Strengthening the conservation value of tree collections for *ex situ* conservation

Moderator: Gerard Donnelly

The Morton Arboretum, Lisle, Illinois, USA

Abstract

With ten percent of the world's tree species threatened with extinction, there is an urgent need and opportunity for arboreta and botanical gardens to play a much more active role in supporting global tree conservation through *ex situ* collections. Although many threatened tree species are included in existing collections, genetic breadth is limited, which reduces the conservation value of the collections. This symposium of four complementary talks was designed to provide a comprehensive overview of *ex situ* conservation collections in botanical gardens. Moderated by Gerard Donnelly, President and CEO of The Morton Arboretum, the first presentation (Sara Oldfield) gave an overview of the process to assess the global threat to tree biodiversity, followed by an assessment of the conservation value of existing tree collections in botanical gardens and arboreta (William McNamara). Examples of best practices and models for *ex situ* tree conservation by botanical gardens were discussed (Sara Oldfield, William McNamara and David Rae). Finally, strategies were presented for arboreta and botanical gardens to strengthen the conservation value of tree collections in support of the Global Trees Campaign (Nicole Cavender).

Keywords

Arboretum, botanical garden, conservation collection, *ex situ* conservation, exceptional species, forest restoration, Global Trees Campaign, integrated conservation management

Developing integrated tree conservation approaches

Sara Oldfield

Botanic Gardens Conservation International, London, UK

Botanical gardens and arboreta hold very important tree collections of value for education, research and conservation. They also have invaluable skills in tree identification, propagation and maintenance. Realising the full potential for tree conservation will involve an integrated approach, with the goal being to restore populations of threatened species in the wild. When feasible, protecting threatened tree species by *in situ* conservation or seed banking are the ideal methods to prevent extinction, but for many threatened trees, especially exceptional species, *ex situ* conservation efforts are critical to ensure survival (Wyse Jackson & Sutherland, 2000; Kramer *et al.*, 2011; Pritchard *et al.*, 2011; Oldfield & Newton, 2012). Some helpful tools and resources available to gardens for the purpose of tree conservation are presented in the BGCI publication *Integrated Conservation of Tree Species by Botanic Gardens: A Reference Manual* (Oldfield & Newton, 2012), together with pertinent case studies.

In order to take the first step towards implementing tree conservation activities, it is important to identify and prioritize target tree species based on their level of threat. An invaluable tool for this process is the IUCN Red List system and other national, regional, local, or taxon-specific threatened species lists. Examples of publications that have collated information on threatened trees include *Temperate Trees Under Threat* (Hunt, 1996), *1997 IUCN Red List of Threatened Plants* (Walter & Gillett, 1998), and *The World List of Threatened Trees* (Oldfield *et al.*, 1998). Currently the IUCN Red List uses a combination of information to assess species, including literature review, database mining (eg. GBIF), range mapping, and consulting expert opinion. Botanic Gardens Conservation International (BGCI) is integral to the compilation of these lists

through facilitating the IUCN Global Trees Specialist Group, which includes many of the world's tree experts. The IUCN defines categories of threat for species based on various criteria, such as the extent of population reduction, geographic range size, and limited population size. If the criteria reach certain quantitative thresholds, the species falls into one of the threatened categories:

