, land area, maximum altitude, isolation from nearest landmass and the size of their native angiosperm flora including the respective proportion of single island endemic species.

Islands	Geological origin	Age (MA)	Size (Km^2)	Maximum altitude (m)	Nearest main landmass (km)	Number of species	Number (%) endemics
Seychelles*	Granitic (Continental)	>65	235	905	900	200[1]	70 (35.0)
Reunion	Volcanic	3	2512	3070	665	550[2]	165 (30.0)
Mauritius	Volcanic	8	1865	828	900	691[3]	273 (39.5)
Rodrigues	Volcanic	10	109	398	1400	150[4]	47 (31.1)

* Seychelles comprises in this analysis mainly islands of continental origin. The archipelago has also coralline islands that are much younger (0.125-0.01 MA), small and with low diversity. Age is given for the time since complete separation from other landmasses.
1 = Friedmann, 1994; 2 = CBNM, 2010.; 3 = Baider & Florens, unpubl.; 4 = Baider, unpubl.

to engage with these ideas, and to start recognising the power and responsibility we have to respect our resources and share them.

The site itself is a living example of what each of us can achieve when we work together and with nature. Built within a 60-metre deep, 15-hectare former china clay pit, Eden houses the largest ethnobotanical collection in the world, and is home to two of the largest conservatories (the Covered Biomes) in the world. The Rainforest Biome is 50 metres high, 110 meters wide, 240 metres long and houses plants from the Tropical Islands, Malaysia, West Africa and tropical South America. The Warm Temperate Biome, 35 metres high and 140 metres long, showcases the Mediterranean (citrus, olives, herbs and vines), the South African regions (proteas and aloes), Californian annuals (poppies and lupins) and shrubs of the Chaparral. In the 30 acre Outdoor Biome the crescent shaped terraces tell the story of plants that have changed the world and which could change the future. This landscape provides a display of plants, many of them productive crops that happily thrive in temperate climates around the world, including hemp, tea and sunflowers.

At Eden, our collection is showcased in unusual ways, and our planting schemes are realised in a way that's different from many other botanic gardens - we have the luxury of finding the stories first, and then painting a planted picture of those stories. Our belief is that, ultimately, education springs from emotion rather than information. So, rather than transmitting information, we aim to encourage discovery, to provoke curiosity, to have visitors make connections with their own lives. The tools we use to achieve this are many and varied, but are informed by simple principles; we want to generate awe and wonder, and encourage understanding, by engaging all the senses. Rather than covering the site with text, we experiment with poetry, dialogue, art, music and performance. At Eden, we engage people by telling stories, using narrative to connect people with each other and the world around them. The gathering places designed into our landscape, large and small, give us the space to engage in stories and conversations, and our exhibits bring these stories to life. That's one of the key functions the Bantaba fulfils in our Rainforest Biome. This gathering place gives us the perfect opportunity to tell some positive stories about the rainforest, and to highlight the fact that rainforest does not exist in isolation but is in fact filled with communities living and working there.

The Bantaba exhibit

Our Bantaba exhibit incorporates three areas, reflecting 3 different facets of village life. First is the 'Bantaba' or gathering place proper – literally, the "meeting-place under a tree" - where village elders gather to discuss the issues of the day pertinent to the villagers (Fig. 2a). Here also weddings, naming ceremonies and other celebrations are held. The nearby *Cola nitida* trees provide kola nuts for the elders to chew. The Bantaba is surrounded by other productive trees and herbs - cola, miracle berry, mango and banana - and forming a backdrop to all this is the chop farm, a communal cropping area which highlights the use of traditional leafy green vegetables in Africa (Fig. 2b).

