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Tree conservation and the role of botanic gardens

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EDITORIAL
BOTANIC GARDENS AND TREE CONSERVATION

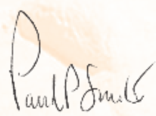
Trees are surely the most charismatic of plant species. The tallest trees in the world grow to a height of over 100 metres and even the common species found in our gardens inspire wonder in our children who feel compelled to climb them as high as they dare. It was trees that first sparked my interest in botany. I worked as a safari guide in Zambia's Luangwa Valley in my early twenties and found myself surrounded by majestic 30 metre winterthorns (*Faidherbia albida*), baobabs (*Adansonia digitata*) and ebonies (*Diospyros mespiliformis*). However, despite the wealth of tree diversity that dominated the riverine landscapes of the South Luangwa National Park, there were no field guides or sources of information on these trees. This was in stark contrast to the wealth of information on the birds and mammals of the valley. Admittedly, it was the lions, leopards, elephants and giraffe that tourists mainly came to see, closely followed by legions of twitchers hoping to get a glimpse of a rare bird like the Angolan pitta. However, the closer you looked the more you realised the importance of the trees to these and other species. Food for the giraffe and elephant; somewhere to stash your kill for the leopard; a perch to spot prey for the lion; and a nest for a rare bird. For us humans, trees provide us with shelter, fuel, medicines and a myriad of other provisioning services. They give us clean water, control erosion and generate the oxygen that we breathe. All of these are the strongest possible reasons for conserving them in all of their diversity.

Last year the first *State of the World's Forest Genetic Resources* report was published by FAO. This report estimates that there are 80,000-100,000 tree species in the world, of which around 8,000 (<10%) are reported as being used. Of these, only 2,400 (<3%) are actively managed, and only 500-600 (<1%) are in tree breeding and improvement programmes. The good news here is that tree diversity represents huge scope for human innovation, adaptation and resilience. The bad news is that we know so little about trees and, in particular, whether we are losing species that may be essential for our own survival.

In this edition of BGjournal you will read about what we, in the botanic gardens community, are doing to address these issues. At BGCI we are building the most comprehensive list of tree species in the world (see page 16 TreeSearch). Currently standing at around 70,000 taxa, we hope to complete this register of tree diversity by early next year. Using this list as a reference, the next step is to carry out a Global Tree Assessment (page 16); working with partners all around the world and led by the Global Trees Specialist Group of the IUCN, we aim to have assessed the conservation status of every known tree species by 2020. You can read about the massive effort under way to assess Brazil's estimated 8,000 native tree species on page 8. These assessments will drive our conservation actions. The Global Trees Campaign (page 15) aims to prevent all tree extinctions. Wherever possible we will work to conserve trees *in situ*, addressing threats directly and ensuring that they continue to thrive in nature as self-sustaining populations. Where this is not possible, we will conserve their seeds in seed banks, keep them alive in tissue culture or grow them in our arboreta. Increasingly, we will need to learn how to translocate trees, reinforce tree populations or restore their habitats in increasingly human-dominated

landscapes. A particular challenge will be to manage tree populations unable to respond quickly enough to a rapidly changing climate, by maximising their genetic diversity and adaptive potential.

Despite the obstacles, I believe that it is entirely possible to conserve, manage and pass on all tree diversity to future generations. There is no technical reason why any plant species should become extinct given the array of management options open to us – both *in situ* and *ex situ*. And it is botanic gardens and arboreta that need to lead these efforts. As the articles in this issue of BGjournal demonstrate, we have the information, skills and knowledge to find, identify, conserve and manage tree diversity right across the taxonomic array. As incoming Secretary General of Botanic Gardens Conservation International I am excited to be part of a community of botanic gardens around the world that is doing something so positive.



Paul Smith
BGCI Secretary General

Authors: Emily Beech and Joachim Gratzfeld

APPROACHES TO TREE CONSERVATION

Above: Magnolia sinostellata *(Shouzhou Zhang)*
Top: Xishuangbanna Tropical Botanical Garden (Barney Wilczak)

BGCI's work in China includes a range of projects to ensure the survival of threatened tree species

Just as there are many tree species, there are many approaches to their conservation. Trees occur in different habitats and ecosystems and are at risk due to a diverse range of threats including land use changes, overexploitation and climate change. These threats result in different consequences on the ground; the habitat may have disappeared, been replaced or become degraded. Some tree species have declined to the point at which they are in need of special help in order to survive.

Covering an area of 9,596,961 km², China features a large diversity of ecosystems with numerous rare and threatened native trees. BGCI's projects operate in a range of these habitats, including tropical rainforests, temperate desert, riparian forest as well as temperate and subtropical forests. The threats to trees differ in each location, requiring multiple approaches to their conservation.

Here we take a quick look at the varied ways in which local Chinese partners and BGCI are working together to conserve the threatened trees of China.

Species recovery

The focus of the Global Trees Campaign is to protect and improve the conservation status of threatened trees (see page 15) There are 9,641 threatened trees worldwide and China is home to at least 760 of these species. Assisted species recovery focuses on one or several species with few individuals remaining in the wild and gives a helping hand to increase numbers and encourage natural reproduction in the future.

Tree planting in Mangyangguan, China (Barney Wilczak)

Target 8 of the Global Strategy for Plant Conservation (GSPC) calls for 75% of threatened species to be in *ex situ* collections by 2020. In order for collections to have the greatest value to conservation and reintroduction programmes they must represent the genetic variation of the species.

However, many threatened tree species are not well represented in *ex situ* collections. It is therefore necessary to improve this representation and develop propagation protocols to enable population reinforcement *in situ*.

In the case of *Magnolia sinostellata*, it is its horticultural value which has directly contributed to its decline. Only three populations are known to remain in the wild with limited genetic diversity. BGCI, in collaboration with Fairy Lake Botanical Garden, Shenzhen has been working to improve the conservation status of this species in Zhejiang. *Ex situ* conservation collections are being established to represent all three remaining populations along with the development of propagation protocols, using cuttings, grafting and dividing. Efforts to enrich the dwindling genetic diversity of *Magnolia sinostellata* are a particular focus in one population (Jingning population) which has the least fertile seeds. This project is in its early stages and it is hoped that work will ultimately lead to population reinforcement and reintroduction programmes in the future. There are plans to plant out 1,000 – 2,000 seedlings in to the wild, to improve the chances of self-reproduction and population growth.

Other BGCI species recovery programmes are in their later stages and show promising results. A project in collaboration with Guilin Botanical Garden, the Guangxi Institute of Botany and the Chinese Academy of Sciences (CAS) aims to improve the conservation status of three rare Golden camellias, *Camellia nitidissima, C. euphlebia* and *C. tunghinensis*. The project has so far successfully propagated all three species and has introduced 6,000 plants into a demonstration base, with an additional 20,000 plants being grown in three nurseries in the vicinity. *Ex situ* collections in Guilin Botanic Garden and Nanning Arboretum are now extensive, harbouring the genetic diversity of the wild populations.

Major efforts to maximise the genetic diversity of botanic garden *ex situ* collections are also being developed at Xishuangbanna Tropical Botanical Garden. See page 18.

Ecosystem restoration

It is not only individual species that are in in danger. Many unique ecosystems are rapidly becoming degraded or damaged to the point where they no longer provide the ecosystem services they once offered. Restoration of an ecosystem involves facilitating natural succession. Human disturbances often prevent this process and interventions are needed to kick-start the process, for instance by removing exotic plants, reducing soil erosion and reintroducing native species.

Camellia nursery in China (BGCI)

Members of the Dai ethnic minority replanting forest in China (Barney Wilczak)

In partnership with Xishuangbanna Tropical Botanical Garden (XTBG), BGCI is working to restore tropical forest remnants in Xishuangbanna, Yunnan. The tropical forest of the region is fragmented due to the increase in cash crop cultivation, especially large-scale rubber plantations. One of the remaining, yet degraded forest areas is Dai Holy Hill Forest. Large, mature native trees have been extensively extracted for timber, leaving the forest floor liable to erosion. With the aid of historical records and *ex situ* collections, this collaborative project aims to restore the forest remnant to a similar plant composition as was present prior to disturbance. Two years into this project, several hundred saplings of 25 endemic woody species have been planted in a ten hectare pilot restoration site in the forest. Exotic weeds have been removed with the help of the local community. In the long term, this project hopes to scale up planting as well as encourage similar activities in other forest remnants.

Another example of BGCI's efforts to restore ecosystems and unique habitats in partnership with our members is the conservation work carried out in riparian forests along the Tarim River in the arid Xinjiang region. The poplar forests are under a triple threat from expanding agriculture, livestock grazing and a shrinking water table. In partnership with Tarim University, BGCI is working to protect the habitat whilst propagating and planting two of the target tree species, *Populus euphratica* and *P. pruinosa* in pilot plots. Seed regeneration is low so studies are ongoing to identify natural ways to promote natural reproduction. In the meantime, planting of vegetatively propagated individuals is being carried out.

Boosting conservation through livelihoods enhancement and community engagement

2010 figures from the World Bank estimate that 84.1 million people in China live on less than $1.25 a day. Poverty pushes communities towards unsustainable levels of harvesting, encouraging conversion of forest to agriculture and the over-exploitation of timber resources for income generation.

Conservation programmes will therefore be most successful when they consider the needs of local communities. In certain locations, communities have been exploiting forest resources without knowledge of the full impact on tree populations. A key to reducing the threats to many of these species is to provide incentives and training to avoid future unsustainable harvesting.

For instance, much of the natural forest surrounding Dahetou village in southern Yunnan is owned by the community and individual households. Threats come in the form of various forms of commercial interest, especially the extraction of timber. Working with the Yunnan Institute of Environmental Science, BGCI is promoting population reinforcement programmes of two rare flagship trees, *Magnolia cathcartii* and *M. doltsopa*, which are heavily utilised in local construction. There is a real need for reliable incomes in the village to prevent further overharvesting of forest resources for economic reasons. In addition to propagating and planting hundreds of saplings of the two species, public outreach materials with information on the ethnobotanical importance of local plant diversity have been produced and distributed to the local community. In future the project will facilitate income generation through enhanced promotion of home gardening of medicinal species to reduce overreliance on the forest natural resources.

Although widely acknowledged, the importance of engaging local communities from the outset of a new conservation endeavour is still often overlooked. When ecosystems and specific tree species are faced with human threats, it is essential to identify the reasons why people resort to unsustainable exploitation. Without tackling the drivers of decline of a tree species it is likely to face further problems in the future. Projects which directly affect local communities can be viewed more positively if they incorporate elements of community engagement, opportunities for employment and education programmes.

Most of BGCI's tree conservation projects therefore include specific social aims, working in harmony and with the help of the local community to ensure that people directly experience the benefits of conserving trees and their habitats. For example, the Golden Camellia project in Guangxi mentioned above, aims to enhance the incomes of local farmers by providing access to high-value plant resources, while work in Yunnan has directly engaged several hundred school children in the restoration of tropical forest remnants in Xishuangbanna.

One of the most successful examples of this approach was a restoration project run between 2008 and 2011 in Pingbian county, Yunnan to conserve three globally threatened trees, *Dipteronia dyeriana, Magnolia odoratissima* and *Magnolia aromatica*. During the project, stakeholder workshops were held to raise awareness in the local community of the importance of plant conservation. Encouraged by these sessions, several farmers set up nurseries for threatened tree species, in addition to partnering on the establishment of a 'near situ' conservation field collection with over 14,200 saplings of threatened species. This generated additional income opportunities from the sale of seedlings.

Education

Target 14 of GSPC calls for plant conservation to form part of education and public awareness programmes.

Magnolia sinostellata *(Shouzhou Zhang)*

BGCI's project in the Zhibenshan Mountains in west Yunnan practises extensive replanting of threatened species in an area degraded from mining activities and extraction of natural resources by local communities. Alongside this, the project has also developed numerous outreach activities to engage local people in the conservation work, linked with the establishment of a series of interpretation materials such as panels along the side of a new road in the project area to promote interest and pride in the surrounding plant diversity and the importance of securing it for the future.

Conclusion

As discussed above, the threats to native tree species are not homogenous across a country like China, with a large range of habitats and social settings. Before embarking on a tree conservation project, there are numerous issues to consider and stakeholders to consult. These include conservation status assessments to identify threatened species of the area, historical records and floras to assess the differences in diversity and the amount of damage which has occurred, the drivers for the threats, as well as uses of plant resources by the local community. All of these factors will influence which approach or combination of different methods would be most successful in conserving the area's target trees and restoring the habitat at large.

The success of former and continuing projects of BGCI and partners in China demonstrates that tree conservation can have benefits which go far beyond the immediate protection of the target species. This work also endeavours to inspire the next generation of 'environmental stewards' and boost ownership of and pride in the local biodiversity. The projects listed above represent only a snapshot of BGCI's work in China. More information about BGCI's China programme can be found on the BGC website (www.bgci.org), with information also available in Chinese (www.bgci.org/china).

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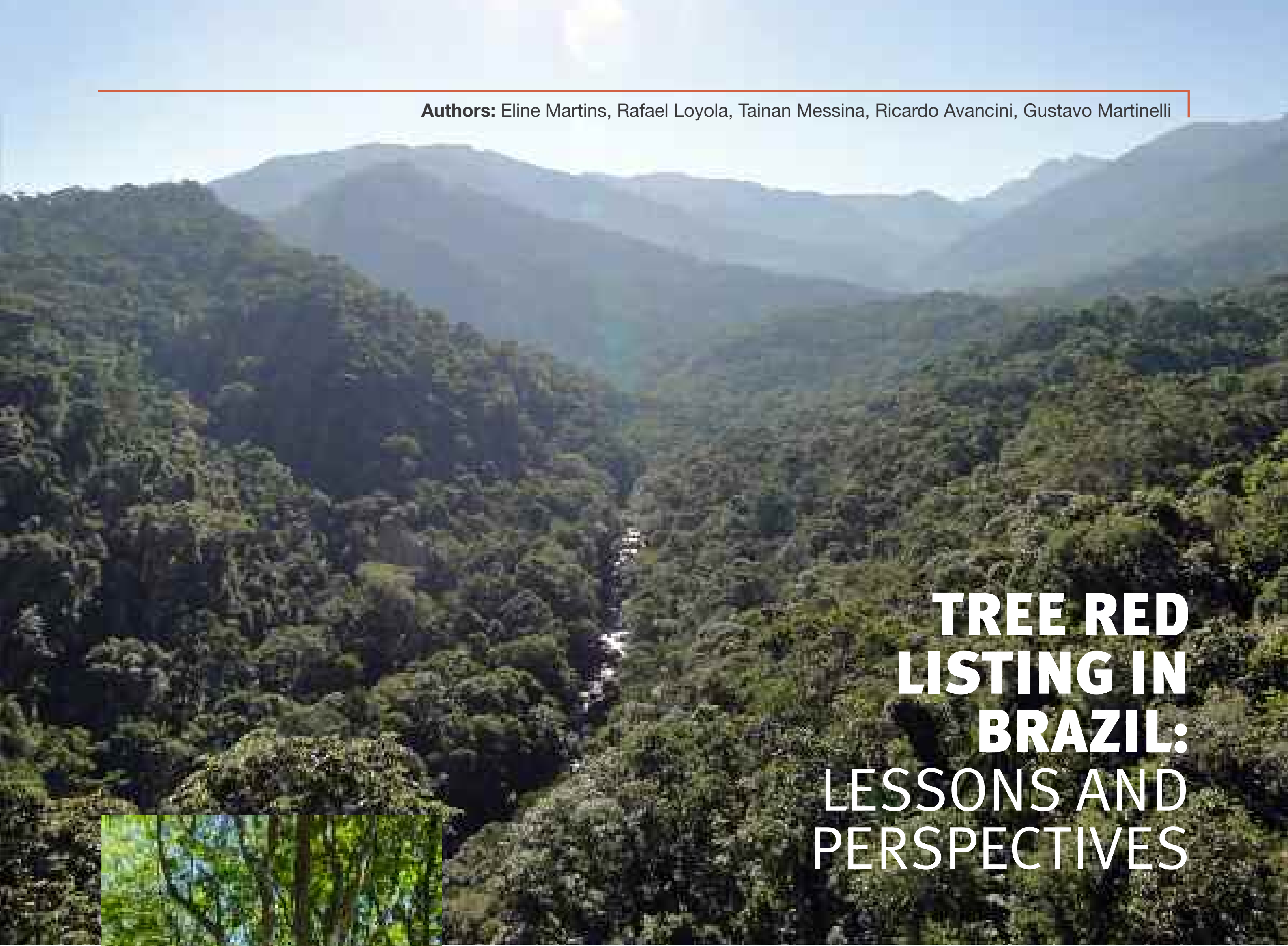
TREE RED LISTING IN BRAZIL: LESSONS AND PERSPECTIVES



A part of the remains of the Atlantic Rainforest in Itatiaia National Park, Rio de Janeiro state, the first National Park in Brazil (Eduardo Fernandez)

An individual of "Brazilwood" (Caesalpinia echinata) in the Rio de Janeiro Botanic Garden (Lucas Moraes)

Introduction

Brazil has the largest number of plant species in the world (46,097) with one new species being described every two days. The country has 8,058 native tree species, mainly concentrated in the Amazon and the Atlantic Rainforest (List of Species of the Brazilian Flora, 2015). The Brazilian National Centre for Flora Conservation (CNCFlora) is responsible, at the national level, for assessing the conservation status of the Brazilian flora and developing recovery plans for species threatened with extinction. CNCFlora is the Red List Authority for plants in Brazil and adopts the standards and procedures recommended by the International Union for the Conservation of Nature (IUCN). Since 2010, CNCFlora has assessed the extinction risk of 5,165 species of the Brazilian flora (11.2% of the national flora). As a result, 2,478 plant species are considered threatened with extinction at the national level: 527 Critically Endangered - CR; 1,378 Endangered - EN, and 573 Vulnerable – VU. (Martinelli and Moraes, 2013; Martinelli *et al*., 2014).