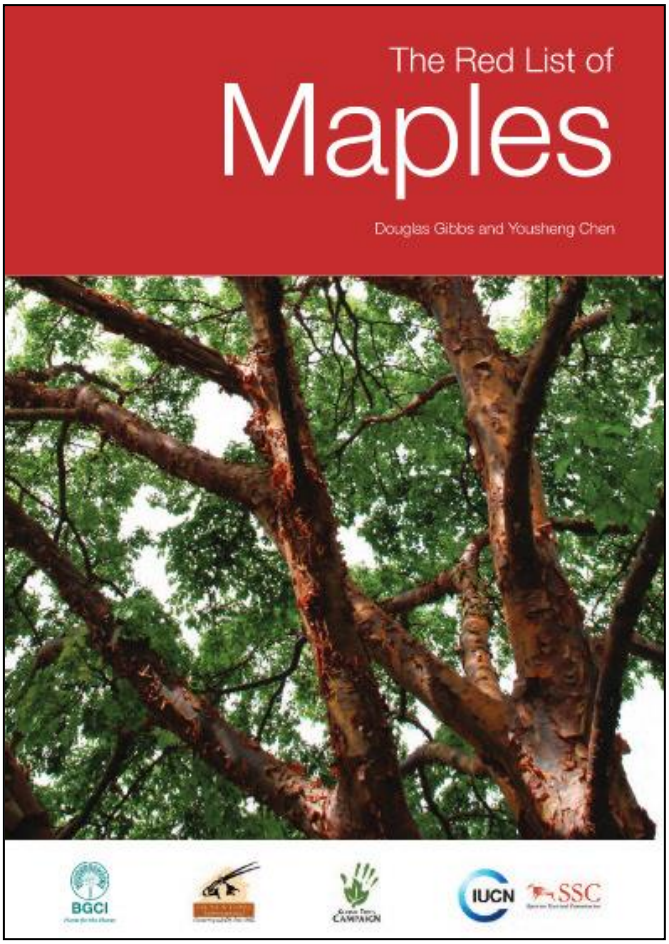

Figure 1:An example of a taxon-specific listing: *The Red List of Maples*.

Critically Endangered (CR), Endangered (EN), or Vulnerable (VU; Figure 1).

As of 2013, the IUCN Red List had assessed 18,719 plant taxa and determined that 12,006 were threatened (including extinct in the wild and data deficient species). Of these plant taxa assessed, 9,553 were woody species and 6,856 of these woody species were determined to be threatened. As not all of the data from the various taxon-specific and national, regional and local threatened species lists have been incorporated into the IUCN Red List yet, this number is likely to be a substantial underestimate of the true number of threatened trees. These threat lists can be used to identify diversity hotspots, monitor climate change impacts, raise public awareness, and prioritize tree species for conservation based on various factors such as threat level, geographic range, taxonomy, or economic value.

It is important to move from threatened species identification towards purposeful conservation action. Botanic gardens and arboreta are the most valuable agents to implement *ex situ* conservation of threatened trees because of their institutional botanical and horticultural knowledge, established tree collections, and ability to conduct tree science and research. BGCI is working to support and promote tree conservation in botanic gardens, as well as *in situ* conservation and education efforts in the native habitats of threatened tree species, a combination of conservation approaches that is known as "integrated conservation management". BGCI administers its tree conservation efforts, through The Global Trees Campaign, a joint initiative

between BGCI and Fauna & Flora International to secure the future of the world's threatened tree species. The Global Trees Campaign was launched in 1999 and works by directly supporting tree conservation programmes, building capacity for organizations to protect trees, and promoting the conservation of trees to local communities, governments, conservation groups, and the forestry sector.

A recent publication by BGCI, *Integrated Conservation of tree species by botanic gardens: a reference manual* (Oldfield & Newton, 2012) is an authoritative guide for gardens to implement not just *ex situ* conservation measures, but also *in situ* approaches for securing the future of threatened trees. This publication highlights case studies that botanic gardens can use as models for effective tree conservation. One interesting case study involves a project, which is being part-funded by BGCI (through the UK-based Ashden Trust), that aims to restore indigenous forests in East Africa. The East African forest restoration project focuses on two recently established botanical gardens: Brackenhurst Botanic Garden in Kenya and Tooro Botanic Garden in Uganda. This project is important to tree conservation because of the rampant deforestation happening in East Africa and the wide gap in the botanical knowledge of indigenous tree species in that region. The latest Forest Resources Assessment (FRA) found that of the approximately 675 million ha of forest cover in Africa, 3.4 million ha are being lost annually to logging, clearing for agriculture, and fuel wood harvest. The IUCN Red List includes 1,568 conservation assessments of tree species native to Africa, with 1,161 assessed as threatened. The reforestation projects happening in the two model botanical gardens involve procuring and planting native tree species, managing invasive species, educating the local communities on the value of native tree species, and promoting sustainable use of native tree forest products. The goal for this project is to inspire other botanical gardens and local governments to use native species in reforestation projects and to influence the direction of future land-use policy decisions. Towards this end, a workshop was held in Uganda in July 2013, which brought together many of the key players and stakeholders in the region for insightful discussions on the benefits of indigenous reforestation projects. BGCI is also collecting information on native tree species held in African botanic garden collections that have potential for restoration using the PlantSearch database. This project will ultimately help develop new partnerships and explore opportunities to expand the initiative across Africa.