Our Bantaba also includes a kitchen, or communal cooking area (Fig. 2c). A three-stone fire fills the centre of the kitchen. We can imagine that a young boy from the village keeps the stocks of firewood and kindling ready for the village cook and her apprentice. The various pots and pans each have a specific purpose – one for the rice or couscous, another for the sauce. The cook uses the large mortar and pestle for pounding the grains to make meal, closely watched by her apprentice, usually her daughter. This girl knows her place - her stool, mortar and pestle are all smaller than those of the cook. She is also responsible for keeping all the cooking utensils clean, and will use sand to scour the pots after each meal.

At the far end of the Bantaba is the well, another village hub, where villagers get their drinking water, bring their livestock to drink from the adjacent trough, and do their laundry (Fig 2d). Many people in rural parts of Africa don't have access to safe water and rely on open, hand-dug wells for their water supply. Ours is a deluxe model, with a rim made from a converted oil drum to prevent young children and animals from accidentally falling in. It's overlooked by a large oil palm, traditionally valued as the source of palm wine, tapped from cut flower-stalks near the top of the tree. The tappers use climbing belts made from twisted palm fronds to reach the top. Also valuable, the palm fruits can be used to make laundry soap, while the stems are used for roofing or fencing.

One of the most important functions of the Bantaba is to highlight the story of the Ballabu Conservation Project (BCP). With a conservation area incorporating 14 villages, the goal of BCP is to alleviate poverty for local people by making each village self-sustaining through local industries such as ecotourism and agriculture. The concept of the Ballabu Conservation Project is to create an 85sq kilometre conservation area, incorporating 14 Gambian villages. Each village will have a community forest park established, as well as some form of industry such as eco-lodges, recycling plants, skill training centres, agriculture or livestock. The forest parks will also deliberately link up to create a wildlife corridor to allow the safe passage of animals through the villages.

The Eden Project will assist with the Ballabu Conservation Project through Gardens for Life, an Eden initiative, which links 20,000 pupils in schools across the UK, Africa, India and the USA, encouraging them to create gardens, grow food and share stories with others across the world. Gardens for Life is about growing healthy children, healthy plants and global citizenship.

The Bantaba is a good example of the way Eden works – we don't always have the resources or the expertise to put something together ourselves, but we do have the connections with people around the world who help us retain the authenticity of what we do. So, with Ballabu, we had people in Gambia who were able to tell us what we might need, source and buy at market authentic artefacts for us, and then come and tell us the correct way to use and display those artefacts. It's an important part of the Eden ethos that we get things right – to show respect, care, attention to detail. In September 2008, the Associate Director of the Makasutu Trust, Mr. Malang Jambang, visited Eden and showed us how each of these objects would be used in everyday village life. A favourite example is the stripy plastic kettle (Fig. 2a), which confuses many of our visitors – how useful is a plastic kettle? – but is immediately recognisable to anyone who has lived in Gambia for any length of time as an essential for hand-washing before eating or praying.

The signs within the exhibit echo the voices of the villagers in the Ballabu conservation area. They were compiled from a series of questionnaires collected by a UK media student during her interviews with the villagers about their lives and home, which she kindly shared with Eden. Once more, connecting with a friend made it possible to use quotes from the questionnaires to tell the story of the space, allowing the people of the area to speak for themselves.

This, then, is our Bantaba. While a useful illustration of Eden's principles in microcosm, it ultimately forms a unique and peaceful heart to our Rainforest Biome. For me, with my responsibility to care for the plants and crops of the West African exhibits, the Bantaba and adjacent Chop Farm give a context to my daily work. Sweeping the Bantaba each morning, my mind wandering through plans for the day ahead, I'm conscious that in villages throughout the Gambia, other women are doing exactly the same, and Africa seems that bit closer.