The importance of trees

Trees play a pivotal role in Brazilian ecosystems. They are important not only because of their ecology and complex interactions with other species and environments, but also because of their cultural and socioeconomic value. Considering these values is essential in understanding the threats and identifying the knowledge gaps for tree species in Brazil. Such information will ultimately inform the development of on-the-ground conservation actions. So far, CNCFlora has evaluated the extinction risk for 1,125 tree species (13.9% of the total of Brazilian tree species), resulting in 420 tree species being assigned to a given threat category (66 CR; 224 EN and 130 VU) (Fig. 1).

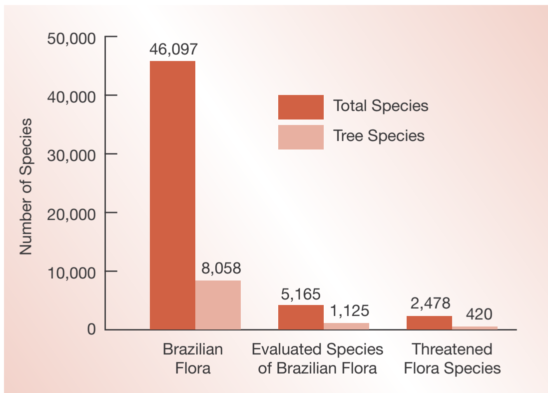


Figure 1: Risk assessment overview in Brazil considering the total number of plant species and the total number of tree species

"Assessments so far reveal that 37% of tree species in Brazil are threatened with extinction."

Threats to trees in Brazil

As in many parts of the world, the main threats for native plants in Brazil are habitat conversion/alteration for cattle ranching, agricultural expansion and mining. Some tree species have also been heavily exploited due to the value of their timber for real-estate and shipbuilding applications, as well as for furniture and medicinal uses, and are consequently experiencing large population reductions. For example, the tree that originally gave the country its name, the "Brazilwood" (*Caesalpinia echinata* Lam. - Fabaceae) is currently classified as EN on the official list of threatened flora in Brazil, and it has a long track record of being unsustainably harvested. Following the colonization of Brazil in the 1500's a red dye taken from the tree's heartwood was extensively used. Although this use ceased with the advent of synthetic dyes during the 1800's, today the wood of this species is prized for the manufacture of high-quality bows for stringed instruments. Currently, the main threat to the species is the extensive habitat destruction arising from the intense urbanization and agricultural expansion that is taking place along the Brazilian coast.

The International Pernambuco Conservation Initiative (IPCI) is dedicated to the conservation and sustainable use of Caesalpinia echinata*, with the aim of ensuring the future of stringed instrument music.*

Recovery plans

After the red listing process, the next step in the conservation of species identified as under threat, is the elaboration of recovery plans (referred to as 'action plans for conservation' in Brazil). Recovery plans consider information about species' ecological traits, historical and current threats and socio economic uses/conflicts to support the elaboration and execution of effective actions for conservation based on the engagement of stakeholders.
The effort to produce red lists (Moraes *et al*., 2014) and recovery plans is very important, but the elaboration, implementation and monitoring of conservation action plans requires significant human and financial resources.

Faveiro-de-Wilson tree classified as Critically Endangered (Fernando Fernandes)

"To date, Brazil has only one officially published recovery plan for a tree species."

The only Brazilian tree species with a published recovery plan is *Dimorphandra wilsonii* Rizzini, (Faveiro-de-Wilson). This species is found in the transition zone between the Cerrado and the Atlantic Rainforest in the state of Minas Gerais, and it is classified as CR. The species was considered top priority for the elaboration of a recovery plan given that there are only 246 adult individuals known after 10 years of intense efforts for its *in situ* and *ex situ* conservation (Martins *et al*., 2014). Since December 2014, new Brazilian legislation protects this species from harvesting, cutting down, transporting without authorization, storing, managing and trading. Legislation also reinforces the need for robust species extinction risk assessments and the elaboration of recovery plans to guarantee the viability of populations for threatened species. Sustainable management is allowed for species classified as VU, as long as the activity respects international agreements, and the recommendations of risk assessments and recovery plans, when in place.

Assessing species' extinction risk in the Atlantic Rainforest of the state of Rio de Janeiro

The original area of the Atlantic Rainforest has been continually devastated since the colonization period. Over the last century it is estimated that close to 86%

Box 1. The case of *Terminalia acuminata* – Is the species Endangered or Extinct in the Wild?

In 2013, CNCFlora assessed the risk of extinction of a mysterious species: *Terminalia acuminata* (Allemão) Eichler - Combretaceae, an endemic species of Rio de Janeiro. The species was formerly listed as Data Deficient (DD) in the last official list of threatened flora of Brazil from 2008. However, after a more comprehensive search and assessment, the species was considered threatened (Martinelli and Moraes, 2013).

The most updated information indicates its occurrence in two locations and with incident threats such as urban expansion, logging and habitat loss. This tree was last seen in nature in 1942 and further records indicated its occurrence in a mountain region of the state, as well as in the Tijuca National Park located in the city of Rio de Janeiro, one of the most important National Parks in an urban area in the world (Pougy *et al*., 2014). Moreover, the literature describes *T. acuminata* as rare and a timber species, since its wood is used for building and furniture making (Marquete, 1984; 2003).

This year, a new systematic search for the species has been carried out and while this text was being edited the species was found in a forest remnant in the city of Rio de Janeiro. Our field team found one fertile tree in a private property close to the limits of a state protected area, as well as a mature tree, two juveniles and two seedlings inside a municipal protected area. Local people appeared to know the species and could help to locate more individuals. This is good news, but there is still an urgent need to increase collection efforts for this species, in order to better understand its real conservation status.

of this forest has been lost (Ribeiro *et al*., 2009). However, when compared to other regions in Brazil, the Rio de Janeiro state has preserved a greater percentage of this forest (21%; Fundação SOS Mata Atlântica and INPE, 2015). This provides an enormous opportunity to focus on effective actions that will ensure the protection of what is left of this astonishing environment.

The state of Rio de Janeiro has high levels of endemism (Jenkins and Pimm, 2006). It harbors 7,662 known plant species, distributed among 198 families, of which 1,897 are trees species (List of Species of the Brazilian Flora, 2015). Nearly 1,000 of these plant species are endemic, including 230 tree species. During 2015, CNCFlora aims to assess the extinction risk of all endemic species in partnership with the Environment Secretary of the State of Rio de Janeiro.

The challenge ahead: towards the achievement of GSPC targets

The challenge to conserve tree species in Brazil is huge and has just started. We have a long way to go to guarantee effective protection of known threatened species and the challenge goes beyond this. Brazil has the most diverse flora in the world and much more yet to be discovered. Since 2010, an average of 1,235 new species have been included per year in the List of Species of the Brazilian Flora.

Considering this challenging scenario, CNCFlora is focused on achieving five targets proposed by the Global Strategy for Plant Conservation (GSPC), which are (1) assessing the extinction risk for the known Brazilian flora (Target 2), (2) ensuring the *in situ* conservation of 75% of the threatened species (Target 7), (3) ensuring the *ex situ* conservation of 75% of the threatened species (Target 8), (4) capacity building for plant conservation (Target 15), and (5) establishing a broader network to accomplish strategic objectives (Target 16).

To reach these targets, CNCFlora has a trained team working with a network of over 500 botanical specialists. CNCFlora also developed a tailor-made online platform for species' evaluation, which allows the recording of up to 49 fields related to the biology of the species, ongoing threats to populations and conservation actions needed for their survival. The data gathered during the assessment phase are stored in a database which is the basis for the elaboration of recovery plans, and which also supports the elaboration of spatial conservation plans, pinpointing priority areas for the conservation and sustainable use of threatened plants in Brazil.

In December 2014, the first results of the extinction risk assessment carried out by this dynamic and integrated online method was officially recognized by the Brazilian Ministry of Environment. This allowed the publication of the updated official list of threatened flora in Brazil, an important tool for public policy and law enforcement for the conservation of threatened flora (MMA, 443/2014), and also regulating the commercial use of tree species. This was a first and critical step towards more effective conservation in Brazil. However, further resources and means to guarantee the execution of the commitments made by the country in accordance with the GSPC targets are still required.

Faveiro-de-Wilson tree, the only tree that has an official published recovery plan in Brazil (Fernando Fernandes)

An individual of Terminalia acuminata *in the Rio de Janeiro Botanic Garden, an endemic tree of Rio de Janeiro state (Lucas Moraes)*

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CONSERVATION ROLE FOR A NEW ARBORETUM IN CANBERRA, AUSTRALIA

National Arboretum Canberra's Central Valley for dignitary plantings (M. Richardson)

Introduction

In 2003, a bushfire that ravaged Canberra, the capital city of Australia, was the catalyst for the creation of an arboretum as originally envisaged by the city's designer, Walter Burley Griffin. This is the National Arboretum Canberra[1]. The goal has been to create a place of outstanding beauty, of international standard and interest. As a part of this, it has provided an opportunity to promote and in some cases conserve threatened species and it provides a valuable future resource in Canberra for education and research.

The arboretum has been developed on a 250-hectare site near Lake Burley Griffin about six kilometres from the centre of Canberra. The site incorporates existing stands of Himalayan Cedar (*Cedrus deodara)* and Cork Oak (*Quercus suber*), much of which were planted about 80 years ago.

A nation-wide design competition for the National Arboretum Canberra commenced in September 2004, and on 31 May 2005 the Australian Capital Territory Chief Minister, Jon Stanhope, announced the landscape architects Taylor Cullity and Lethlean, with the architects Tonkin Zulaikha Greer, as the winners with the "100 Forests 100 Gardens" entry. The design includes a series of single species forests, such as the existing ones of cedars and oaks, instead of the usual wider arboretum collection of individual trees or small groups. The first trees were planted in 2007 and ninety four of the forests have been planted so far. The National Arboretum opened to the public in February 2013.

Tree Conservation

An important aspect of the "100 Forests 100 Gardens" design concept was the designers' focus on rare and threatened trees. While the conservation of Australia's flora must still be seen as the priority for the majority of conservation programs in Australia, the work that is being done at the National Arboretum takes into account its role to promote the importance of trees in a worldwide sense. Being the diplomatic capital of Australia, Canberra is well placed to fulfil such a role.

The National Arboretum's conservation theme has provided it with an excellent opportunity to contribute to the Global Strategy for Plant Conservation and as a national institution, it is already playing its role in supporting the GSPC Targets 8 (*ex situ* conservation and restoration) and 14 (education and public awareness).

GSPC Target 8

In line with GSPC Target 8[2], one of the National Arboretum Canberra's principal roles is to grow threatened species in the climatic conditions of Canberra, so as to gather horticultural information that may assist their *ex situ* conservation generally. It will also be a source of propagation material.

As an important part of this, the National Arboretum has been working with in-country and international conservationists to obtain provenanced propagation material of several of the species being grown. One collection that has been established using these connections is *Cedrus libani*, the Cedar of Lebanon. While the species has been growing in Australia for some time and is reasonably

[1]www.nationalarboretum.act.gov.au/
[2]Target 8: At least 75% of threatened species in *ex situ* collections, preferably in the country of origin and at least 20% available for recovery and restoration programmes.

National Arboretum Visitor Centre including interpretation (M. Richardson)

easy to acquire, a closer link with the natural stands in Lebanon was sought. A contact was made in Lebanon with the Lebanese Agricultural Research Institute who collected the seed at the Al Chouf Cedar Nature Reserve. The seed was then passed on to the National Arboretum via the Millennium Seed Bank in Kew. By doing so it has not only made other conservationists aware of Australia's new National Arboretum but could be an opportunity to promote the species and the Al Chouf Cedar Nature Reserve through the Lebanese Embassy in Canberra.

As some of the forests are being planted with species that are endangered or even critically endangered in the wild, the amount of seed available can be very limited and this has had to be addressed to enable the of planting a large forest lot. An example is *Sophora toromiro* which was endemic to the Pacific island of Rapa Nui (Easter Island) but is now is extinct in the wild (Maunder *et al*., 1999). As the National Arboretum was initially not able to produce a large enough number of plants for the total forest planting, it currently shares the forest lot with a 'host species'. In this case it is *Styphnolobium japonicum*, a species from China, which has been planted with the *Sophora toromiro* and will be slowly replaced as the *S. toromiro* is propagated. Until the forest is only one species, propagation will be through vegetative material collected from across the *S. toromiro* planting of over 100 seedlings, not using seed collected from *S. toromiro* in the Arboretum. Despite this, testing from other collections around the world indicates that the National Arboretum's *S. toromiro* planting is still likely to have only a low level of genetic diversity (Maunder *et al*., 1999).

Although the majority of the forests are non indigenous trees, about 20% of the plantings are indigenous to Australia, with currently six being threatened Eucalyptus species. These are *Eucalyptus argophloia, E.benthamii, E.lacrimans, E.michaeliana, E.morrisbyi* and *E.parvula*. The Arboretum's oldest eucalypt forest, *Eucalyptus benthamii* (planted in 2007), has started producing seed and a request for seed has already been received. In addition to the eucalypt forests, a diverse display of locally occurring eucalypt species is being developed by a community-based group, Southern Tablelands Ecosystems Park (STEP) and a mixed forest of *Corymbia maculata* and *E. tricarpa* are being grown as research lots for the Australian National University.

Another notable indigenous species in the National Arboretum is the Wollemi pine (*Wollemia nobilis*). Since the first planting at the National Arboretum, much has been learned about the growing, and associated *ex situ* conservation, of this genetically limited species (Peakall *et al*., 2003). There is considerable microhabitat variation in the forest where the trees were planted and the impact of that variation has obviously affected the growth of the trees. The part of the forest that appears to be most suitable for growing Wollemi pine is steeper, south facing and on the edge of a rock outcrop. In that relatively small area some of the trees planted in 2007 are now over 3 m high and have already produced seed. Outside that area, most trees have died and the planting strongly demonstrates the possibility for developing healthy *ex situ* collections in climatically challenging locations if the best microhabitats can be identified. It is possible that a second forest of the Wollemi pine will be established in a section of the National Arboretum that strongly suits the tree's habitat needs.