References

Hunt, D. (ed.). (1996) *Temperate trees under threat*. International Dendrology Society, Kington, UK.

Kramer, A., Hird, A., Shaw, K., Dosmann, M. and Mims, R. (2011). *Conserving North America's threatened plants: Progress report on Target 8 of the Global Strategy for Plant Conservation*. Botanic Gardens Conservation International US.

Oldfield, S., Lusty, C. and MacKinven, A. (1998). *The world list of threatened trees*. World Conservation Press, WCMC, Cambridge, UK.

Oldfield, S. and Newton, A.C. (2012). *Integrated conservation of tree species by botanic gardens: a reference manual*. Botanic Gardens Conservation International, Richmond, UK.

Pritchard, D.J., Fa, J.E., Oldfield, S. and Harrop, S.R. (2011). Bring the captive closer to the wild: redefining the role of *ex situ* conservation. *Oryx* 46 (1): 18-23.

Walter, K.S. and Gillett, H.J. (eds.). (1998). *1997 IUCN red list of threatened plants*. IUCN, the World Conservation Union, Cambridge, UK.

Wyse Jackson, P.S. and Sutherland, L.A. (2000). *International agenda for botanic gardens in conservation*. Botanic Gardens Conservation International, Richmond, UK.

Making our Collections more valuable: a case study from Quarryhill BG's *ex situ* conservation programme

William McNamara

Quarryhill Botanical Garden, Glen Ellen, California, USA

While many botanical gardens and arboreta include *ex situ* conservation in their mission statements and interpretation displays, few of these institutions are involved in effective *ex situ* conservation activities that will actually save threatened tree species from extinction. In reality, most institutions typically have just a few, and often only one individual, of a plant species they hope to conserve, and these individuals may have little or no provenance information. For example, of 29 globally endangered oak taxa, a survey found that only 13 were represented in collections, by just 91 records. In another study, Dosmann and Del Tredici (2003) showed that 45% of the remaining living collections from the 1980 Sino-American Botanical Expedition were represented by a single accession growing in a single location. These lone, often poorly curated, specimens are of little real conservation value when it comes to sourcing genetically diverse and representative germplasm for future reintroductions of a threatened species. Limited resources and available space pose additional challenges for gardens that wish to hold sufficient specimens to represent adequate genetic diversity, especially for trees. Poor or non-existent provenance data for collections, open pollination, and selection issues also limit viable *ex situ* conservation programmes.

The Database of Asian Plants in Cultivation (DAPC), a searchable database maintained by Quarryhill Botanical Garden, to which other institutions can upload their collection data, provides an additional opportunity to assess the conservation value of *ex situ* collections. Many of the largest and most prestigious botanical gardens and arboreta in the world have uploaded their collections data to this database. Using taxa-specific Red Lists published by the IUCN-SSC Global Trees Specialist Group (in collaboration with BGCI and FFI), the critically endangered and endangered species of the genera *Acer* and *Magnolia* were examined to determine what proportion were cultivated by botanical gardens and arboreta, according to DAPC. The results are not encouraging for effective conservation. Of seven critically endangered *Acer* taxa, only one (*Acer pentaphyllum*) is in cultivation in any of the 28 DAPC registered botanical institutions. Of 19 endangered *Acer* taxa, only three are cultivated in DAPC institutions. For *Magnolia* taxa, the outlook is worse, although it should be noted that many of the critically endangered and endangered species of *Magnolia* are subtropical, so they are unlikely to be maintained in the DAPC botanical gardens and arboreta, as most of them are in temperate climates. Nevertheless, of the 31 critically endangered *Magnolia* taxa, only one (*Magnolia zenii*) is in cultivation at a DAPC institution. Of the 58 endangered *Magnolia* taxa, only three are in cultivation, one of which is represented by as few as six individual specimens spread throughout three different institutions. For the four threatened *Magnolia* species in cultivation, only between 22–66% of the individuals are of wild origin. These results show that, in practice, very few of the threatened species currently held in *ex situ* collections are actually being effectively curated for the purpose of species conservation. With the prevalence of depauperate conservation collections in mind, the Quarryhill Botanical Garden took action to ensure that one critically endangered maple species, *Acer pentaphyllum*, would be protected from extinction.