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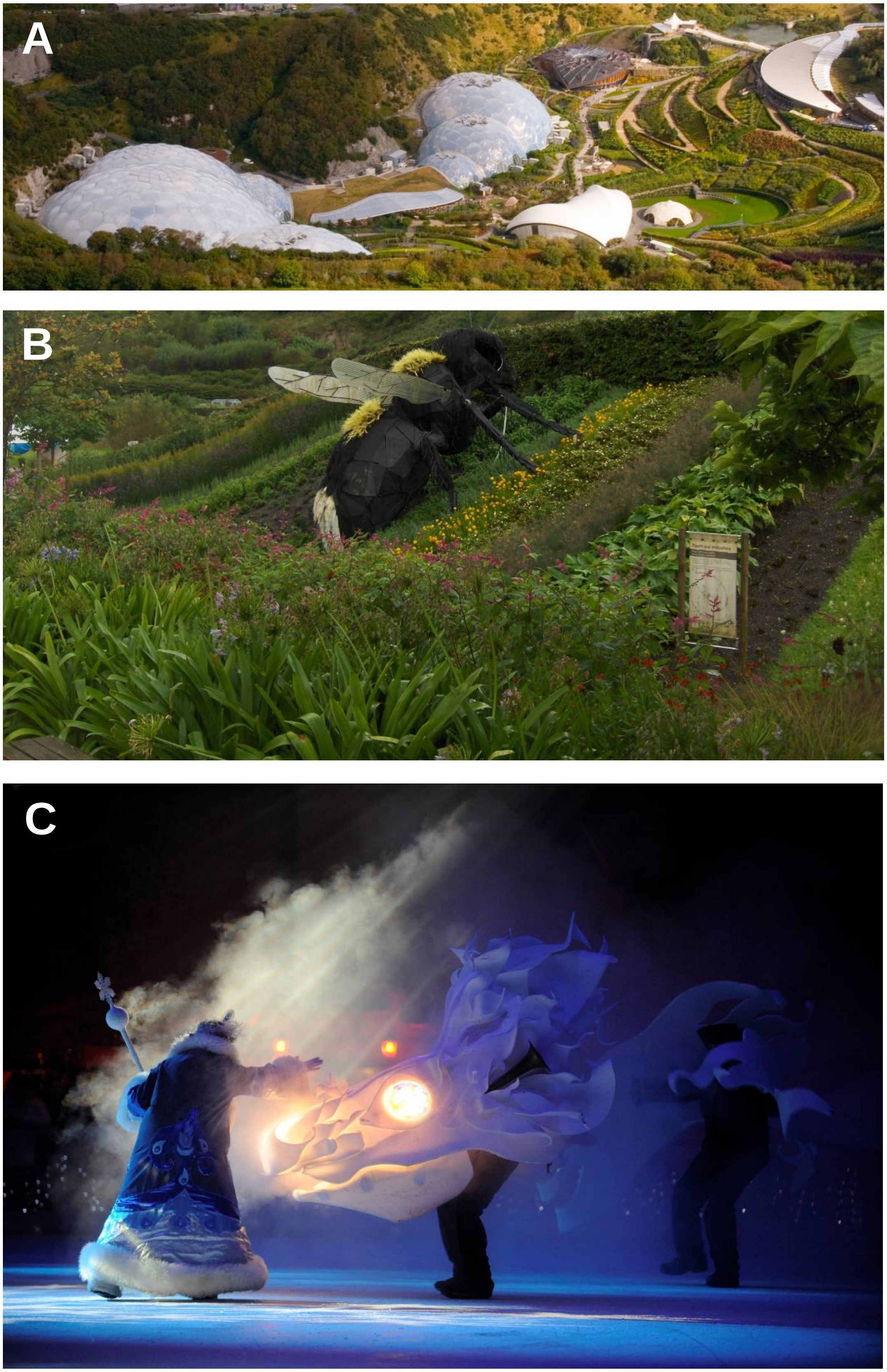

Fig. 1 Eden Project overview. (A) Aerial view of the site in 2009; (B) painting a planted picture of the pollination story; (C) integral role of performance, music and dance at Eden.

Fig 2. The Bantaba area in the Rainforest Biome, Eden Project, illustrating (A) overview of the seating area, with stripy kettle at bottom right; (B) adjacent chop farm; (C) the kitchen area; (D) the well, with descriptive signs from village voices.