One of the issues that has been taken into account when selecting the species for the National Arboretum is the possible or recorded weediness of the trees and the weed status list produced by the CRC for Australian Weed Management (Randall, 2007) played an important role. As a result of this review, several threatened species have been rejected because of likely weed issues in Canberra. However, this has not been an easy task as the variation in the localities in which plants have become weedy is substantial. As a result trees known to have been weedy in areas thought significantly different to Canberra have sometimes been accepted. But the previous records must still not be ignored and it is noted in management plans that if

Early plantings at the National Arboretum (M. Richardson) a newly introduced species commences to show a weediness that could lead to it becoming naturalised, it will be removed.

GSPC Target 14

As an important part of its role, the National Arboretum is also actively supporting the GSPC's Target 14 to promote *'the importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programmes'*.

Easterly view from Dairy Farmers Hill (M. Richardson)

Although the Arboretum has only been open for two years it has already attracted over a million people, and its importance in Canberra continues to climb. In addition, many members of the Canberra community have generously donated their time. The assistance provided has included the monitoring of tree growth and health as well as the interpretation of the forests, including a one and a half hour guided tour about plant conservation.

In addition, an education program for school children addresses the issue of conserving our forests. It looks at how trees have changed over time and how they have adapted to their environment. It also addresses the role that institutions like the National Arboretum must play in preserving these trees for the future.

Since the National Arboretum Canberra was established, a significant number of dignitaries from different countries (including the UN Secretary-General) have planted a tree that is relevant to their country or role. The majority of the trees planted have been threatened species and it has always emphasised the importance of the world's trees. The domestic and international media accompanying these ceremonial tree plantings have also been encouraged to promote the importance of global tree conservation. Such events will continue to provide a powerful avenue for disseminating the conservation status of particular tree species and the work underway to maintain them.

Summary

Although the National Arboretum has only been open for two years, its visitation and level of community involvement has already shown the strong role that it could play in increasing people's understanding of plant conservation. In addition, there will be an excellent opportunity for the National Arboretum to further refine the genetic make-up of its collections and continue to play its role in *ex situ* conservation.

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Microhabitat most preferred by the Wollemi nobilis *at the National Arboretum (M. Richardson)*

Author: Kirsty Shaw

THE GLOBAL TREES CAMPAIGN – SAFEGUARDING THE WORLD'S THREATENED TREES FROM EXTINCTION

Forest restoration work at Brackenhurst Botanic Garden, Kenya, has incorporated over 100 rare and threatened East African tree species (Barney Wilczak)

The Global Trees Campaign (GTC) is a joint initiative between Botanic Gardens Conservation International (BGCI) and Fauna & Flora International (FFI). The Campaign was launched in 1999, responding to *The World List of Threatened Trees* (Oldfield *et al*., 1998) which assessed over 7,000 tree species as globally threatened. Since its initiation, the GTC has gone from strength to strength, running projects that directly support the conservation of threatened tree species with partners in over 25 countries, leading training programmes to build capacity for tree conservation, and campaigning to scale up the use of threatened trees in planting schemes and conservation programmes.

Many of our key GTC partners are botanic gardens and arboreta. Their horticultural and research expertise, documented collections of living plants, seeds and herbarium specimens, and outreach potential make them excellent partners for spearheading innovative conservation programmes for the world's threatened trees, providing training to build the capacity of other stakeholders to take action for the conservation of threatened trees, and raising awareness of the importance of tree conservation.

The number of trees threatened with extinction continues to rise as a result of land clearance and habitat degradation, unsustainable exploitation, and the impact of invasive species, pests and diseases, among other threats. Individual trees offer cultural, ecological and

Diospyros nodosa *, a Critically Endangered ebony endemic to Mauritius (George Schatz)*

Euphorbia cussonioides, a Vulnerable succulent tree growing in the restored indigenous forest at Brackenhurst Botanic Garden, Kenya (BGCI)

ornamental values; they provide food, medicine and timber, and some tree species can serve as flagships to drive larger conservation programmes.

GTC recognises that saving forests will not necessarily save the immense variety of tree species. It therefore adopts a species-focused approach to drive and guide tree conservation efforts worldwide, through four main approaches:

1. Prioritisation of tree species of greatest conservation concern

BGCI holds the Secretariat of the IUCN/SSC Global Trees Specialist Group, the lead authority undertaking Red List conservation assessments for trees to determine their conservation status in the wild. By publishing taxonomic and regionally focused Red List reports, and ensuring up to date assessments are published on the IUCN Red List of Threatened Species, we identify which trees are threatened in the wild and highlight the need for conservation action. BGCI has recently compiled a list of globally threatened trees from 36 sources in addition to the IUCN Red List. This is the most comprehensive global list of threatened trees, and the results indicate that over 9,600 trees are threatened with extinction.

*The African Zebrawood (*Microberlinia bisulcata*) is endemic to Cameroon. GTC works with partners in Cameroon to protect this Critically Endangered tree* in situ *(FFI)*

GTC is working with The Morton Arboretum, U.S.A. to undertake a conservation assessment for all of the world's oak species. This international effort will identify which oaks are threatened in the wild and in need of urgent protection.

Using BGCI's PlantSearch database, we undertake analyses to assess representation of threatened trees in *ex situ* collections. Our recent *ex situ* survey of the world's most threatened trees (assessed as Critically Endangered and Endangered using IUCN Categories and Criteria, or equivalent) has identified that only 1 in 4 of the most threatened trees are backed up in *ex situ* collections. Look out for the full report, including a list of CR and EN trees and representation in *ex situ* collections, which will be published and available to download from the BGCI and GTC websites soon.

GTC is working with Missouri Botanical Garden, U.S.A. to undertake a global ex situ *survey of ebony collections. This study will assess the value of current conservation collections, and be used to guide and mobilize future collecting and conservation programmes to secure the future of the world's ebonies.*

Our prioritisation work underpins the GTC programme. The results of tree Red List assessments and ex situ *surveys are shared with our network of partners and the wider conservation community to inform which species should be prioritised as a matter of urgent concern for conservation action.*

TreeSearch – a world list of trees

BGCI is developing a world list of trees which has been compiled from various data sources. Still in development, this list already contains 65,000 accepted names, making it the most comprehensive list of the world's tree species. "TreeSearch" will provide a valuable resource to botanic gardens as well as many other stakeholders including international and national forestry and agroforestry bodies, land managers and conservation and restoration practitioners.

This searchable tree list provides the backbone for the Global Tree Assessments, led by the IUCN/SSC Global Tree Specialist Group (GTSG), which aims to undertake conservation assessments for all of the world's tree species by 2020. TreeSearch enables a gap analysis to be performed, to identify where conservation assessments are lacking.

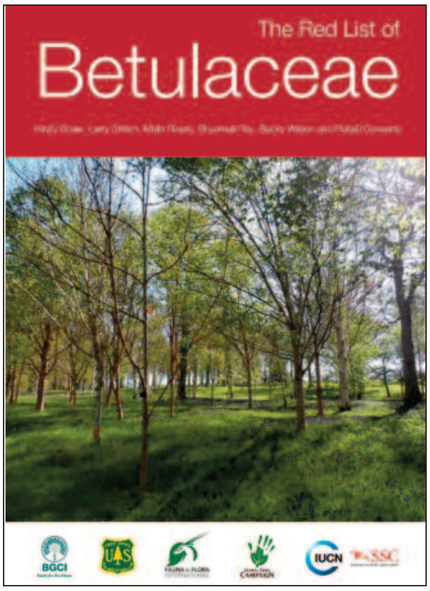
TreeSearch has compiled data from multiple information sources, as well as contributions from GTSG members. Additions from other sources are welcome, with the aim of creating a fully comprehensive global list of tree species. TreeSearch, Red List assessments and PlantSearch collection data will allow BGCI, along with our partners, to prioritise conservation action for the world's most threatened trees.

To find out more about the IUCN/SSC Global Tree Specialist Group, visit: http://globaltrees.org/iucn-ssc-global-tree-specialist-group/

To contribute to TreeSearch, please contact globaltrees@bgci.org

2. Empowering partners and practitioners to undertake tree conservation

With over 9,600 tree species threatened with extinction, conservation requires action from a large number of stakeholders. GTC delivers training programmes to partners and local stakeholders to develop the technical skills and knowledge required to



implement effective conservation of threatened trees, in addition to the production of technical manuals and guidance for non-specialists.

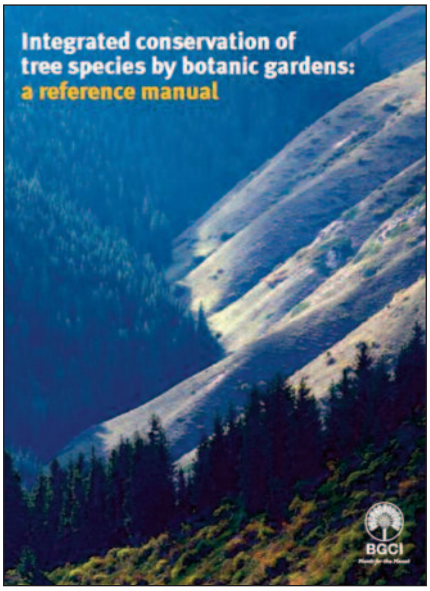
Building the capacity of our partners and other stakeholders scales up our influence and ensures impact is sustained in the long-term.

GTC is working with the University of Oxford Botanic Garden and Harcourt Arboretum, U.K. to deliver training in seed collection, propagation, nursery management and recovery and restoration programmes to the national network of botanic gardens in Ethiopia. Training will empower and enable Ethiopian botanic gardens to lead conservation efforts for the wide variety of endemic and endangered tree species in Ethiopia.

3. Taking direct action to secure priority tree species and ensure populations are recovering in the wild

Working in collaboration with our international network of partners and local stakeholders, GTC carries out direct and practical interventions to reduce threats, and ensure wild populations of threatened tree species are stable or recovering. Actions include monitoring, protection and sustainable use of *in situ* populations, *ex situ* conservation of living and seed collections and recovery and restoration programmes.

GTC is working with the Royal Botanic Gardens, Jordan, to develop propagation protocols for the country's tree species that are restricted to small remaining populations, at the edge of their range, with little natural regeneration. Propagation



protocols will be shared with NGOs and government bodies to enable a supply of material to be cultivated for planting and population restoration programmes.

GTC adopts best practice, trials novel approaches and shares outcomes to ensure our projects provide inspiration and guidance to other conservation practitioners.

In Kenya, GTC is working with Brackenhurst Botanic Garden to incorporate threatened trees in an area of restored indigenous forest. Over 100 rare and threatened East African trees have been planted in an area of 40 hectares, providing ex situ *protection and producing valuable guidance to inform reintroduction efforts to support the recovery of wild populations.*

4. Mobilizing other groups to act for threatened trees

By sharing the results of our prioritisation work, lessons learnt from practical projects, and GTC resources, we work to encourage a larger group of protected area managers, conservation NGOs, government agencies, tree planting groups and other stakeholders to protect, plant and promote conservation of threatened trees as part of their work programmes.

Through our website and social media channels, GTC also engages the public, with the aim to inspire broader society interest in threatened trees and raise awareness of the need for their conservation.

Our international network of partners, including botanic gardens and arboreta, extends outreach ability considerably.

With an estimated 500 million visitors each year, the world's botanic gardens offer huge outreach potential for highlighting the need for tree conservation and the values that each individual tree species offers.

GTC is uniquely placed to play this advocacy role, drawing on lessons learned from 15 years of species-focused conservation action for threatened trees.

Conclusions

The GTC provides a vehicle for guiding conservation action for the world's most threatened trees, for promoting the tree conservation work of our international network of partners, and for sharing best practice. As GTC scales up its programme of work, we will be calling upon and supporting botanic gardens and arboreta to take integrated conservation action for the threatened trees in their region, adopting a collaborative, coordinated and informed approach to secure the future of the world's threatened trees.

For more information about the Global Trees Campaign, please visit our website www.globaltrees.org, follow us on Twitter @globaltrees, or get in touch globaltrees@bgci.org

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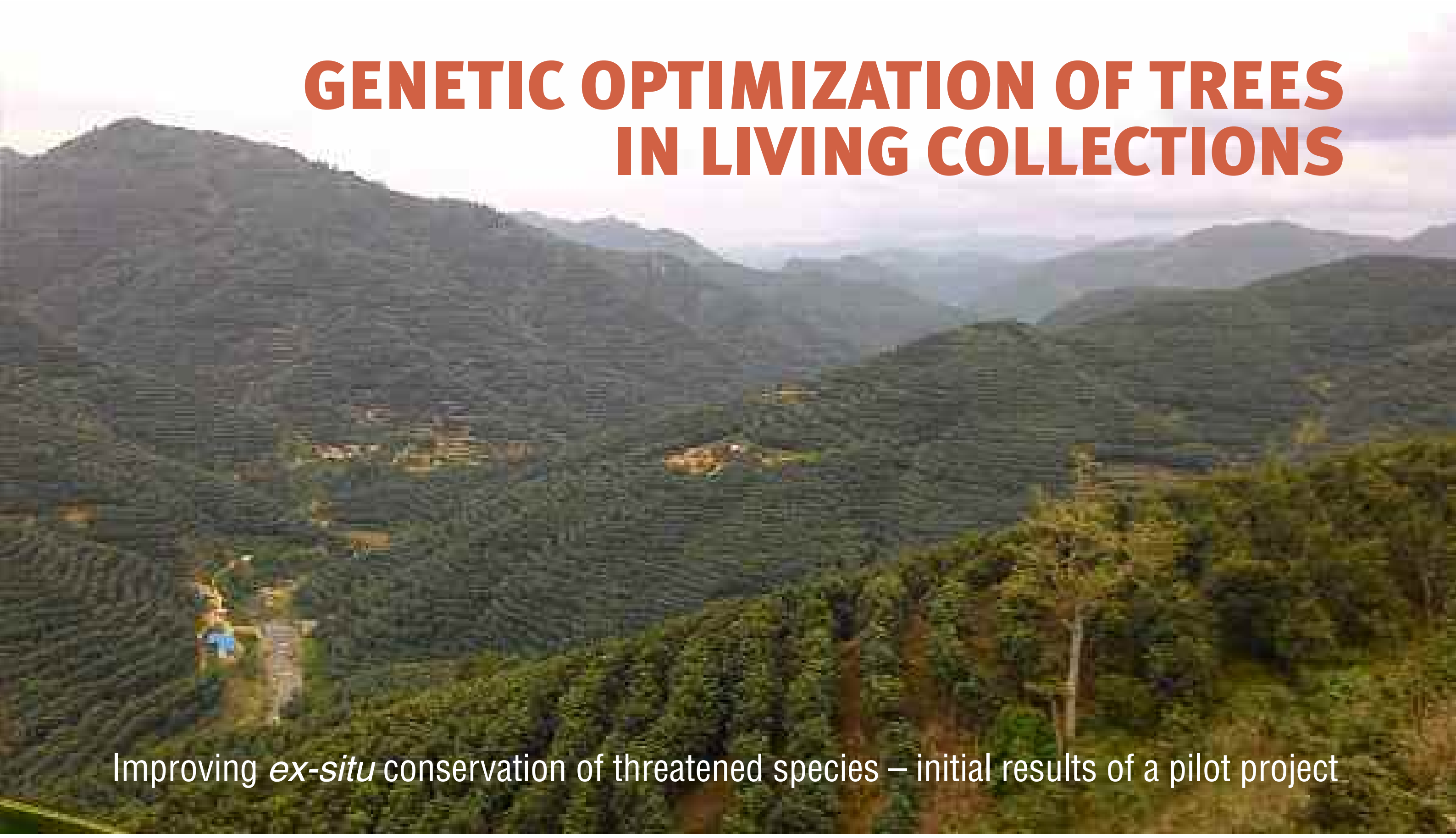
Magnolia sinica*, a Critically Endangered tree endemic to China, with only c. 50 mature individuals remaining in the wild (FFI)*

Authors: Alison KS Wee, Yann Surget-Groba and Richard Corlett

GENETIC OPTIMIZATION OF TREES IN LIVING COLLECTIONS



Improving *ex-situ* conservation of threatened species – initial results of a pilot project

The extent of rubber plantation expansion in Xishuangbanna, China

Introduction

In the face of rapid habitat loss and heightened threats to biodiversity, *ex-situ* conservation has become an increasingly important strategy to preserve viable populations of threatened taxa. Ideally, *ex-situ* collections should include genetically diverse individuals, in order to prevent inbreeding (Krauss *et al*., 2002), maintain the long-term evolutionary potential of the species (Enßlin *et al*., 2011) and to ensure the success of future reintroduction efforts (Hogbin & Peakall, 1999). However, the high cost of molecular work and the absence of molecular markers that can be used for all angiosperm species have prevented genetic screening from being a routine procedure in establishing *ex-situ* populations (Heywood & Iriondo, 2003).