First introduced to the west by Joseph Rock in 1929, *Acer pentaphyllum* is a beautiful, critically endangered maple tree native to western Sichuan, China. Since 2001, several expeditions led by Quarryhill botanists have discovered three relict populations of less than 200 trees along a roughly 100km stretch of the Yalong Jiang river valley. The trees are plagued by heavy grazing from livestock and eroding soil from the construction of a road. There is imminent threat to the entire species from the ongoing construction of a power plant and its associated dam project which will eventually flood the valley and submerge every remaining population.

Figure 1: *Acer pentaphyllum* in the wild and the *A. pentaphyllum* conservation grove of 200 plants at the Quarryhill Botanical Garden

In light of the imminent threat to the remaining wild *A. pentaphyllum* populations, an ambitious *ex situ* collection strategy was launched by Quarryhill which involved planting a conservation grove of 200 individuals from 17 wild-collected accessions. This conservation grove is now the largest population of *A. pentaphyllum* in the world. The trees in the conservation grove are carefully monitored so that botanists can learn more about the growth, development, and reproductive ecology of the species. Tree scientists are also conducting a variety of ecological experiments on the collection, such as testing different mycorrhizal treatments to optimize growth conditions. *A. pentaphyllum* is extremely late to flower in California, so the trees in the conservation grove are unlikely to hybridize with other maples in the garden, making the conservation grove resistant to genetic contamination by other species. The *A. pentaphyllum* conservation grove is a powerful research tool for botanists and tree scientists to understand the biology of this critically endangered species. The grove also contributes to conservation education for the general public, and it will provide the genetically diverse germplasm for eventual seed banking and repatriation of this species to its native habitat in Sichuan, China. Staff from Quarryhill Botanical Garden are working with local officials and the community around the wild populations in Sichuan to promote *in situ* protection of *A. pentaphyllum*. However, the impending dam project that will flood the river valley means there is little hope for *in situ* protection of this species. The Quarryhill conservation grove is the only chance for the survival of this species and its future reintroduction to China.

References

Dosmann, M. S. and Del Tredici, P. (2003). Plant introduction, distribution, and survival: a case study of the 1980 Sino-American Botanical Expedition. *BioScience* 53:588-597.

The International Conifer Conservation Programme: an effective network for safe-guarding threatened conifers

Martin Gardner and David Rae

The Royal Botanic Garden, Edinburgh, UK

Recently the second global assessment of conifers was undertaken, using the 2001 IUCN criteria version 3.1, with 211 (34%) of the world's 615 conifers assessed as threatened, a 4% increase since the first global assessment. To address the impending biodiversity crisis facing conifers, the International Conifer Conservation Programme (ICCP) was established at the Royal Botanic Garden, Edinburgh, in 1991. The ICCP was an early pioneer of the practice of *integrated conservation management*, employing a combination of conservation techniques including scientific research, public education, horticulture, and *ex situ* and *in situ* conservation measures to prevent the extinction of threatened species.

One of the most innovative and successful conservation strategies implemented by the ICCP was its network of partner "safe sites" for *ex situ* conservation of the world's most threatened conifers; for many conifers, *ex situ* conservation in safe sites may be the best or only method for conserving the few remaining genotypes before their native habitats are destroyed. Networking with carefully chosen partner sites is a prerequisite for the effective *ex situ* conservation of large growing trees such as conifers, where there is often insufficient space to maintain a large population in a single garden location. Safe sites are chosen by the ICCP based on a series of criteria. Ideally, a safe site should have institutional longevity, staff with horticultural expertise, a location conducive to growing conifers, good public access, and owners with a genuine interest in conservation. The list of partner safe sites includes public parks and gardens, private estates, UK Forestry Commission land, golf courses, hotel and hospital grounds, botanical gardens, and even a monastery in Ireland. The ICCP provides the wild-collected plants and labels for the conservation collection at the safe site and encourages the partner institution to install interpretive displays to educate the local community about the importance of conifer conservation. Once a conservation collection has been established at a safe site, botanists and tree scientists from the ICCP conduct regular monitoring and research on the conservation collection by recording growth rates and phonological observations and documenting the collection through photographs, herbarium specimens and DNA samples. The safe site programme has been extremely successful, cultivating over 13,500 plants from 180 species (70% of which are threatened) in 200 different safe site locations (Table 1). The ICCP is also collaborating with the Montgomery Botanical Center, a conservation-focused garden in the southeastern United States that is able to grow and distribute tropical conifers to a network of tropical safe sites in the US.