Building on its existing programmes, in 2009 the Garden significantly expanded its educational activities thanks to a project, sponsored by the Association of Moscow Higher Educational Institutions, entitled “MSU Botanic Garden: A Platform for Education and Innovation”.

The purpose of the project was to create a modern teaching environment in the Garden, using up-to-date forms of interpretation (electronic guides, information displays, and multi-functional internet resources) and developing an innovative educational programme for training specialists within the “Secondary School – Higher Education - Labour Market” and “Higher Education – Business – Staff” streams.

The project involved developing science-information and science-education materials for a multi-tier education system in the Garden, designed to improve training and provide early occupational guidance for secondary school pupils, to train students from pedagogical institutes, to enhance the skills of biology teachers and provide high-quality training to local government landscaping specialists.

Internet resources are becoming an ever more important part of the educational process at the expense of traditional materials and textbooks. Ease of access makes them highly effective. Although internet resources are now widespread in many countries, they are only now beginning to appear in Russia. It is therefore most important that they be developed by professionals – scientists and specialists in various fields. This task, together with the reorganization of the Botanic Garden’s existing website, is a vital aspect of the project.

The website resources will include teaching materials and tests for self-instruction by school pupils. Publication via the website will deliver major savings on printing costs and target the resources towards potential users, helping to make Garden-based teaching more effective and relevant – a matter of priority for all teachers today.

Professional training in the Botanic Garden

The main part of MSU Botanic Garden (Garden on Moscow’s Sparrow Hills) is located in the grounds of the university campus close to most of the faculties, making it an ideal base for academic and research work.

The Garden has traditionally been close to the botany department of the Biology Faculty, but in recent years it has enjoyed an upsurge in interest from a range of departments in the Soil Science Faculty (5 graduation projects and 2 candidates of science dissertations on the Garden’s soils in the past 10 years). Following a 40-year break, ornithologists have resumed their research in the Garden and there are proposals for entomology studies. For many years now, the Garden has collaborated with the University’s Geography Faculty, number of Moscow colleges specializing in medicine, agriculture and landscape gardening.

We are currently inviting as many departments as possible to use the Garden as a field base for some of their class hours with students or as a venue for part of their summer fieldwork. Opening the Garden to the natural science faculties is an obvious step; less obvious, but no less interesting, is the potential for collaboration with the humanitarian faculties.

Skills Enhancement and Vocational Retraining

There are several advantages to running further education and skills enhancement programmes in the Botanical Garden rather than in other educational facilities:

1. Being the oldest botanical garden in Russia, MSU's garden has one of Moscow's most extensive collections of outdoor plants, which can be studied without leaving the city;
2. The Garden has a unique landscaped environment - a vivid example of sustainable development management;
3. The Garden has a wealth of experience in running education programmes, including international workshops; it is Russia's leading botanical garden in the field of Education for Sustainable Development;
4. It is a showcase for the work of Moscow's best gardeners;
5. With an extensive network of creative and scientific contacts, the Garden is able to pull in colleagues from other educational centres and the Moscow city government.

In 2008, we launched an 80-hour skills enhancement course designed for local government staff with responsibility for urban landscaping. Since then, the course has been completed by over 200 people, and has resulted in changes to the way Moscow regulates landscaping issues.

In 2009, we launched a professional training programme for gardeners. This aims to provide students with a basic understanding of biology, soil science and ecology (taught by research staff from the University's Biology and Soil Science faculties) and a minimum level of practical skills (taught by Garden staff) to begin a new career and equip themselves for future development.

The programme consists of 4 modules:

- Botany module. The first semester begins with the rudiments of plant morphology and anatomy, and plant classification. This is followed by a course on the basics of plant physiology, and at the end of the second semester, the students go the University's S.N.Skadovskiy biostation in Zvenigorod for geo-botanical field practice.
- Soil science module. Basics of soil science, soil agrophysics, soil biology, soil agrochemistry, agronomy and plant breeding.
- Ecology module. Basics of topographic science, plant ecology and plant protection. Within the context of these disciplines we demonstrate the need for an integrated, interdisciplinary approach to the study of ecosystems.
- Landscape gardening module: the basics of landscape gardening and design, garden architecture, flower layout, lawns and decorative dendrology.