The Zero Extinction Project in Xishuangbanna, China

Xishuangbanna is a plant diversity hotspot, supporting 10% of China's angiosperm flora. Agricultural expansion in recent decades had resulted in habitat loss and fragmentation, threatening the survival of native flora. To ensure the long-term survival of these threatened species, the Xishuangbanna Tropical Botanical Garden (XTBG) initiated the "Zero Extinction Project", which aims to prevent extinction in Xishuangbanna (Fig. 1). Central to this project is the *ex situ* conservation of threatened species in the living collection within XTBG, which is mainly intended for species with recalcitrant seeds, i.e. those with drying-sensitive seeds that cannot be stored in the seed bank.

The need for genetic optimization

Conserving the maximum genetic diversity of threatened species in the living collection is a challenging undertaking. The main technical issue stems from the shear diversity and number of the species involved. An assessment of the conservation status of 3,851 native angiosperm taxa in Xishuangbanna identified 106 taxa as

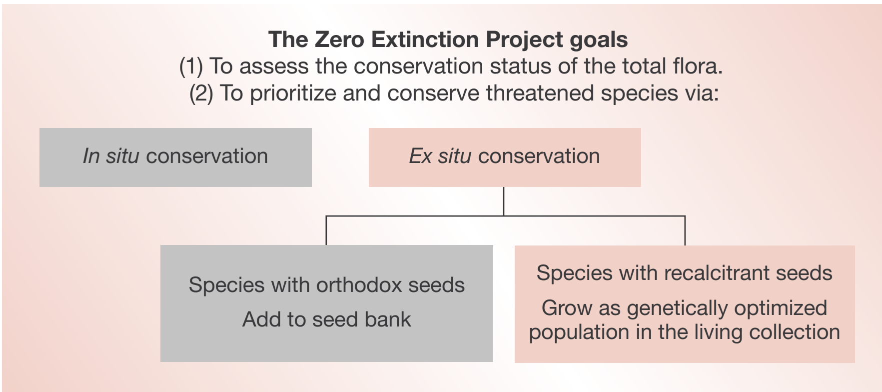


Figure 1: Components of the Zero Extinction Project in Xishuangbanna Tropical Botanical Garden. Genetic optimization aims to improve ex situ *conservation of species with recalcitrant seeds*

endangered or critically endangered and 493 taxa as vulnerable to extinction. Many of these threatened species are large trees and hence space is a major constraint to the number of individuals a botanical garden can preserve. This places great priority on genetically optimizing the living collection, i.e. ensuring that the genetic diversity of a species is represented by the least number of individuals. Fig. 2 outlines a simple work flow for genetic optimization of living collections.

The search for a practical genetic optimization protocol

Traditionally, candidate individuals for *ex-situ* conservation are genotyped with species-specific, fast-mutating microsatellites markers to select for a genetically diverse subgroup among them (Storme *et al*., 2004; Dreisigacker *et al*., 2005). However, with a large number of target species from across the plant phylogeny, employing species-specific markers for genetic screening is too labour-intensive, time-consuming and costly for the process to be practical. Consequently, genetic optimization of the entire living collection remains a model practice that is yet to go beyond textbooks and technical guidelines. Therefore, there is a need for a genotyping protocol that is rapid, universal and cheap.

Aglaia teysmanniana *sapling growing on limestone substrate*

In September 2014, the Center for Integrative Conservation in XTBG started exploring potential genotyping protocols. We focused our search on methods that utilize next generation sequencing (NGS), with the expectation that genotyping costs via NGS will become affordable and the technology accessible to many botanical gardens in the near future. By enabling botanical gardens to increase the capacity of their living collections without a substantial investment in space, genetic optimization represents a large technological step forward in the *ex situ* conservation of tropical plant species. Currently, the Zero Extinction Project initiated by XTBG has been replicated in other gardens in the Chinese Union of Botanical Gardens. Therefore, genetic optimization can potentially be widely applied in these botanical gardens.

The requirement for universality narrowed down our methodological options to genotyping-by-sequencing, either with Restriction-site associated DNA sequencing (RAD-seq) (Baird *et al*. 2008) or a newly developed PCR-based method termed MIG-seq (Suyama and Matsuki in preparation). Both methods generate large numbers of single nucleotide polymorphisms (SNP) loci, can be used without any prior knowledge of genomic sequences, and promise cheap and fast output. Data can be obtained within a month from DNA extraction, and can cost less than 15 USD per sample with multiplexing (Henri *et al*., 2015; Suyama and Matsuki in preparation). Also, both RAD-seq and MIG-seq protocols are sufficiently generic for outsourcing. For future large-scale implementation of genetic optimization, botanical gardens without molecular facilities can choose to outsource the NGS library preparation and sequencing to private companies.

Aglaia teysmanniana: a pilot study for genetic optimization

A pilot study was initiated to test the genetic optimization protocol. Creating an *ex-situ* collection of rare and threatened species is a challenging task, in terms of locating the individuals or populations, and understanding the phenology (for fruit or seed collection) and germination requirements. In addition, there is a prolonged waiting period for fruiting and seed germination prior to transplantation. Therefore, the focal species in the pilot study has to have (1) known and accessible populations, (2) known phenology, and (3) fairly simple and rapid germination.

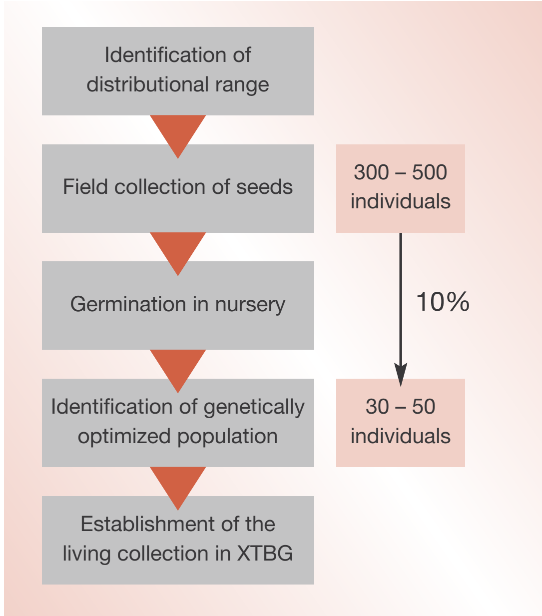
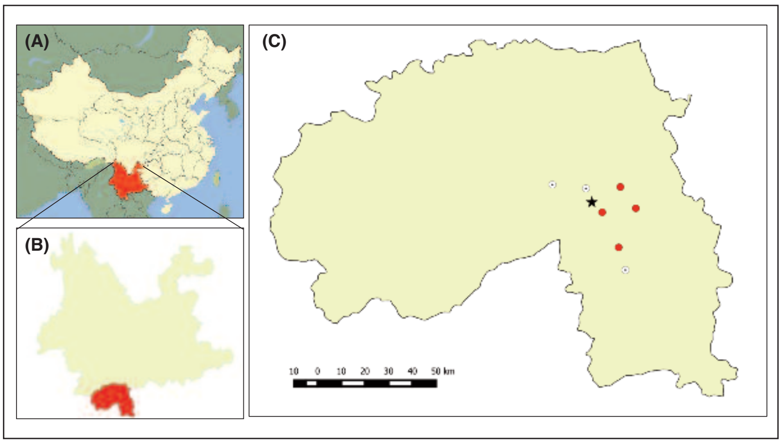


Figure 2: A schematic diagram of the workflow for genetic optimization

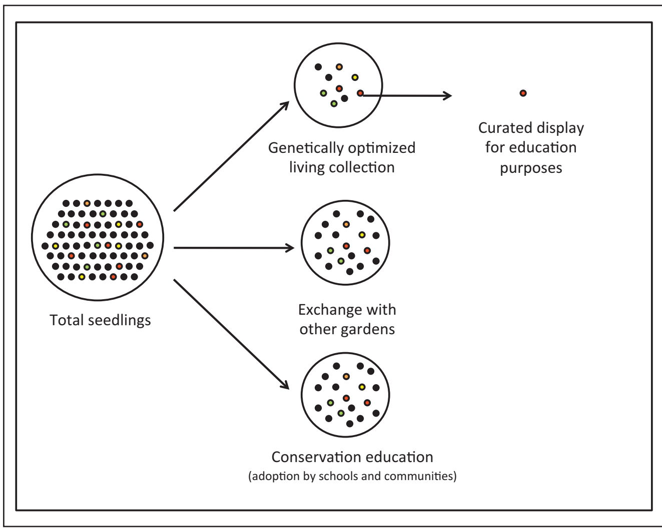
Aglaia teysmanniana (Meliaceae) is an ideal focal species for the pilot study. The seedlings are easy to identify in the wild and can be found in clusters near to the mother tree. Collecting seedlings from the wild allowed us to circumvent the phonological and germination challenges of sample collection. The species is distributed across most of Southeast Asia, including Indonesia, Malaysia, the Philippines, and Thailand. In China, it is found only in South and Southeast Yunnan, and is largely restricted to limestone forests. *Aglaia teysmanniana* is listed as Near Threatened on the IUCN Red List and Vulnerable on the Zero Extinction Project assessment in Xishuangbanna.

We collected 418 seedlings from seven populations in four locations in Xishuangbanna (Fig. 3). The GPS coordinate of the seedling patches were recorded, leaf samples of potential

Field collection of Aglaia teysmanniana *seedlings*



Map of the sampling locations. (A) The location of Yunnan province (in red) in China. (B) The location of Xishuangbanna prefecture (in red) in Yunnan province. (C) The locations of XTBG (black star), the limestone forest fragments (red) where Aglaia teysmanniana *seedlings were collected, and the limestone forest fragments (white) where* A. teysmanniana *was not found*



Future plan for transplanted seedlings

mother trees in the vicinity were collected, and the seedlings were transplanted to the XTBG nursery. Only 204 seedlings (49%) survived the transplantation process; root damage may be the cause of most of the mortality. The surviving seedlings will be genotyped with both RAD-seq and MIG-seq to evaluate the cost, time and labour requirements of both methods.

Future plans

The genotype of the seedlings (from both RAD-seq and MIG-seq) will be analyzed, and the most genetically diverse 10% of the total seedling population will be included in XTBG's living collection (Fig. 4). Among these, several individuals will be transplanted into the garden area that is open to the public for education purposes. The remaining seedlings will either be transplanted to other botanical gardens (as a backup living collection) or adopted by local schools and communities as part of XTBG's outreach program.

Upon completion of the pilot study, the most efficient and low-cost genotyping method of the two will be used to improve the *ex situ* conservation of other threatened tree species in the Zero Extinction Project's assessment, e.g. *Magnolia hypolampra, Cephalotaxus mannii* and *Goniothalamus cheliensis*.

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Transplanted seedlings in the XTBG nursery

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WHITHER RARE RELICT TREES IN A CLIMATE OF RAPID CHANGE?

Conservation challenges of *Zelkova sicula* and *Z. abelicea* – two Mediterranean narrow endemics

Zelkova serrata. *Buddhist shrine, Hita, Japan. (S. Bétrisey)*

Shepherd's crooks ('Katsouna') made from Zelkova abelicea. *Omalos, Crete. (G. Kozlowski)*

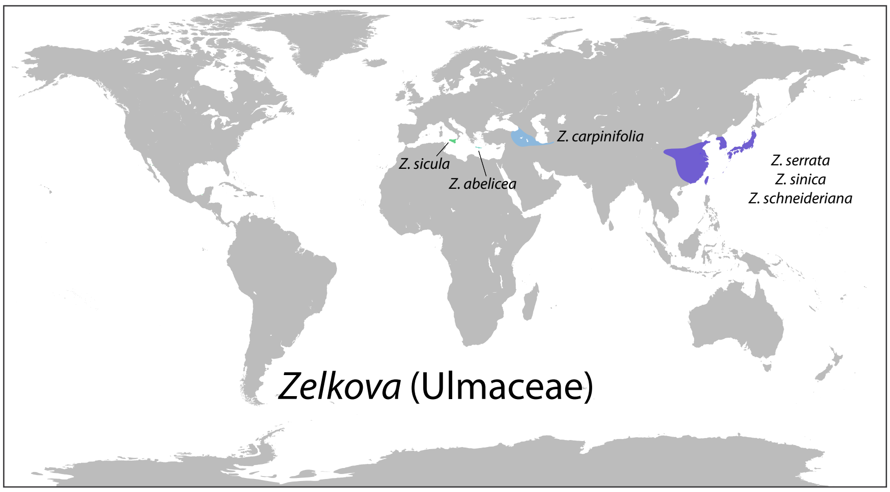
Introduction

Specimens of *Zelkova* spp., which may be up to 1,000 years old, found in places of worship and contemplation in eastern Asia, give evidence to the ancient and close relationship of people with these trees. Likewise, traditional herbal medicine, household items and other objects made from various parts of the tree, are testimony to the strong cultural and socio-economic values and customs associated with this genus.

Relict trees

Zelkova species form part of the Arcto-Tertiary relict flora that covered large parts of the northern hemisphere during the Caenozoic Era (some 55 – 2.5 million BP). Fossil discoveries attributed to the genus, dating back more than 50 million years, give proof of the plant's once wider, circumboreal occurrence. Today the highly disjunct distribution of the six extant species – *Z. sicula, Z. abelicea, Z. carpinifolia, Z. schneideriana, Z. sinica* and *Z. serrata* – from the Mediterranean over to the Caucasus and East Asia, make this genus a fascinating subject for phylogenetic and biogeographic studies to advance the understanding of evolutionary processes.

Zelkova zelkovifolia. *Pliocene. Willershausen, Germany. (H. R. Siegel)*



Global distribution of Zelkova *spp. Map by Natural History Museum Fribourg, Switzerland*

Unfortunately, the relict nature of the genus is no recipe for survival in a rapidly transforming environment. As elsewhere in the world, habitat loss, overexploitation, fast changing climatic conditions and many other drivers of change exert high pressure on remaining natural *Zelkova* populations, especially the two Mediterranean species, *Z. sicula* and *Z. abelicea*. These species occur in exceptionally isolated and fragmented locations. Among the rarest trees in the world, they require specific management approaches combining a set of integrated *in* and *ex situ* conservation measures.

Zelkova sicula – one of the rarest trees in Sicily and in the world

Within the genus, *Z. sicula* Di Pasq., Garfì & Quézel has a particularly remarkable position. Discovered in 1991 (Di Pasquale *et al*., 1992), this narrow endemic is known from only two locations. Both populations cover an area of occupancy of less than one hectare and include a few hundred small trees each. Occurring between 350 and 450 m above sea level on the north-eastern slopes of the Iblei Mountains (south-eastern Sicily), the populations are found in open forest communities with other tree species such as *Quercus suber, Q. virgiliana, Olea europaea* var. *sylvestris, Pyrus spinosa* and *Calicotome infesta*.