A second programme recently implemented by the ICCP, the iCONic Project (**I**nternationally **T**hreatened **CON**ifers **I**n our **C**are), is in partnership with the Forestry Commission Scotland. The iCONic Project aims to draw attention to the many stately, ancient conifers growing at high profile historic sites in Scotland, such as castles and cathedrals. These sites are popular tourist attractions that provide an opportunity to engage the public through high quality interpretation displays, thus raising public awareness of conservation issues. A third ICCP programme underway at the Royal Botanic Garden, Edinburgh, is the planting of a yew hedge around the entire perimeter of the garden. The conservation hedge will consist of many accessions of *Taxus baccata* from across its entire geographic range in Europe, as well as a selection of heritage yews from around Britain. In another project partnering with the Forestry Commission, the ICCP is managing a variety of research programmes investigating propagation techniques for germinating seeds of certain conifers that are rare and/or particularly difficult to cultivate, such as *Amentotaxus formosana*. To ensure the wide dissemination of the results of these studies, the propagation protocols are published in *Sibbaldia*, the horticultural journal of the Royal Botanic Garden, Edinburgh.

Species	No. of sites	No. of accessions	No. of individuals
Araucaria araucana	43	155	1125
Fitroya cupressoides	64	74	293
Pilgerodendron uviferum	43	59	325
Podocarpus salignus	59	52	529
Prumnopitys andina	55	59	325

Table 1: Five examples of threatened conifers protected in "safe site" conservation collections through the ICCP

.

Collaboration and partnership with a wide variety of public and private gardens is the foundation of the ICCP strategy. The benefits of this far-reaching, well-managed network system are numerous, but key among them are a wider choice of growing sites and habitats, the ability to grow an exponentially greater number of trees, spreading the risk of local loss of trees, an increased opportunity to engage the public, increased research opportunities, and a stronger case for funding applications. The success of this carefully managed network shows that a similar protocol could be adopted for other groups of plants instead of the *ad-hoc* collection method normally employed in botanical collections. Where possible, integrating *ex situ* with *in situ* conservation is essential although this may be difficult to put in to practice for some smaller gardens.

References

Rae, D. and Gardner, M.F. (1993). The Conifer Conservation Programme - an overview. *Scottish Forestry* 47(40):175-182.

Gardner, M.F. (1999). Managing *ex situ* conifer conservation collections. In*:* S. Andrews, A.C. Leslie and C. Alexander (Eds). *Taxonomy of Cultivated Plants: Third International Symposium*, pp. 19-23. Royal Botanic Gardens, Kew.

Gardner, M.F. (2003). The International Conifer Conservation Programme. Acta Horticulturae (ISHS) 615: 405-409.

A path to the future: challenges and practical approaches for strengthening *ex situ* conservation efforts for trees

Nicole Cavender

The Morton Arboretum, Lisle, Illinois, USA

The concept of botanical gardens participating in *ex situ* plant conservation is not new. From the first International Congress for Nature Protection held in Paris in 1923, to the adoption of the Global Strategy for Plant Conservation (GSPC) by the Parties to the Convention on Biological Diversity (CBD) in 2002, gardens have acknowledged the need to protect threatened plant species in *ex situ* collections for decades. Many organizations and working groups are actively involved in directly or indirectly supporting *ex situ* tree conservation, such as the IUCN/SSC Global Trees Specialist Group (responsible for compiling the Red List publications), the Center for Plant Conservation (a network of botanical gardens that coordinates species-specific conservation plans), BGCI, and the Global Trees Campaign. The botanical garden community also has several policy frameworks, strategic plans, and practical guides that help to inform conservation action, such as the GSPC (Convention on Biological Diversity, 2002; 2010), the *International Agenda for Botanic Gardens in Conservation* (Wyse-Jackson & Sutherland, 2000; BGCI, 2012), *Integrated Conservation of Tree Species by Botanic Gardens* (Oldfield & Newton, 2012), *Ex situ Plant Conservation: Supporting Species Survival in the Wild* (Guerrant Jr. *et al.*, 2004), and *Plant Reintroduction in a Changing Climate: Promises and Perils* (Maschinski & Haskins, 2012). Despite these helpful resources, as the other three presentations in this symposium have shown, there is a clear and urgent need for arboreta and botanical gardens to do more to protect threatened trees and to improve the conservation value of their *ex situ* collections.