The curriculum for each discipline includes both classroom and practical sessions (30-70% of total).

Formal basic education

There has also been progress on formal education, as the botanic gardens become more involved. The Apothecary Garden's (historic garden of Moscow University) education programme is expanding into new areas with an initiative to pilot a school-garden collaboration scheme.

The educational programme aims:

- to teach about the biodiversity of the plant kingdom and the economic and cultural importance of plants;
- to stimulate children to learn more about plants and nature;
- to involve schoolchildren and teachers in an environmental educational programme and practical nature conservation activities.

Schools are also making much more use of the Garden: in addition to the “Lessons in the Botanic Garden” cycle, they are working with Garden staff to develop a school curriculum in fields such as ethno-botanic and local flora, and setting up “local flora corners” and “apothecary gardens” within their own school grounds.

The school lessons include plant identification, microscope studies, observation of pollination, phenology etc., and engaging school children in research activities.

We are building a “biosphere ideology”, focused on global problems:

- organization of the biosphere in space and time
- circulation of matter and energy in ecosystems
- climate change, depletion of the ozone layer, soil degradation and environmental pollution
- role of plants in ecosystems
- plants and people

Nowadays, one of the education tasks is to introduce visitors not only to the variety of the plant world, but also to examples of man’s indirect impact (via changes in ecological conditions) on plants, and to the ways in which plants adapt to their environment. With the schoolchildren we look at the condition of buds, study seed maturation and assess their germination capacity. These observations demonstrate anomalies in the development process – even at the qualitative level.

Successful development of Educational programmes is impossible without creating new educational resources such as manuals, textbooks and reference books. And our greatest achievement in this area has been the publication, this year, of Endangered-species Lists for Moscow Region and Russia as a whole, and books on Moscow and Caucasus flora. The editorial work on these vital publications was led by Moscow University’s Botanic Garden, though unfortunately, due to financial constraints, the print-runs were very limited. And this is another big problem – finding the resources to publish and distribute these important books and publications in sufficient quantities, as well as providing access to them via the Internet.

Another step forward in formal schools education is the Garden’s role in running classes and giving lectures to teaching staff under a city-sponsored skills enhancement scheme, together with pilot developments of educational programmes and textbooks. The Garden is also used to teaching students from pedagogical institutes – future teachers. We regard our lectures for teachers and teacher trainers as an important step in promoting Plant-Based Education. One of the aims of these lectures is to introduce teachers to actual topical issues such as climate change ore invasion. Invasion has become a global issue. As international tourism continues to expand the danger of invasive flora penetrating natural communities is increasing fast. As a result, invasion not only needs to be studied, but the public needs to be made aware of the dangers and possible consequences of attempting to grow exotic plants at home. This is an issue that also needs to be addressed in school biology lessons.

It is now time for gardens to play an active role in formal education system, both in the universities and in schools, developing resources to deliver regional components of the national educational programme now being created in Russia.

Figures

Fig. 1. Course for local city staff managers and ecologists- 2008-2009

Fig. 2. Workshops for the teachers in plant science education in BG

Fig. 3. University students, studying the local flora and collecting plants for the Garden (Oka region)

Fig. 4. Schoolchildren during the Lessons in the Botanic Garden (“Apothecary garden”)

Methods, research and results

Seeds are collected of varieties considered as ancient tasty varieties with good nutritional qualities. These varieties have been multiplied and cultivated in catalogue fields for reintroduction amongst farmers and also for use in local agrotourism.