Z. sicula*. Population of Ciranna, Sicily. (G. Garfì)*

Distribution of Z. sicula *(red colour). Map by Natural History Museum Fribourg, Switzerland*

Staying alive in a changing climate

Several of the morphological and life traits of *Z. sicula* can be interpreted as the result of a long-lasting process of adaptation to a rather suboptimal environment. Unlike the other *Zelkova* species, *Z. sicula* is a shrub or a small tree. Characteristic for plants at the limit of their distribution range, this habit is most likely a response to water shortage in the current habitat. The location of both populations restricted to the bottom of gullies and along narrow streams, suggests that these micro-habitats play a key role in enabling the species to withstand drought. Nonetheless, extreme environmental hazards, such as prolonged drought can cause moderate to severe damage, ranging from withering of leaves to dieback of branches and stems. What is more, rising habitat fragmentation and livestock grazing represent major further threats to both populations. Due to its rarity, *Z. sicula* has been included as Critically Endangered (CR) on the IUCN Red List of Threatened Species.

Z. sicula *micro-habitat.(G. Garfì)*

Z. sicula *leaf withering. (G. Garfì)*

Two populations – two clones: two individuals?

Recent studies (Christe *et al*., 2014b) suggest that *Z. sicula* has been subject to severe isolation and genetic impoverishment. Fructification is irregular and seeds are most probably sterile due to its triploidy. Regeneration relies on vegetative mechanisms such as root suckering and layering; as a result, individuals in both genetically impoverished but distinct populations are assumed to be of clonal origin; hence, each population could be regarded as a single individual. This, in addition to the extended geographic isolation, has most likely caused a sharp decline in gene flow and a decrease in intra-specific genetic variability. On the other hand, clonality and vegetative reproduction are adding a further trait of uniqueness to this species in the genus *Zelkova*; as with *Lomatia tasmanica* (Proteaceae) – known from a single, clonal population estimated to be several ten thousands of years old (Lynch *et al*., 1998), each *Z. sicula* population could potentially represent a many thousand year-old genetic unit.

Young tree of Z. sicula *developing by root suckering. (G. Garfì)*

Rescue trials in progress

Since 2011, a major project funded through the European Commission EC Life Programme (http://www.zelkovazione.eu/) is implementing a range of integrated *in* and *ex situ* conservation actions in the areas of knowledge and monitoring, active conservation, expertise, and education/awareness and communication. To date, a number of key milestones have been achieved, including the exclusion of grazing through fencing and a sustainable management plan involving formal agreements with local stakeholders, as well as the legal protection of the target species through the enactment of a Councillor's Decree by the Regional Department of Environment.

The recent successful development of protocols for *in vitro* and *in vivo* vegetative multiplication is a further major step towards effective *in* and *ex situ* conservation, with the poor intra-specific variability in the species facilitating the establishment of the field collections.

Z. sicula in vitro *rooted plantlet. (A. Carra)*

Introduction to other ecosystems?

Securing viable populations *in situ* nevertheless remains the main conservation challenge. Introduction to other ecosystems is being studied to establish further populations in new locations. These have been identified using the guidelines for 'assisted colonisation' (Brooker *et al.*, 2011), and build on paleo-ecological data and observations of specimens grown under different *ex situ* conditions which reveal the growth potential of *Z. sicula* into actual trees (Garfì *et al.*, 2011; Garfì and Buord, 2012). These findings suggest that more humid and cooler climatic conditions typical to montane mixed deciduous forests with *Fagus, Acer*, deciduous *Quercus*, etc. may offer a

Bosco Pomieri, Madonie Mountains, 1340 masl, a potential introduction site. (G. Garfì)

better match for the ecological requirements of *Z. sicula*. This conservation approach is applied as the 'last resort' for narrow endemics confined to very specialised habitats and increasingly encroached upon by unfavourable environmental conditions.

Zelkova abelicea – a Cretan persisting against all the odds

Zelkova abelicea (Lam.) Boiss. is the only endemic tree of the east-Mediterranean island of Crete. The species is found in open, mountain forest communities between 900 and 1,800 m above sea level, where it grows in mixed stands with *Acer sempervirens, Quercus coccifera* and occasionally *Cupressus sempervirens*. Populations of *Z. abelicea* occur in all four main mountain ranges including Levka Ori, Psiloritis, Dhikti and Thripti. Primarily, they occupy north-facing slopes and areas around dolines (sinkholes) with adequate and relatively constant water supply, but the species is also found near river beds and gullies, where moisture tends to remain close to the surface during the dry summer period.

Threatened and fragmented populations

More than 40 populations of *Z. abelicea* are known, mainly in Levka Ori (ca. 30) and in the Dhikti Mountains (ca. 10). Only two populations occur in the Psiloritis Mountains, and one small population in the Thripti Mountains. This fragmented distribution occurred already prior to the modern, botanical exploration of Crete (ca. 300 years ago) and forms part of a lively debate whether Crete was ever dominated by continuous woodland

Z. abelicea*, Omalos, Crete. (J. Gratzfeld)*

Distribution of Z. abelicea *(red colour). Map by Natural History Museum Fribourg, Switzerland*

before the arrival of man. To date, it is not resolved if the fragmented pattern of *Z. abelicea* populations is the result of anthropogenic habitat transformation or if its occurrence always consisted of a patchy distribution (Kozlowski *et al.*, 2014).

Recent studies confirm however, that all populations are subject to threats from overgrazing and browsing (goats and sheep), as well as from soil erosion, drought and fires. As a result, all stands of *Z. abelicea* are dominated by dwarfed and heavily browsed individuals. This habit is especially pronounced in relatively small and isolated populations (e.g. in Thripti where there are no large trees at all). This is of great concern to conservation as only fully developed trees are able to flower and produce fruits (Fazan *et al.*, 2012; Kozlowski *et al.*, 2014). *Z. abelicea* has been included as Endangered (EN) on the IUCN Red List of Threatened Species.

Isolated, shrub habit population of Z. abelicea *in the Thripti Mountains, Eastern Crete. (G. Kozlowski)*

Each mountain chain represents a separate genetic and conservation unit

Because of the extreme fragmentation, gene flow between distant populations is highly unlikely, mainly because of the limited dispersal capacity of seeds. This was confirmed by recent genetic studies demonstrating that *Z. abelicea* populations are highly genetically diverse within and between the four mountain regions (Christe *et al*., 2014a). This indicates on the one hand that the colonization of Crete by *Z. abelicea* is very ancient (probably before the early Miocene, some 25 million years ago), and, on the other hand, that each mountain chain with *Z. abelicea* populations should be considered as a separate genetic unit.

Ex situ conservation challenges

In comparison with other *Zelkova* species, especially those from Eastern Asia, *Z. abelicea* is underrepresented in botanic garden collections (Kozlowski *et al*., 2012). In addition, only a very small portion of the genetic variability in natural populations is found in *ex situ* collections (Christe *et al*., 2014b). In fact, all investigated individuals cultivated in botanic gardens and arboreta, originate from one single region of the Omalos Plateau (Levka Ori), while the other genetically distant populations do not appear to be in *ex situ* collections.

Future *ex situ* conservation efforts will need to consider the entire genetic diversity of the species, whilst avoiding genetic mixture of differentiated populations from the four mountain chains, especially when establishing field living collections (Kozlowski *et al*., 2012, 2014). Furthermore, dwarfed and heavily browsed populations do not produce seeds. Vegetative propagation is the only option to establish collections of these populations, enhancing the complexity and costs of *ex situ* conservation measures.

In situ conservation challenges

Conventional measures of protection and management, including effective methods to limit and/or completely prevent livestock grazing and browsing should be implemented by means of fencing, and should comprise the entire range of the genetic diversity of the species. Such measures require to be developed in close collaboration with

Seed collections for ex situ *conservation of* Z. abelicea *at the Mediterranean Agronomic Institute of Chania, Crete. (G. Kozlowski)*

shepherds and other stakeholders (e.g. local administration, municipalities, national park administration), and accompanied by long-term scientific surveys to monitor progress and allow adaptive management.

Ongoing conservation action

Based on the thorough research work undertaken in recent years, an international, interdisciplinary and integrated conservation programme for *Z. abelicea* has been initiated. The implementation of the project is assumed by the Mediterranean Agronomic Institute of Chania (MAICh) in collaboration with the Forest Directorate of Chania (FDC) as well as with forest agencies from other administrative regions of Crete. International coordination and scientific support is assured by researchers and conservationists from the Universities of Fribourg (Switzerland) and Athens (Greece), Botanic Gardens Conservation International (BGCI, United Kingdom) and the Institute of Biosciences and BioResources of the National Research Council in Palermo (Sicily, Italy). Amongst others, new and genetically representative *ex situ* collections (field living collections as well as seed banks) are being established using seeds and vegetative plant material sampled from all mountain regions where *Z. abelicea* occurs. Additionally, selected pilot plots have been fenced and are regularly monitored by the team of MAICh and researchers and students of the University of Fribourg. What is more, a range of local and international campaigns and public

Fenced pilot sites with Z. abelicea. *On the left: non-fenced and heavily grazed area. Xeropotamos, Crete. (M. Beffa)*

outreach events have been realized, including scientific seminars, conferences and exhibitions, accompanied by a series of first-rate public outreach materials.

Conclusions

The conservation challenges presented by *Zelkova* spp. have attracted the attention of researchers, conservation practitioners and horticulturalists in a joint endeavour to secure the remaining genetic diversity in the genus. Inspired by this shared concern, since 2010, a highly interdisciplinary and international research group represented by partners from Europe, the Caucasus and East Asia have been participating in the development and implementation of an integrated conservation action plan for *Zelkova* spp. (Kozlowski G. & Gratzfeld J., 2013).

The isolated occurrence and rarity of *Z. sicula* and *Z. abelicea* provide an ideal context to practise integrated conservation action and serve as models for safeguarding other threatened species. While the exclusion of grazing pressure such as through fencing is the most pragmatic measure for immediate protection in the wild, long-term *in situ* conservation efforts need to be implemented in close collaboration with local stakeholders and anchored in national legislation and policy. Systematic scientific evaluations to monitor progress and allow adaptive management will in turn, inform the nature of population reinforcement programmes and options for potential introduction to other analogous environments in situations where the original habitat has been lost, or no longer provides a viable option for the species survival. This is especially urgent for *Z. sicula*, known from only two locations.

As elsewhere in the world, *ex situ* conservation of *Zelkova* faces the challenge of ensuring genetically representative collections, preferably in the countries of the species' natural distribution, where current *ex situ* holdings are still largely inadequate. The complexity of capturing the whole range of a species' genetic variation for *ex situ* conservation is well illustrated by the distinct genetic diversity of *Z. abelicea* found in each of its four main locations of occurrence. While the remoteness and inaccessibility of some of the last remaining natural *Zelkova* populations prevent the broader public from appreciating their grandeur in the wild, *ex situ* collections at botanic gardens and associated scientific institutions, play a critical role in enhancing environmental awareness and education. Linking reports of fossil finds with their extant relatives and new population discoveries, *Zelkova* and relict plants in general, can provide compelling stories to reach out to the wider society. Relict species from ancient times not only function as storehouses of information of the Earth's transformations over millions of years but also deliver a diverse range of ecosystem services. Though ultimately a matter of societal choice, their conservation may therefore present a vital element in the development of future ecosystem management approaches, especially in a period of unprecedented, rapid global change.

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EX SITU CONSERVATION OF ENDANGERED MALAGASY TREES AT PARC IVOLOINA

The nurseryman at Parc Ivoloina (Jean Francois) with seedlings of Schizolaena noronhae *growing strongly at Parc Ivoloina*

Introduction

The flora of Madagascar is both highly diverse (with 11,000 named species of flowering plants and ferns, and an estimated 3,000 species that have yet to be named) and largely endemic to the island (with ca. 90% of species known from nowhere else) (Callmander *et al*. 2011). Unfortunately this botanical wealth is also highly threatened by the survival tactics of the impoverished and growing human population, many of which remain largely dependent on natural resources for their livelihoods. Following centuries of ever increasing habitat degradation, the country is now faced with a wave of species extinctions. Typically the most threatened species occur as tiny populations in small, degraded fragments of natural vegetation. Ideally, these fragments should be included within protected areas but this rarely occurs because of their small size, degraded nature and the normal absence of large, prestigious animals. Thus, the most viable alternative to extinction for these species will be *ex situ* conservation followed, where possible, by introduction into secure and appropriate native habitats.

To date the most important contribution to the *ex situ* conservation of Madagascar's flora has been the Royal Botanic Garden, Kew's Millennium Seed Bank (MSB) Project that through a partnership with Madagascar's *Silo Nationale des Graines Forestières* has collected and preserved the seeds of ca. 1,900 species (pers. comm. Stuart Cable, 2015). However, many of the trees of Madagascar's evergreen forests have seeds that do not survive normal seed banking protocols (i.e. they are recalcitrant). Currently the only option for these species is conservation as growing plants at safe locations: either gardens or possibly field gene-banks.

Madagascar's only significant native plant collections are at the National Botanic Garden at Parc Tsimbazaza, Antananarivo; the Antsokay Botanical Garden, where a collection of plants from the south west of Madagascar is maintained; and the former forestry station at Parc Ivoloina that is now managed by the Madagascar Fauna and Flora Group (MFG) – a consortium of international zoos and botanical gardens. Between October 2006 and August 2011, with the financial support of the National Geographic Society, Conservation International and St Louis Zoo, MFG and the Missouri Botanical Garden (MBG) worked in partnership to collect and propagate material of 36 threatened tree species from central eastern Madagascar, and then grow these plants within the Parc Ivoloina.

Collecting material, propagation and planting out

The target species for this project were selected using information obtained from the literature and experts. Prior to launching fieldwork to locate the target species, a dossier was compiled on each that included information concerning their distribution, identification, vernacular names, phenology, and images of the species. Sometimes exact location information was available and the species was re-found easily. However, in many cases, such detailed location information was unavailable and then we found that soliciting the help of local people was the most effective way of relocating the species.

Priority was given to the collection of seeds over the collection of material for vegetative propagation. This is because the seeds, if selected carefully, normally germinate easily and grow into strong saplings, represent a genetically diverse population and their collection has little negative impact on the parent plant. Thus field trips were planned to coincide with the period when our analysis of herbarium specimens suggested that the target species were likely to be fruiting. To maximize the genetic diversity of the collections the team tried to follow the seed collection protocols developed by the MSB Project (Royal Botanic Gardens Kew, 2001). Voucher herbarium specimens were made to accompany each collection. When we were unable to obtain un-predated, ripe seeds we resorted to vegetative propagation by cuttings or air-layering.

The material collected by field botanists was propagated in a simple nursery at Parc Ivoloina which was constructed of locally available materials. The seeds were cleaned to remove traces of the fruit, sorted to identify and discard immature, rotten or parasitized seeds, and sown. According to their size, the seeds were either sown in seed beds of compost or directly into polythene pots filled with compost. The composition of the compost was: two parts river sand,

Although many fruits of Baudouinia louvelii *were obtained, nearly all the seeds within had been predated*

one part well-rotted organic matter and one part alluvial soil. The seeds were covered with compost to a depth of approximately their own width.

When the seeds had germinated and the seedlings had grown three to five leaves, they were pricked out into plots. These remained in the nursery, being watered as required, until they had attained a height of 30 to 60 cm, at which time they were planted out into the Park. Planting out was conducted during the wet season. Six weeks prior to planting the bamboo roof sheltering the saplings was first partially removed and then totally removed, to "harden off" the young plants to the sunny conditions they would likely experience at the planting site.

Pests and diseases attacking the plants in the nursery were controlled using treatments made from locally available materials. The most effective of these, used to control insect pests, was made by crushing chili peppers and mixing the resultant pulp with water. This was painted on affected plants in the afternoon.

After planting, the location of each young plant was defined using a description and precise geo-coordinates provided by a global positioning system unit. Each plant was marked with an individually coded aluminum tag.