To better understand the complicated issues surrounding *ex situ* tree conservation in arboreta and botanical gardens, The Morton Arboretum initiated a series of interviews with nearly twenty of the world's most influential botanists, garden directors, and tree conservationists. During these interviews, the tree experts were asked their opinions on questions such as:

- What are the greatest challenges faced by gardens with respect to tree conservation?
- What are the greatest assets gardens can provide for tree conservation worldwide?
- How should gardens prioritize which tree species to protect, given the high number of threatened taxa and lack of information on many species' threat status?
- How should the conservation value of an *ex situ* collection be measured?
- What are some examples of *ex situ* and *in situ* tree conservation projects that can be used as good models for gardens to follow?
- Who else can gardens can work with to achieve tree conservation goals?
- What is the ONE change that could strengthen the ability of gardens to do effective *ex situ* tree conservation?

Based on the responses of the experts, a list of challenges faced by gardens for effective *ex situ* tree conservation was identified; they included lack of focus (e.g. conservation not in garden mission), lack of information (e.g. species lists, threat level, distribution maps), collection management limitations (e.g. large size of trees, genetic drift, allele attrition), lack of capacity and resources (e.g. shrinking number of universities offering botany degrees), ineffective coordination between institutions, and poor public and/or governmental awareness of and interest in conservation issues. This list is can provide a starting point for gardens to self-assess strengths

and weaknesses and then prioritize areas to address. Furthermore, the botanical garden community should consider how to overcome these challenges when drafting policies, designing conservation strategies, and forming collaborations and working groups.

How to prioritize tree species for *ex situ* conservation efforts was a topic that generated a variety of responses from the tree experts. Several factors were considered particularly important when prioritizing threatened trees, such as their level of endangerment, economic value, ecological value, degree of endemism, and phylogenetic position. One characteristic that was considered particularly important by the tree experts was whether or not a species could be preserved through conventional seed banking methods of low humidity and freezing temperatures. Those species whose seeds cannot be seed banked, or species that are no longer producing viable seeds in the wild, are considered "exceptional" and should be the highest priority for *ex situ* conservation in living collections. Once a species has been chosen as highest priority for *ex situ* conservation, a garden must decide how to measure the conservation value of its *ex situ* collection. There were many suggestions from the interviewed experts on how to do this, but the common opinion was that high value conservation collections must be well-documented and curated, and be composed of as many wild-collected individuals from as many maternal lines as possible, given the space and resources available to the garden.

The results of these interviews form a powerful tool to identify gaps in knowledge and resources, and suggest steps at many different levels that gardens of all sizes may implement to improve tree conservation efforts. Ultimately, the goal of this exercise is to promote and unify the conservation mission of the garden community and to provide a set of practical, achievable recommendations that individual gardens can implement to protect trees from extinction. An in-depth analysis of the state of *ex situ* tree collections, based on the compiled interviews of tree experts and the presentations from this symposium, with recommendations for how to move forward as a community of public gardens, will be described in a future publication that is currently in preparation. Briefly, the recommendations for improving the conservation value of *ex situ* collections include:

- Consider knowledge base and institutional capacity when prioritizing tree species for conservation
- Be opportunistic when collecting germplasm in the wild
- Integrate conservation strategies (think beyond just the living collection)
- Evolve the collection mentality to recognize the need for high-value conservation collections
- Use published threat lists but also rely on expert opinion when prioritizing tree species
- Champion BGCI and the Global Trees Campaign
- Articulate an easy to comprehend conservation strategy
- Develop reasonable and achievable objectives
- Develop more integrated research
- Strengthen links with academia
- Recognize the achievements of colleagues and collaborators
- Increase capacity and network with small gardens

- Train others to carry on the work
- Improve and focus interpretation to engage the public with inspirational stories
- Improve collaboration between gardens of all sizes and build a global network.