Vegetable cultivars still occupy an important place in Salento agricultural production, but they have an exclusively local market. Genetic erosion processes have also affected interesting local Salento varieties. For fruit-bearing species, vegetative material is collected from local custodians that preserve the species in their fields (often small pieces of land) or in closed gardens. Fig trees, blackthorns, vines, almond tree, apple trees, pomegranates, citrus fruit and others were collected - 215 varieties in total (Minonne *et al*., 2004).

Seed companies and agro-consortia were investigated for accessing varieties available at national or local level, and comparing with those which had been preserved by farmers for more than 20-30 years. These local varieties often do not have a common name and, morphologically they don't show particular distinctive characters different to the more commercialized varieties. Therefore characterization and phenological information was collected and recorded in a database.

Around 670 horticultural crop accessions are made, belonging to 10 families (Figure. 1), 43 genera and 58 species. This genetic material is preserved in the Botanic Garden's seed bank and is in part under cultivation. The collection represents around 362 varieties, of which 74 are stabilized varieties (Accogli *et al*., 2008).

A very important accession is *Daucus carota* L. cv *pestanaca Santo Ippazio*. This is a local variety of carrot, grown in Tricase, Tiggiano and in Leuca; it's not produced in trade, but is only maintained through folk traditions; it's a yellow carrot, with burgundy nuances. On St Ippazio day (18th January) in Tiggiano the population organizes the "Sagra della pestanaca" (pestanaca festival): the farmers sell tasty vegetables on their stalls in the church square. This cultivar produces a specific cyanidine quantity (5,2 mg/100 g WF) (Figure.2) and β-carotene (8,13 mg/100 g WF), with very marked antioxidant and anti-inflammatory compounds (Accogli *et al*., 2006). These two aspects give it interesting nutritional characteristics and it is much appreciated in the local market.

Another niche variety is *Brassica oleracea* L. var. *botrytis* and var. *italica* Plenck; it's a cabbage cultivar similar to Italian "broccolo rapa" (*Brassica rapa* L. ssp. *oleifera* (DC) Metzg.); the crop is well known in different parts of Salento but almost unknown in some Apulia regions and other parts of Italy: it represents probably, an ancestor of more well known varieties of cabbage (Laghetti *et al*., 2005). It's still produced and so appreciated by local people. "Mugnuli" cultivation is carried out only for family consumption and in a few cases for local markets (Accogli *et* Marchiori, 2007). In "mugnulu" cooked inflorescences, indole Glucosinolates (GLS) are predominant GLS (2.96 μMol/g) followed by aliphatic GLS (2.12 μMol/g) and aromatic GLS (0.59 μMol/g). Cooked inflorescences differ from raw ones in total content (Argentieri *et al*., accepted).

Winter tomato (a long natural shelf-life) is still a largely cultivated vegetable by farmers; 9 varieties, cultivated in Salento were analysed for their antioxidant compounds content, and antioxidant activity (AA). Results showed variability in carotenoid compounds (β-carotene, lycopen and lutein) (Figure. 3). The β-Carotene amount was greater than that reported in the literature for traditional varieties; lutein was determined in these tomatoes for the first time. Hydrophilic and lypophilic fractions antioxidant activity was high (test DPPH, referred as TEAC), comparable with cherry tomatoes activity (Negro *et al*., 2010).

Legumes are recognized for their broad use as a human food and as livestock feed. They are associated with ancient agricultural practices and popular traditions. Genetic resource recovery and maintenance guarantees the conservation of ecotypes that have been selected by farmers over centuries, for taste as well as for the ability to produce under dry conditions.

In the framework of the CoAlTa project (Tobacco Alternative Crops), several old chickpea ecotypes and peas were collected during a survey carried out in Salento.

Twelve local chickpea ecotypes, (Alessano, Corigliano, Leverano, Monteroni, Muro Leccese, Sannicola, Soleto, Tricase 08, Tricase 19, Uggiano la Chiesa, Vitigliano and Zollino), were compared to four commercial varieties (Kairo, Pascià, Sultano, Visir) in field trials during a two year experiment, using low input traditional agricultural techniques. Various characters were measured. Two commercial varieties Sultano and Visir showed the lowest yield value (1.58 t/ha), the Uggiano la Chiesa and Vitigliano ecotype instead, were the most promising (yield 2.31 and 2.23 t/ha respectively) (Raimo *et al*., 2010a).