Outcomes

From the original list of 36 target species, 20 species are now growing at Parc Ivoloina. Some of these species are represented by many individuals and some by one sole plant.

To illustrate some of the species that were included in our project consider the following three examples: *Schizolaena noronhae* (Sarcolaenaceae) from Andohakakavy Forest; *Pentachlaena betamponensis* (Sarcolaenaceae) from Betampona Reserve, and *Rhopalocarpus parvifolius* (Sphaerosepalaceae) from Ambila Lemaintso Forest.

Schizolaena noronhae is classified as Critically Endangered because it is now known from less than 100 individuals from two adjacent, unprotected and highly threatened littoral forests. With the assistance of a local person, who diligently monitored the phenology of the plants at Andohakakavy, we were able to obtain 500 seeds. From these we obtained 249 seedlings of which 82 were planted at Parc Ivoloina (72 of these survive and are growing well today) and 167 were used to reinforce the wild population.

Pentachlaena betamponensis is also classified as Critically Endangered because it is known only from the Betampona Reserve where we have been able to locate just 12 individuals. During the entire project these individuals were monitored by a local guide (Roilahy) but all remained sterile. Then in November 2011, after the conclusion of this project, we were notified that Roilahy, on his own initiative, had continued to monitor these plants and successfully obtained seeds and propagated 200 seedlings. One hundred of these seedlings were planted at Parc Ivoloina and 95 have been planted in the "protection zone" of the Betampona Reserve. Survival of the seedlings planted at Parc Ivoloina after 12 months was 100%.

So many plants of Sarcolaena grandiflora

Mammea castrae is known only from the Analalava forest where we were able to locate ten mature plants only

Rhopalocarpus parvifolius is another Critically Endangered tree. It is now known from less than 50 individuals that are all found in just two forest fragments that are both unprotected and highly threatened by shifting cultivation, timber extraction and charcoal production. Although the trees at Ambila Lemaintso were monitored for nearly three years they never produced fruits therefore we resorted to trying to propagate this species by air-layering. In total we made 20 attempts at air-layering but only two of these succeeded. One of these young plants was planted locally to raise awareness of the plight of this species, and the other was planted at Parc Ivoloina.

There are several reasons why 16 of the target species were not successfully integrated into the *ex situ* collection including:

- Two species were found to be synonymous with other quite widespread species and therefore dropped from the list. These include *Hubertianthus cardiostegius* that is now considered to be a synonym of the *Macrostelia laurina* (Malvaceae), and *Tinopsis tampolensis* that is a synonym of *Tinopsis conjugata* (Sapindaceae).

- Seven species were not located in the wild and at least three of these are likely to be extinct at the location where they were sought. Among these species is *Gnidia neglecta* (Thymelaeaceae) that is known only from a single herbarium specimen collected in 1912 from Andevoranto. On four occasions, our team and other botanists have unsuccessfully searched for this species at this site (and other sites nearby) and it is likely that this species is now extinct.

- Seven species were located in the wild but no viable seeds were obtained and attempts to propagate the species using techniques for vegetative propagation failed. One of these species was the endangered tree *Pentachlaena orientalis* (Sacrolaenaceae) from Tampolo (Fenerive-Est). While we re-found three individuals of this plant at this site we were not able to obtain viable seeds despite several visits, nor were we successful in propagating this species using air-layering. It would seem that this species does not flower and fruit annually and local people report that several years may pass between successive fruiting events.

Challenges and perspectives

In total this project cost just $50,000 yet has enabled 20 threatened Malagasy trees to be conserved ex situ. While we are proud of this result, we are also aware that our work has some important weaknesses, these are listed and discussed below.

- **Low genetic diversity in collections**

In several cases the seedlings now growing at the Park were derived from seeds (or cuttings) collected from a small number of parent trees and thus our *ex situ* population is likely to include low genetic diversity. Little can be done about this situation when the remaining wild population is very small but, in some cases, the wild population was larger but few individuals were fruiting at the time our collectors visited the site. In this latter

Species name	Number of individuals surviving to 2014
Baudouinia louvelii	20
Chaetocarpus rabaraba	1
Dypsis hovomantsina	7
Dypsis poivreana	30
Hyperacanthus ravinensis	214
Leptolaena raymondii	127
Mammea castrae	1
Mantalania longipedunculata	82
Marojejya darianii	194
Melanophylla sp. nov.	1
Molinaea brevipes	138
Orania trispatha	397
Pentachlaena betamponensis	100
Poupartiopsis spondiocarpus	34
Rhodolaena leroyana	329
Rhopalocarpus parvifolius	1
Sakonala madagascariensis	5
Sarcolaena grandiflora	99
Schizolaena manomboensis	2
Schizolaena noronhae	72

Endangered Malagasy trees now growing at Parc Ivoloina

Less than 50 individuals of Mantalania longipedunculata *(Rubiaceae) remain in the Kilalao Forest, Ile Ste Marie*

situation it is desirable to organise multiple collection trips to the same population thereby sampling different individuals during each trip. Alternatively we could seek to practise vegetative propagation more frequently and improve its outcomes. Two of the species now growing in Parc Ivoloina's collection were propagated through air-layering or cuttings (*Rhopalocaprus parvifolius, Melanophylla sp. nov*.), but we tried unsuccessfully to propagate several of the other species using these techniques. Even for the two species that were successfully propagated using these techniques, the success rate was low and consequently both species are represented in the collection by just one individual. However it is likely that our propagation protocols could be improved to increase the efficacy of these approaches.

- **Wasted expenditure on futile field trips**

The most important expenditure during this project was the organisation of field trips to locate and collect seeds from the target species. Therefore it is of concern when, despite careful planning informed by the phenology of the species, field trips failed to coincide with the fruiting of the target species. A solution to this problem, that we trialled with some success in the later stages of the project, is to identify and motivate a local person to monitor the target species and either inform us when fruiting occurs or to collect fruit themselves and dispatch these samples to us. In this latter option it is important to provide the local collector with training in seed collection techniques.

- **Lack of secure system for documenting and tracking accessions**

A major weakness of this project is that although each seedling planted in Parc Ivoloina has been carefully labelled, the information linking the code on the label to its origin and history is spread between diverse field-books and computers. Such information is clearly very susceptible to loss and it is now essential that we invest in capturing this information in a secure system. For this reason we are currently exploring adapting MBG's Live Collections Monitoring System for this purpose (Wyatt and Sucher, 2014).

- **No long-term funding available**

Serious *ex situ* conservation requires long-term funding. Yet most conservation funding available in Madagascar is for short periods only, and currently there is no support to continue the *ex situ* conservation of plants at Parc Ivoloina. Therefore it is fortunate that the target species of this project are all woody plants and now are sufficiently big and vigorous to require little further care. The project described here is best considered as a pilot project during which we were able to trial the viability of *ex situ* plant conservation in Madagascar and develop low-cost and effective protocols. Generally the results were very positive and with the integration of the improvements listed above this approach could constitute a very realistic and effective method of preventing the extinction of a portion of Madagascar's tree flora for which no other conservation options are currently available.

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The planting plan for part of the ex situ *collectoin at Parc Ivoloina*

Author: Murphy Westwood

THE GLOBAL TREES CAMPAIGN AND ARBNET

WORKING TOGETHER TO ADVANCE PROFESSIONALISM AND TREE CONSERVATION IN ARBORETA

Discussions between staff from the Harcourt Arboretum in the UK and Wondo Genet College Arboretum, Ethiopia (BGCI)

ArbNet – the interactive community of arboreta – and its ArbNet Arboretum Accreditation Program set industry standards for arboretum management, collections curation, and scientific and educational programming among tree-focused gardens. In collaboration with the Global Trees Campaign, the Accreditation Program supports and encourages an active role in tree conservation at the higher levels of arboretum accreditation.

Introduction

With at least 10% of the world's tree species threatened with extinction, there is a great need for gardens to support tree conservation efforts both *ex situ* and *in situ*. The Global Trees Campaign provides the mechanism and guidance through which gardens can act as a community to engage in active tree conservation initiatives. While acknowledging that gardens have a variety of missions and goals they seek to fulfill (e.g. display, public education, horticulture training, providing green space to the community, etc.), and that gardens of different sizes will have varying capacities for active conservation, it should be emphasized that even small gardens can take steps to improve the conservation quality of their collections and work to support the mission of the Global Trees Campaign (Cavender *et al*., 2015). To encourage and support gardens of all sizes to participate in tree conservation, ArbNet (www.arbnet.org) is working in collaboration with BGCI to facilitate more engagement by gardens in the Global Trees Campaign.

ArbNet is an interactive, collaborative, global community of arboreta that supports the common purposes and interests of tree-focused public gardens. Sponsored and coordinated by The Morton Arboretum (Lisle, USA), ArbNet was launched on Arbor Day (April 29), 2011 to facilitate the sharing of knowledge, experience, and other resources to help arboreta meet their institutional goals and to raise

The Montgomery Botanical Centre, USA

FOUR LEVELS OF ACCREDITATION

Join the professional arboretum network

Different levels of accreditation recognize arboreta of various degrees of development, capacity, and professionalism.

	LEVEL I	LEVEL II	LEVEL III	LEVEL IV
Arboretum plan	■	■	■	■
Organizational or governance group	■	■	■	■
Labeled trees/woody plant species				
25+	■			
100+		■		
500+			■	■
Staff or volunteer support				
Volunteer or paid	■			
Paid management		■	■	■
Curator			■	■
Scientific or conservation staff				■
Public dimension				
Public access and at least one event per year	■	■	■	■
Enhanced public and educational programs		■	■	■
Substantial educational programming			■	■
Participation in ArbNet	■	■	■	■
Collections policy		■	■	■
Collaboration with other arboreta			■	■
Collections data sharing with networked collections			■	■
Agenda for tree science, planting, and conservation			■	■
Collections conservation				■
Conservation role in Global Trees Campaign				■

VISIT ARBNET.ORG/ACCREDITATION FOR MORE INFORMATION ABOUT SPECIFIC ACCREDITATION REQUIREMENTS.

AN INTERNATIONAL NETWORK

of tree-focused professionals

In addition to offering the Arboretum Accreditation Program, ArbNet is also an interactive community that supports information exchange and collaboration. Through arbnet.org, individuals can:

- Access helpful resources.
- Participate in online forum discussions.
- Read about arboretum-focused news.
- Identify other arboreta to collaborate with in scientific, collections, and conservation activities.
- Work collectively as part of a broad network to help advance the planting, care, and conservation of trees.

ArbNet THE INTERACTIVE COMMUNITY *of* ARBORETA

The Morton Arboretum

ACCREDITED ARBORETUM

LEVEL IV

The Morton Arboretum, Lisle, IL

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ArbNet THE INTERACTIVE COMMUNITY *of* ARBORETA

BECOME ACCREDITED.

GET CONNECTED.

Strengthening the arboretum community

professional standards through the ArbNet Arboretum Accreditation Program. Through ArbNet, arboreta from around the world can work collaboratively as part of a broad network to help advance the planting and conservation of trees. ArbNet provides:

- The ArbNet Arboretum Accreditation Program to recognize standards of excellence in tree-focused gardens.
- Helpful resources to improve arboretum management, operations, research, conservation, and educational programming.
- The Morton Register of Arboreta – a database of arboreta and other public or private gardens that have a substantial focus on woody plants.
- Relevant arboretum news and events from around the world.
- The opportunity to identify and connect with other arboreta to collaborate on scientific, collections, and conservation activities.
- A broad network of professionals to help advance the planting, care and conservation of trees.
- An online forum for tree-focused discussions.
- A platform to demonstrate value and importance of tree collections to local land planners and policy makers.

In addition to providing these benefits, ArbNet is also a powerful tool for advancing the conservation efforts of tree-focused gardens of all sizes.

Mission

"The mission of ArbNet is to foster the establishment and professionalism of arboreta; identify arboreta capable of participating or collaborating in certain scientific, collections, or conservation activities; and advance the planting and conservation of trees."

The ArbNet Arboretum Accreditation Program

The Morton Arboretum created the ArbNet Arboretum Accreditation Program to establish a widely recognized set of industry standards for the purposes of unifying the arboretum community, providing a mechanism for benchmarking tree-focused gardens, and establishing guidelines for professional development. The ArbNet Arboretum Accreditation Program recognizes arboreta at various

Table 1: ArbNet Accreditation

No. of accredited arboreta:	108
No. of countries represented:	7
Level I arboreta:	40
Level II arboreta:	40
Level III arboreta:	13
Level IV arboreta:	15
No. of tree-focused gardens listed in the Morton Register:	954

	Level I	Level II	Level III	Level IV
Arboretum plan	■	■	■	■
Organizational or governance group	■	■	■	■
Labeled trees/woody plant species				
25+	■			
100+		■		
500+			■	■
Staff or volunteer support				
Volunteer or paid	■			
Paid management		■	■	■
Curator			■	■
Scientific or conservation staff				■
Public dimension				
Public access & at least one event per year	■	■	■	■
Enhanced public & educational programs		■	■	■
Substantial educational programming			■	■
Participation in ArbNet	■	■	■	■
Collections policy		■	■	■
Collaboration with other arboreta			■	■
Collections data sharing with networked collections			■	■
Agenda for tree science, planting, & conservation			■	■
Collections conservation				■
Conservation role in Global Trees Campaign				■

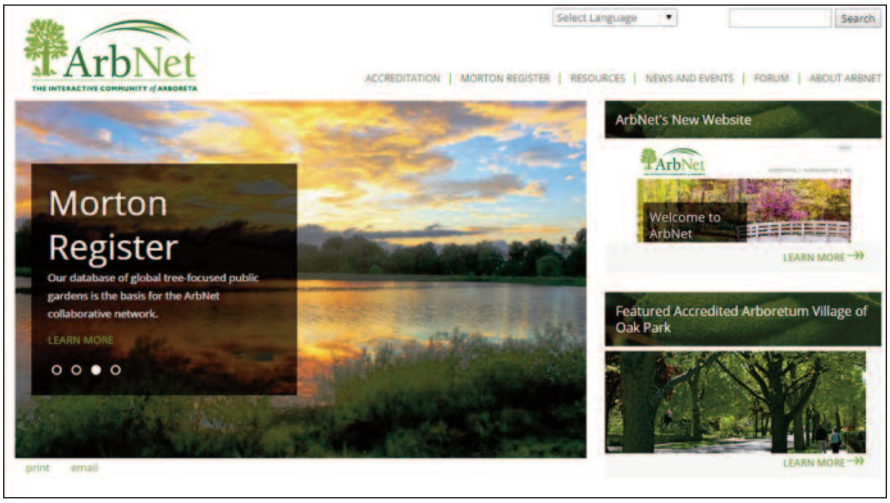
levels of development, capacity, and professionalism. No other international program of accreditation exists that is specific to arboreta.

"Individuals and organizations have long sought definitions, standards, and means of establishing an official or legitimate arboretum." according to Dr. Gerard T. Donnelly, President and CEO of The Morton Arboretum, which sponsors and coordinates ArbNet.

Any international arboretum or public garden with a substantial focus on woody plants may apply for accreditation. Examples of institutions that may be accredited arboreta include botanical gardens, cemeteries, zoos, city tree collections, historic properties, college campuses, corporate campuses, retirement communities, nature reserves and municipal parks. Accreditation is based on self-assessment and documentation of an arboretum's level of achievement of accreditation standards, including planning, governance, number of species, staff or volunteer support, education and public programming, and tree science research and conservation.

Benefits of accreditation

- Be recognized for achievement of specified levels of professional practice.
- Work toward higher levels of professional standards once accredited.



- Identify other organizations at similar or higher levels of accreditation to provide comparative benchmarks and models for further achievement.
- Earn distinction in your community, university, or government agency.
- Exert leadership and influence by serving as a model to encourage professional development in other organizations
- Identify opportunities for collaboration with other arboreta for scientific, collections, or conservation activities.