As part of its initiative to provide leadership in international tree conservation efforts, The Morton Arboretum is implementing two innovative programmes focused on improving collaboration and building a global network of botanical gardens and arboreta:

- Firstly, the Center for Tree Science is a strategic initiative to facilitate collaboration, integrate the many dimensions of tree science research, and enable researchers to more efficiently address important research questions. As traditional funding sources for tree science decline, the Center seeks to facilitate collaborations that allow researchers to increase their collective achievements to raise capital. The Center will generate new knowledge and provide training opportunities for the next generation of tree scientists. A main focus of the Center is to address some of the challenges gardens face when working to protect populations of threatened tree species. Among the outcomes of this initiative will be effective models of integrated conservation, greater cross-institutional collaboration, and more training opportunities for tree scientists.

- The second programme developed by The Morton Arboretum that will support international tree conservation is ArbNet. ArbNet is an interactive community of arboreta that fosters professionalism and builds up the global botanical garden network, facilitating collaboration between tree-focused gardens in scientific, collections, or conservation activities. ArbNet produces and centralizes a vast array of resources on its website (www.arbnet.org) for arboreta and tree-focused botanical gardens, including how-to guides, publications, conservation targets, policies, case studies, and an interactive discussion forum. ArbNet also administers an arboretum accreditation programme that recognizes four different levels of achievement based on specified criteria of professional practice. Profiles of the 80+ officially accredited arboreta, as well as the Morton Register of Arboreta, can be found on the ArbNet website. Through this network, gardens can identify future collaborators for conservation projects, for example other gardens that focus on a similar taxonomic group or geographic region. ArbNet could also facilitate institutional partnering as “safe sites” for *ex situ* tree collections, like the programme pioneered by the ICCP (see above). The CTS and ArbNet represent complementary strategic initiatives by The Morton Arboretum to build capacity and improve resources for conservation-focused gardens to contribute to the global effort to prevent the loss of tree biodiversity.

References

BGCI. (2012). *International agenda for botanic gardens in conservation: 2nd edition*. Botanic Gardens Conservation International, Richmond, UK.

CBD. (2002). *Decision VI/9 Global Strategy for Plant Conservation*. Conference of the Parties to the Convention on Biological Diversity.

CBD. (2010). *Global Strategy for Plant Conservation: Technical rationale, justification for updating and suggested milestones and indicators (UNEP/CBD/COP10/19).* Conference of the Parties to the Convention on Biological Diversity.

Guerrant, E.O. Jr., Havens, K. and Maunder, M. (eds.). (2004). *Ex situ plant conservation: supporting species survival in the wild*. Island Press, Washington, D.C., USA

Maschinski, J. and Haskins, K.E. (eds.). (2012). *Plant reintroduction in a changing climate: promises and perils*. Island Press, Washington, D.C, USA

Oldfield, S. and Newton, A.C. (2012). *Integrated conservation of tree species by botanic gardens: a reference manual*. Botanic Gardens Conservation International, Richmond, UK.

Sharrock, S. (ed.). (2012). *A guide to the GSPC: all the targets, objectives and facts*. Botanic Gardens Conservation International, Richmond, UK.

Wyse Jackson, P.S. and Sutherland, L.A. (2000). *International agenda for botanic gardens in conservation*. Botanic Gardens Conservation International, Richmond, UK.

Conclusion

Gerard Donnelly

Arboreta and botanical gardens must face the challenges of safeguarding threatened trees. While recognizing the limitations of *ex situ* collections for conservation, the significant role they play in preventing extinction must not be undervalued. *Ex situ* tree conservation presents grand logistical, practical, and scientific challenges. Long-term seed storage, although cost-effective and efficient, is not possible for "exceptional species" and has other limitations. While other preservation techniques are in development, living collections remain vital. Trees are long-lived and require large amounts of limited collections space. Most living tree collections lack significant genetic diversity for species of conservation concern. Fundamental biological research is limited for many trees, and many threatened populations are poorly understood. Much knowledge, however, has been acquired. Red lists have been developed, collections databases are more accessible, models are being developed to guide genetic management of *ex situ* collections, and integrated efforts for tree conservation are being mobilized. As we move forward as a more coordinated community, opportunities and practical steps emerge that can enable both large and small gardens to strategically contribute to tree conservation and improve the conservation value of their collections. Further cooperation and work will be necessary to fill gaps in knowledge, determine best practices, and take strategic action to save more of the world's trees from extinction.