Similarly, eight pea ecotypes (Alessano, Corigliano, riccio di Sannicola, San Donato, Sannicola, Soleto, Tranesi and Zollino) were tested in field trials during a two year experiment, using traditional, low input agricultural techniques. Yields spanned from 0.67 t/ha for the Soleto ecotype to 1.43 t/ha for the Alessano ecotype; the observed values were consistently lower compared to commercial varieties actually cultivated (Raimo *et al*., 2010b)

Conclusions

Cultivation of local crop and vegetable varieties can guarantee on the Salento table, local food with good flavour and high nutritional value. Cultivation of such varieties can also help reduce soil erosion and restore agricultural land.

The advantages of local, typical products can be passed on through local knowledge and thorough the determination of their intrinsic values; their qualities contribute to the environmental and cultural image of a territory, giving it its own identity through germplasm recovery connected to ancient cultural varieties and older knowledge.

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Figures

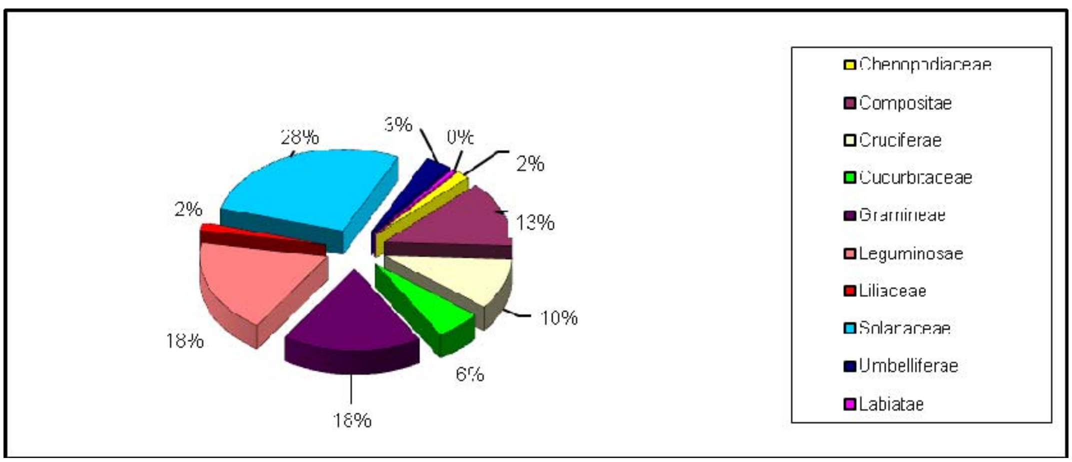

Figure 1 – Families of crops in Salento

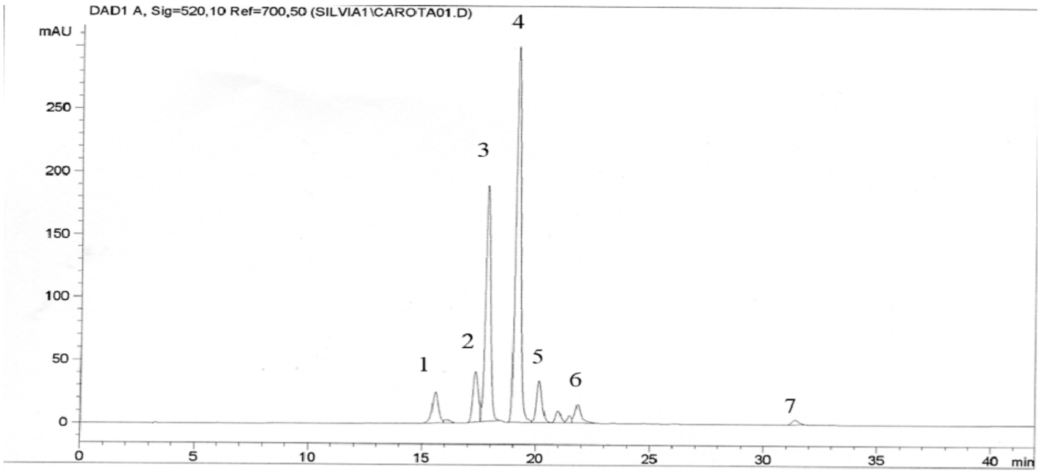

Figure.2- cromatogramm HPLC DAD in order to cyanidin (cyn3) t in Salento *Daucus carota* L.:
(1) cyn 3(2"xil-gal); (2) cyn 3(2"xil-6"sin-gluc-gal); (3) cyn 3[2"xil-6"-(4cum)-glu-gal]; (4) Glu; (5) cyn 3(2"xil-6"glucgal); (6) cyn 3(2"xil-6"fer-gluc-gal); (7) cyn 3[2"xil-6"-(idrben)gluc-gal].

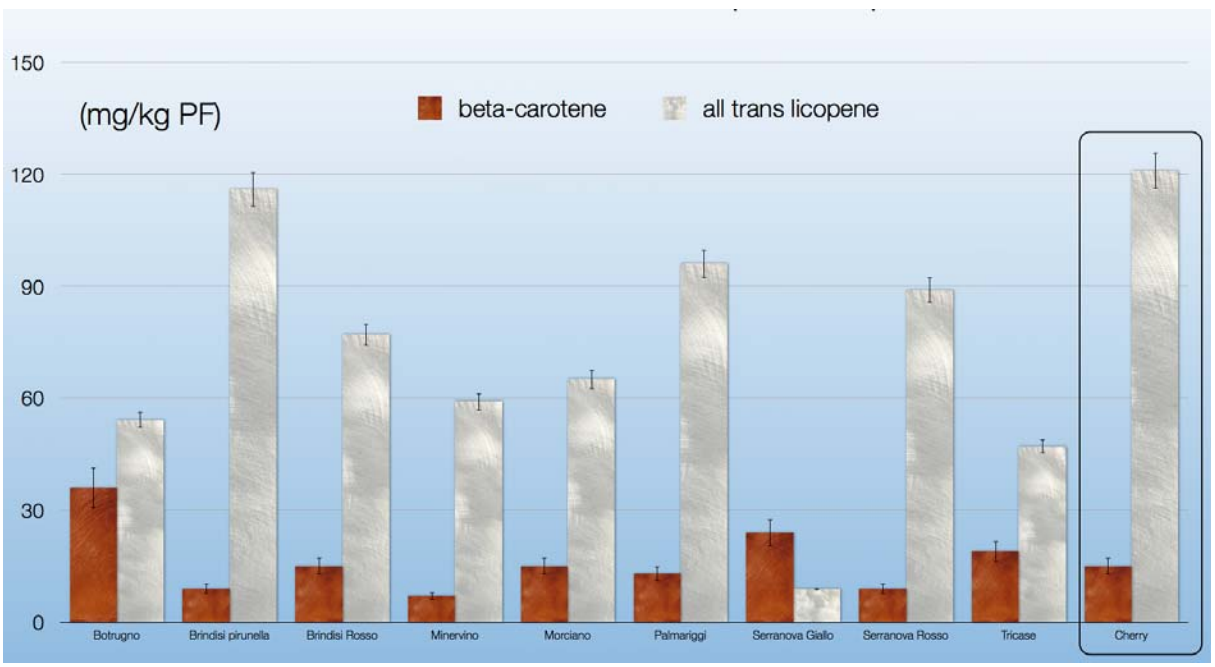

Figure. 3: β-caroten and *all*-trans licopen content in winter tomatoes