Four levels of accreditation

The four levels of accreditation recognize arboreta at various degrees of development, capacity, and professionalism. Accredited arboreta are encouraged to seek and achieve higher professional standards and move up through the levels. Categorization also allows an assessment of which arboreta are capable of participating or collaborating in certain scientific, collections, or conservation activities.

Level I arboreta are generally smaller publicly accessible sites with at least 25 species of woody plants, one or a few employees or volunteers, a governing body, and an arboretum plan. Examples of arboreta at this level may include golf courses, college arboreta, cemeteries, zoos, private estates, or towns with a labeled and curated tree collection. Level II arboreta have at least 100 species of woody plants, employ paid staff, and have enhanced public education programs and a documented collections policy. Level III arboreta have at least 500 species of woody plants, employ a collections curator, have substantial educational programming, collaborate with other arboreta, share their collection data, and actively participate in tree science and conservation. At the highest level of accreditation, Level IV arboreta employ well-qualified tree scientists engaged in publishing sophisticated research, manage living tree collections for the purpose of conservation, and take an active role in supporting tree conservation thereby contributing to the mission of the Global Trees Campaign. Level IV arboreta are world-renowned tree-focused institutions.

ArbNet-accredited arboreta working in support of the Global Trees Campaign

By becoming accredited as an arboretum at any level, gardens are already improving their potential conservation efforts by becoming part of the global network of arboreta. However, at the highest level of accreditation (level IV), specific consideration for a conservation role in the Global Trees Campaign is explicitly required. Level IV arboreta can participate in a variety of tree conservation activities that directly support the mission of the Global Trees Campaign (GTC), including for example:

- Curate wild-collected trees of well-documented, known provenance;
- Include and prioritize threatened trees in their collections and collecting strategy;
- Highlight threatened trees in *ex situ* collections with GTC interpretation;
- Participate in collaborative collecting or seed banking field trips for threatened trees;
- Propagate and exchange germplasm of threatened trees with other institutions and conservation networks;
- Undertake planting trials for threatened trees, develop horticulture and propagation protocols;
- Carry out education and awareness for threatened trees;
- Provide training workshops on threatened trees (e.g. identification, seed collecting, nursery management, IUCN red listing, propagation, germination, population monitoring, etc.) locally or remotely in locations of need;

- Undertake active *in situ* conservation efforts for threatened trees in regions of high biodiversity and low capacity for conservation. Activities include population monitoring, surveys, invasive species removal, seed collecting, reintroduction of threatened and associated trees, local community engagement and education, developing sustainable management plans for threatened trees, etc.;
- Participate in ecological restoration programmes for degraded habitats of threatened trees, for example in collaboration with the Ecological Restoration Alliance of Botanic Gardens (www.erabg.org);
- Host GTC conferences, seminars, or training workshops;
- Promote the work of the GTC and provide information and a GTC link on their website;
- Host staff who are members of the IUCN Global Trees Specialist Group;
- Support a joint staff position between the host institution and BGCI/GTC;
- Provide support, guidance, training and mentorship to arboreta at lower levels of accreditation;
- Lead or substantially contribute to IUCN red listing efforts for trees within a taxonomic group or region;
- Author GTC manuals, reports, interpretation content, articles, or other conservation-focused resources.

Examples of how arboreta in Accreditation levels I, II and III can support tree conservation and improve the conservation value of collections:

Level I and II arboreta
- Document and database tree collections, including provenance data, and maintain detailed records;
- Collaborate with other local tree holding institutions on conservation projects, staff exchanges/training, plant exchange;
- Label trees, verify identity;
- Strive to obtain wild-collected seed of known provenance;
- Provide education and interpretation that advocates for tree conservation and builds awareness of threatened trees;
- Share collections data with PlantSearch;
- Collaborate with larger arboreta that can act as a coordination hub for conservation projects.

Level III arboreta
- Support local/regional collecting efforts for threatened trees;
- Work to protect locally threatened trees and their habitats;
- Monitor locally threatened tree populations;
- Collaborate with a conservation consortium or other arboretum to participate in *ex situ* and/or *in situ* conservation;
- Prioritize wild-collected seed of known provenance for living collections;
- Contribute wild-collected seed to seed banks for long term preservation if the species is amenable to seed banking conditions (i.e orthodox seeds);
- Phase out accessions with unknown provenance;
- Conduct a conservation value audit on the living tree collection;
- Support Level I and II accredited arboreta to improve the conservation quality of their collections;
- Contribute to IUCN Red List assessments;
- Engage citizen scientists to increase capacity for conservation efforts

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University of Oxford Botanic Garden and Harcourt Arboretum (UK)

In support of the GTC and to achieve level IV accreditation, the University of Oxford Botanic Garden and Harcourt Arboretum in the UK established a valuable partnership with Wondo Genet College Arboretum (WGCA), a level I accredited arboretum in Ethiopia. Harcourt is supporting WGCA in developing a conservation program for rare and endangered endemic trees. This includes establishing seed collecting, germination and propagation protocols; improving operations in the tree nursery; developing a long term strategy for restoration and reintroduction of threatened trees; providing training workshops for staff; helping build capacity; improving curation standards; and conducting a conservation audit of the existing tree collection. This partnership helps drive forward the conservation mission of both organizations, creates enhanced fund raising opportunities, and results in valuable information and expertise exchange between the organizations.

Montgomery Botanical Center (USA)

The Montgomery Botanical Center in Coral Gables, FL, USA is a world leader in palm and cycad conservation and an active participant in several GTC initiatives and projects. One of the many activities it undertakes that contributes to its level IV accreditation is developing manuals and resources in collaboration with BGCI that build capacity for gardens to engage in *ex situ* tree conservation. One such resource is *"Building living plant collections to support conservation: A guide for public gardens"* that was published in 2014. This guide provides helpful advice on how to prioritize target species, leverage existing institutional assets, collect seed, curate the *ex situ* collection, and gain support from donors and the public. Montgomery Botanical Center is an excellent model for other tree-focused gardens to follow, as it prioritizes wild-collected, genetically representative germplasm in its *ex situ* palm collections. Conservation of threatened palms and genetic diversity is at the forefront of its mission, and its living collection is testament to this objective. As a level IV arboretum focused on conservation, Montgomery provides a gold standard benchmark that other arboreta can work towards as they achieve higher levels of accreditation.

Author: Paul Smith

SAVING MALAWI'S NATIONAL TREE

*Mulanje cedar (*Widdringtonia whytei*), Sombani Basin, Mt Mulanje, Malawi*

Can a combination of *in situ* and *ex situ* conservation approaches bring this iconic species back from the brink?

Introduction

The Mulanje cedar (*Widdringtonia whytei* Rendle) is Malawi's national tree. Its natural distribution is confined to the 30 km^2 Mount Mulanje massif in the south of the country, south-central Africa's highest peak at 3,002 metres above sea level. Despite its mountain fortress – or perhaps because of it – the Mulanje cedar is critically endangered (Bayliss *et al*, 2007). The latest estimates suggest that the area covered by Mulanje cedar has declined from 1,462 hectares in 1986 to 917 hectares in January 2014, i.e. a 37% decline in 28 years. The main cause of the cedar's destruction has been logging for timber and fire, although there are also strong indications that other factors may be contributing to its demise. As of January 2014, overall estimates indicated that there were 63,747 standing cedar trees on the mountain and, of these, 25,609 were dead (41.5% of the population). It is necessary to investigate the causes of the cedar's decline in more detail if we are to come up with a recovery plan that might have some chance of success.

Over-exploitation

The wood of the Mulanje cedar is very beautiful, it polishes well, is light to moderately heavy, and extremely durable. In fact, it is so resistant to termites, wood borers and rot that the Thuchila Forestry cottage, built from this timber 110 years ago, still stands today, as do a number of mountain huts built for hikers and climbers in the 1920s. The wood of the Mulanje cedar emits a distinctive fragrance from the tannins and resins that it contains, and which presumably give it durability. As well as being an excellent building timber, the cedar is useful for shipbuilding, furniture and for roof shingles. As a result of its multiple uses, Mulanje cedar wood has a very high economic value.

"At an auction of confiscated wood held by the Malawi Department of Forestry in 2010, a cubic metre of cedar wood fetched nearly US$4,000."

Sombani mountain hut, constructed from Mulanje cedar

For these reasons the cedar is heavily exploited, and much of this offtake is illegal. Furthermore, poor law enforcement, and the presence of so many people on the mountain, has led to a proliferation of wild fires, despite the efforts of a local NGO (Mulanje Mountain Conservation Trust (MMCT)) to set up firebreaks and fire control measures[1].

Despite its thick bark, the Mulanje cedar is highly flammable, and it is particularly vulnerable at the seedling stage. In fact, fire has been the main cause of the destruction of *Widdringtonia* seedlings that have been planted on the mountain by MMCT since 2004. Ironically, the cedar also needs fire to establish otherwise it is outcompeted by other native evergreen trees and exotic invasive species such as *Pinus patula* and *Rubus ellipticus*.

Other threats to the Mulanje cedar

The over-exploitation of *Widdringtonia whytei* is only one part of the story. The large proportion of dead standing trees hints at a species that is under some stress. In the 1990s there was an aphid infestation of *Cinara cupressi* on the mountain that severely affected mature cedars but this was treated successfully with a biological control. More worrying is the very restricted ability of the Mulanje cedar to regenerate and establish itself.

The 2014 cedar assessment further shows very low natural regeneration taking place within the cedar clusters. This could be attributed to several factors including low viable seed output (Chanyenga, 2013). 285 naturally regenerating seedlings were recorded in 16 clusters out of the 34 clusters that are still stocked with cedar trees. This represents 1 seedling ha^{-1}. 152 seedlings were in the ≤20cm height category, 106 seedlings in the 21-150 cm height category while only 7 seedlings were found in the sapling category. Examination of the remaining mature stands on the mountain shows that the tree exhibits very distinctive size classes, or cohorts, rather than a continuum of trunk diameters. This suggests that the right climatic and ecological conditions for cedar regeneration and establishment don't come along very often. These intervals will be even further apart when the occurrence of fires is factored in.

Over the past two decades, tens of thousands of *Widdringtonia* seedlings have been produced and planted out by the Forestry Department and MMCT but they have nearly all failed to establish. The result is a species that appears to be in terminal decline.

Changing conditions

It is often our assumption that plants are happy where they are and, for this reason, most species recovery efforts aim to augment existing populations or reintroduce plants to their historical sites. The Mulanje cedar is an interesting case study of why this may not always be appropriate.

It is entirely likely that the Mulanje cedar's historic range was far greater than it is today and that the Mulanje massif is a refugium for this species where it has been afforded some protection from fire in a warming climate. It is also quite possible that the climatic conditions on the mountain are not optimal for the species. The natural distribution of the tree ranges from 1,500-2,200m on the mountain and, interestingly, while efforts to plant the tree on Mulanje mountain itself have failed, the tree has been successfully planted on the Zomba Plateau (1,500 m) and Viphya Plateau (1,600 m) with growth rates far exceeding those on Mount Mulanje. In addition, the Mulanje cedar is reported as growing in Bogor Botanical Garden, only 265 meters above sea level and only 6 degrees south of the equator!

The Management Plan

Given the challenges associated with understanding the Mulanje cedar's growing requirements and autecology, a multi-disciplinary approach will be required to ensure its continued survival. The following actions are proposed in the Mulanje cedar's recently published Management Plan:

- To plant approximately 1,400 hectares of cedar seedlings in the approximately 1,600 hectares of historical cedar habitat sites on the mountain;
- To protect the growing stock from forest fires, insects and disease, and illegal harvesting;

Lichen-draped cedars on the slopes of Mount Mulanje

- To develop and manage good working relationships with all stakeholders and the surrounding communities to promote cedar protection and restoration;
- To develop and conduct appropriate ecological research on the species.

BGCI will work with local and international partners to support this work and, in addition, will:

- Establish trials of Widdringtonia in 'field genebanks' elsewhere in Malawi, in order to better define its optimal growing conditions.
- Conduct horticultural research to improve seedling survival and establishment in nurseries, and enable older trees to be reintroduced.
- Work with local communities and the Malawian Forestry Department to include the Mulanje cedar in the portfolio of (mainly exotic) plant species for sale in community and private tree nurseries.

The reintroduction of the cedar to Mulanje mountain has some precedence. Before the Second World War, 190 hectares (470 acres) of the Mulanje cedar were planted. Most of these established successfully under the strictly controlled fire regime of the day. From the 1970s, however, a number of these stands were destroyed by fire. Clearly, effective protection from fire, pests and invasive species will require pro-active management and good relations with local communities.

The research required to fully understand the autecology of the Mulanje cedar will embrace a number of disciplines. The population genetics of the cedar is poorly understood, even to the extent of there being some doubt about whether *Widdringtonia whytei* is synonymous with the far more widespread *Widdringtonia nodiflora* (L.) Powrie. The most recent study of Widdringtonia systematics (Pauw & Linder, 1997) suggests that the two species live side by side on the mountain. Regardless of whether there is one species or two, it will be essential to know more about the genetic diversity of the remaining populations on the mountain as well as those populations that have been established on Zomba and Viphya. In this way, we will be able source seed from as wide a genetic base as possible, and thereby maximize the adaptive potential of reintroduced seedlings. It should also become clearer about whether inbreeding depression is a factor for the remaining populations on the mountain.

Mulanje cedar seedlings, Fort Lister, February 2010

A further topic for research is the pathology of the cedar. Currently, seedling survival drops off drastically after the plants reach 5-10 cm in height in the nursery. As mentioned above, survival after planting in the field is even lower. This may be due to a microbial pathogen or it may be due to the absence of a symbiont, such as an ecto-mycorrhizal fungus.

Finally, optimal abiotic and edaphic conditions are not well characterized for this species. Experimentation in the nursery and in reintroduction sites will help to resolve this knowledge gap, as will trial planting in different sites in Malawi. To this end, the World Agroforestry Centre (ICRAF) has five field genebanks (or seed orchards) distributed throughout Malawi's different ecological zones and these will be ideal for testing the edaphic and climatic tolerance of the cedar.

Our final strategy will be to define optimal horticultural protocols for *Widdringtonia whytei*. This will involve testing the species in a range of potting media, watering regimes, containers (including aerial pruning), light and temperature. The ultimate aim here is to domesticate the species to the extent that it can be grown and sold in nurseries throughout Malawi. There are a number of precedents for this approach. Other indigenous timber species sold in nurseries in Malawi include the pod mahogany (*Afzelia quanzensis*), the Natal mahogany (*Trichilia emetica*) and the red mahogany (*Khaya anthotheca*). All have a ready market and, best of all, represent a potential income stream for local communities that currently can only earn money from cutting these trees down.

We will keep you informed of progress but are hopeful that, by applying a range of *in situ* and *ex situ* conservation approaches, we can conserve this iconic species and improve the livelihoods of the inhabitants of Mulanje Mountain.

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BGCI's PlantSearch database together with the Atlas of Living Australia and the managers of relevant botanic gardens are providing new insights into the climatic requirements of rare tree species

Eucalyptus kruseana *(T. Booth)*

LEARNING ABOUT THE CLIMATIC REQUIREMENTS OF THREATENED TREE SPECIES

Introduction

A limitation with most climate change impact analyses of tree species is that they have only assessed species natural distributions. It is obvious to many people involved with botanic gardens that many species can grow successfully under climatic conditions somewhat different from those within their natural distributions (Booth *et al*., 2015). Determining the extent to which threatened tree species can tolerate different climatic conditions is important for devising appropriate conservation strategies. For example, if a rare species can cope with changing climatic conditions it is desirable to conserve it in its current locations, rather than undertake risky and expensive relocations. BGCI's PlantSearch database[1], together with recently developed biodiversity databases such as the Atlas of Living Australia[2], are providing exciting opportunities to analyse the climatic requirements of threatened tree species.

Eucalypt species are particularly interesting for climate change studies as many of the more than 800 species found in Australia have been tested widely in trials. Often these trials have been under hotter and drier conditions than where the species grow naturally. However, endangered or vulnerable eucalypt species, of which there are more than 50 species, tend to be small and/or multi-stemmed trees. These have little potential for commercial use, so have usually not been included in trials. Many of these species have relatively limited distributions and narrow climatic ranges, so may be particularly vulnerable to climate change.

A recent study has examined the potential for using information from botanic gardens to provide some indication of the climatic adaptability of rare eucalypt species. Data for 12 rare species were obtained from BGCI's PlantSearch database. Each species was recorded in between 11 – 28 gardens. The scientific paper describing the study will be published shortly (Booth, in press). To illustrate the method here we consider just one species, *Eucalyptus kruseana* F. Muell (Bookleaf Mallee). This is a small bushy multi-stemmed tree, with a limited natural distribution mainly to the east and south-east of Kalgoorlie, in Western Australia. As this was an initial proof-of-concept study, the focus was on examining only annual mean temperature. More detailed studies would assess more climatic variables.

Natural distribution

The first step in the analysis was to examine the species natural distribution. This was carried out using the freely accessible Atlas of Living Australia (ALA, www.ala.org.au). The ALA contains more than 50 million records of species occurrence, as well as more than 400 spatial layers describing climatic,

[1]www.bgci.org/plant_search.php
[2]www.ala.org.au

substrate, topographic, social and vegetation data. An ALA-generated map showed 88 locations where *E. kruseana* grows in Australia. The natural distribution has been highlighted here and the scatterplot tool of the ALA used to show ranges of annual mean temperature and annual mean precipitation within the natural distribution (Fig. 1).

The ALA was used to zoom in and look at the natural distribution in more detail (Fig. 2). The main part of the natural distribution was found where the annual mean temperature ranges from 17.8-18.8ºC, but at two outlying locations annual mean temperatures were 19.5ºC and 19.9ºC. Outliers such as these are sometimes omitted in species distribution modelling studies, as they may be observations of cultivated specimens, misidentifications or data entry errors. Considering climatic conditions at locations clearly outside the natural distribution may lend credibility to conditions estimated for these outlying sites.

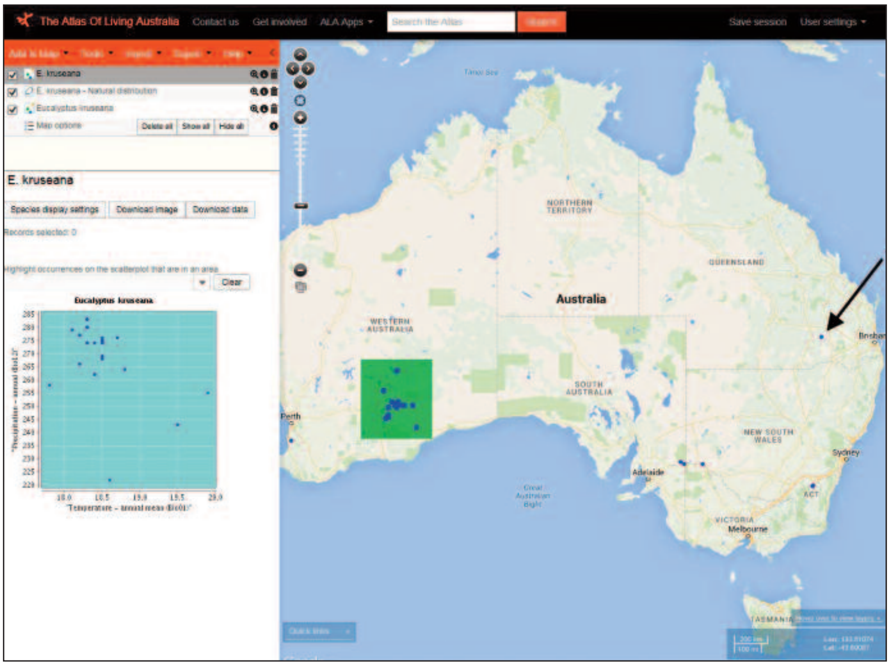

Fig. 1: E. kruseana *occurrence records in the ALA, including natural locations (in highlighted box) as well as cultivated locations in southern Australian and at the Myall Park Botanic Gardens in Queensland (indicated with an arrow). Map data: Google, ALA*

Fig 2: E. kruseana *natural distribution shown in greater detail. Arrows indicate outlying locations experiencing annual mean temperatures of 19.5ºC and 19.9ºC. Map data: Google, ALA*

Returning to the first ALA map (Fig. 1), a small number of cultivated locations were shown in southern Australia. However, only the Myall Park Botanic Garden location in Queensland (shown with the arrow) was of particular interest, as the annual mean temperature estimated for this location (20.2ºC) was warmer than any location within the natural distribution.

PlantSearch data

Latitude and longitude data from the PlantSearch database for 16 botanic gardens growing *E. kruseana* were entered into the ALA. Climatic conditions at these locations were estimated using the WORLDCLIM data included in the ALA and the scatterplot tool was used to examine the range of conditions for these sites. The scatterplot analysis showed that most botanic gardens were growing *E. kruseana* at similar or cooler annual mean temperatures to those in its natural distribution. However, a small number of locations in the United States, as well as the Myall Park Botanic Gardens in Australia already mentioned, were growing it at warmer annual mean temperatures up to 21.3ºC (Fig. 3).

Data from the literature

Only two of the 12 rare species assessed had any previously published descriptions from which information on their climatic tolerance, beyond that of their natural distributions, could be estimated. *E. kruseana* was one of these species, but information was only available from one site at Shushtar in the Khuzestan province of Iran (Abravesh *et al*. 2007). The annual mean temperature estimated by the ALA for this location was surprisingly high at 25.5ºC. However, the exact location of the trial site in relation to the town was not known, so the estimate may not be reliable.

Challenges

An important limitation to using ALA data for estimating the climatic requirements of rare species is that the accuracy of locational data for the natural distribution is intentionally obscured. That is the full accuracy is not provided, but is simplified in the case of *E. kruseana* to a 20 km grid, to protect the exact locations of this rare species. Fortunately, Australia is a relatively flat continent. So, if a reasonable number of observations are

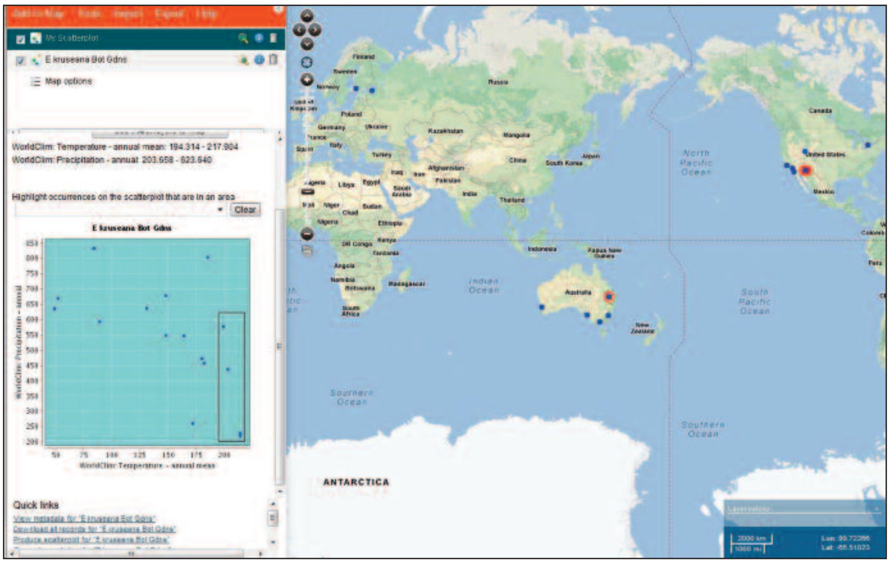

Fig. 3: E. kruseana *planted locations from PlantSearch database. Locations in box of scatterplot are warmer than those in the natural distribution and are circled in red with on the map. Map data: Google, ALA*

available, as was the case with *E. kruseana*, the scatterplot analysis can still provide a reasonable indication of the range of climatic conditions.

A particular limitation for Australian species is that there are relatively few botanic gardens in warmer environmental conditions than those experienced by many species in Australia. Using PlantSearch data may be more useful for plants from cooler countries and regions. These species would be likely to be growing at many more botanic gardens under warmer conditions than those in their natural distributions.

Using data from botanic gardens to infer climatic adaptability has several important limitations, which are discussed in detail in the Booth (in press) paper. The use of irrigation in botanic gardens is one of the main limitations. This may allow species to tolerate conditions somewhat warmer than they would otherwise be able to do. Similarly, planting locations within botanic gardens may be carefully chosen to suit particular species. The influences of particular slopes, aspects and positions on slope will not be captured by information about just the latitude, longitude and elevation of the site. Soil differences between natural locations and botanic gardens might also be considered to be a major problem, but an important concern for rare eucalypts is whether they can continue to grow under climate change where they are presently located. Soil conditions are not likely to be a major factor limiting survival at these existing sites under climate change, climatic adaptability is the key issue.

In view of the limitations of using data from botanic gardens it is suggested that if observations from warmer locations are few these should only be used to confirm climatic conditions at outliers within or near to the natural distribution that might otherwise be rejected. Data from botanic gardens are particularly valuable when other data relevant to climatic adaptability are either not available from other sources, such as commercial trials, or are very limited.

Opportunities

The Booth (in press) paper indicates that rare eucalypts do show some signs of climatic adaptability beyond the conditions found within their natural distributions. Overall, 11 of the 12 species assessed showed some signs of possessing climatic adaptability beyond that indicated by their natural distributions. In most cases the differences in annual mean temperatures were of several degrees Celsius. This suggests it may well be worth carrying out some more detailed analyses for some selected species, including studies of their genetic diversity as well as climatic adaptability.

Whether future climate change analyses prove to be helpful or not for rare species, systems such as the ALA may be very useful for botanic gardens for other purposes. For example, the ALA can help to provide information about conditions at the origins of particular specimens already growing in botanic gardens, as well as assisting the selection of potential new specimens that might be grown. An ALA-based system is already in operation in Spain (datos.gbif.es) and the Global Biodiversity Information Facility (GBIF) is supporting the development of similar systems in several other countries.

In summary, the exploratory analysis of the 12 rare eucalypts indicated that useful information can be obtained using PlantSearch and the ALA. However, the number of observations outside those of the conditions of the natural distribution were small, so considerable caution should be used in interpreting the data. More detailed studies would be useful and the establishment of trials to further explore the climatic adaptability of rare species may well be worthwhile.

Acknowledgements

Thanks to BGCI for providing access to the PlantSearch database and to the Atlas of Living Australia team. Thanks also to botanic garden managers (see Booth in press for full acknowledgements).

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Copies of the recent papers are available from Trevor Booth (Trevor.Booth@csiro.au). The 2015 paper is available now and the second will be available soon, but can be requested now.

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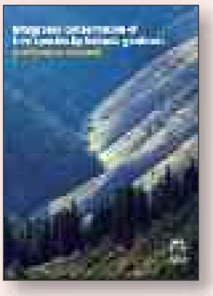
RESOURCES

Integrated conservation of tree species by botanic gardens: a reference manual
Oldfield, S. and Newton, A.C. 2012
Botanic Gardens Conservation International, Richmond, UK
ISBN: 978-1-905164-44-8



This reference manual has been developed to support the integrated conservation of threatened tree species by botanic gardens and arboreta. It is aimed at the staff and associates of the world's botanic gardens, and is designed to help the development, planning and implementation of conservation activities focusing on tree species. Botanic gardens are exceptionally well placed to make an important contribution in this area, as they have access to the skills and techniques to identify, cultivate and propagate a wide range of tree species. In addition, they hold important collections of living trees, seeds and other germplasm that can be of value in supporting both *in situ* and *ex situ* conservation efforts. This manual builds on *A handbook for botanic gardens on the reintroduction of plants to the wild* published by BGCI in 1995 and reflects the increasing imperative to restore and conserve damaged ecosystems. It draws on both the scientific literature and on practical experiences gained in tree conservation projects from around the world. The manual first briefly considers why tree species should be conserved and restored and how integrated approaches to conservation can be developed. A step-by-step guide is then provided to support the design and practical implementation of integrated conservation approaches. While this manual can only serve as a brief introduction to what is a large and complex subject, it is hoped that it will both facilitate and encourage botanic gardens and land management agencies to develop integrated conservation activities focusing on tree species.

A copy of this publication can be downloaded here: http://www.bgci.org/files/Worldwide/News/SeptDec12/tree_species_low.pdf

The State of the World's Forest Genetic Resources
Commission on Genetic Resources for Food and Agriculture
Food and Agriculture Organization of the United Nations, Rome, 2014
ISBN 978-92-5-108402-1 (print)
E-ISBN 978-92-5-108403-8 (PDF)

Published in 2014, this first report on the State of the World's Forest Genetic Resources addresses the conservation, management and sustainable use of forest tree and other woody plant genetic resources of actual and potential value for human well-being in the broad range of management systems. This report aims to help differentiate between the state of the world's forest resources (as reported in FAO's annual State of the World's Forests and the periodic Global Forest Resources Assessment) and the state of the genetic resources on which they depend for their utility, adaptability and health. The report indicates that about half of the forest species in the 86 reporting countries are threatened or subject to genetic erosion, and only about one-quarter are actively managed for their products and/or services. The report documents the value and importance of forest genetic resources (FGR) and looks at the current state of conservation *in situ* and *ex situ*. It also explores the drivers of change and trends affecting FGR and examines current and emerging trends in forest conservation and management. The report notes that the status of botanical knowledge varies from country to country. Very few countries have detailed tree species checklists that include species characteristics allowing distinction between different plant life forms, e.g. trees, shrubs, palms and bamboo. Furthermore information on the conservation status of species populations is not available in many countries. Among other recommendations, and of relevance to botanic gardens, the report calls for:

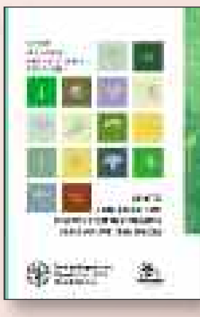
- The establishment and development of efficient and sustainable *ex situ* conservation systems
- Enhanced restoration and rehabilitation of ecosystems using genetically appropriate material
- Reinforcement of regional and international cooperation, including networking, to support education, knowledge dissemination, research, and conservation and sustainable management of FGR.
- Promotion of public and international awareness of the roles and value of FG

A copy of the report can be downloaded here: http://www.fao.org/3/a-i3825e.pdf

Genetic considerations in ecosystem restoration using native tree species. State of the World's Forest Genetic Resources - Thematic study.
Bozzano, M., Jalonen, R., Thomas, E., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Loo, J., eds. 2014.
FAO and Bioversity International, Rome. 2014
ISBN 978-92-5-108469-4 (print)
E-ISBN 978-92-5-108470-0 (PDF)

There is renewed interest in the use of native tree species in ecosystem restoration for their biodiversity benefits. Growing native tree species in production systems (e.g. plantation forests and subsistence agriculture) can also ensure landscape functionality and support for human livelihoods. Achieving full benefits, however, requires consideration of genetic aspects that are often neglected, such as suitability of germplasm to the site, quality and quantity of the genetic pool used and regeneration potential. This study provides fundamental information for the achievement of knowledge-based ecosystem restoration using native tree species. It draws attention to the importance of embedding genetic considerations in restoration activities, an aspect which is often overlooked both by restoration scientists and practitioners, but is nonetheless crucial to rebuilding resilient landscapes and ecosystems. The study includes a review and synthesis of experience and results; an analysis of successes and failures in various systems; and definitions of best practice, including genetic aspects. It also identifies knowledge gaps and needs for further research and development. Of particular relevance to botanic gardens is the fact that limited information and knowledge of native species biology and lack of appropriate planting material is a major constraint to the use of native species in restoration programmes. The report concludes with a series of recommendations to guide research, restoration practice and policy.

A copy of the report can be downloaded at: http://www.fao.org/3/a-i3938e.pdf



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