ASSESSING BOTANIC GARDENS’ SUPPORT FOR INTEGRATED PLANT CONSERVATION - WITH FOCUS ON SPECIFIC THREATENED MAGNOLIA TAXA (MAGNOLIACEAE)

by

Martin Smit

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Public Horticulture

Summer 2013

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ON SPECIFIC THREATENED MAGNOLIA TAXA
(MAGNOLIACEAE)

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Martin Smit

Approved: _________________________________________________________
Robert E. Lyons, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: _________________________________________________________
Blake Meyers, Ph.D.
Chair of the Department of Plant and Soil Sciences

Approved: _________________________________________________________
Mark Rieger, Ph.D.
Dean of the College of Agriculture and Natural Resources

Approved: _________________________________________________________
James G. Richards, Ph.D.
Vice Provost for Graduate and Professional Education
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ABSTRACT

Magnoliaceae is one of three unrelated Angiosperm plant groups identified as top priorities for conservation research by Botanic Gardens Conservation International (BGCI) and its research partners. The focus for these flagship groups is to compare the genetic representation of ex situ collections with in situ populations, to inform and prioritize conservation efforts. Research has shown that only 39% North America’s threatened plants are held in ex situ collections with most taxa only represented in one or two collections. Very little is known, however, about the current use and representativeness of ex situ collections and botanic gardens and other interest groups’ involvement in integrated plant conservation efforts.

Three Magnolia taxa native to the USA and Mexico were used as case studies, specifically Magnolia macrophylla var. ashei, M. macrophylla var. dealbata and M. fraseri var. pyramidata. Institutions keeping germplasm were identified via BGCI’s PlantSearch database. Data were collected using an online survey and follow-up communication with institutions to gauge support for integrated plant conservation.

Overall results indicated that relatively few collections (11-40%) had wild-collected accessions, with wild-collected material only representing a minority of the remaining wild populations of these taxa. Few institutions (6–26%) interpreted these threatened taxa for visitors and fewer institutions (2-13%) displayed the conservation
status. Current and past involvement in wild-collecting efforts was also low (13–20%). Alarmingly few institutions were involved in any in situ conservation efforts such as monitoring of wild populations or habitat preservation/restoration efforts (0–7%). Other observations included insufficient recordkeeping and apparent disparities between institutions’ self-stated conservation mission and their willingness to get involved in integrated conservation efforts for these taxa already in their collections. The results of this and similar studies suggest that much work is needed if Target 8 of the Global Strategy for Plant Conservation (GSPC) is to be reached by 2020.
Chapter 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Biodiversity Conservation and Botanic Gardens

Considering the current global decline in biodiversity, compounded by aspects such as climate change, the contributions to plant conservation by botanic gardens and other conservation organizations have never been as critical (Hawkins et al. 2008). It is estimated that approximately one third of all plant species is threatened with extinction (Pitman and Jorgensen 2002). Worldwide, botanic gardens are reviewing their policies and increasing their capacity to support conservation, yet botanic gardens and seed banks still remain mostly underutilized conservation resources (Hurka 1994, Maunder et al. 2001a, Maunder et al. 2001b). A study by Myers et al. (2000) found that the available global conservation resources were not sufficient to adequately support the number of plant species threatened with extinction, emphasizing the need for greater efforts from botanic gardens to make efficient use of their resources to support integrated plant conservation.

The Global Strategy for Plant Conservation (GSPC), first adopted by governments worldwide in 2002, aims to stem the current loss of plant diversity through the achievement of conservation targets. Target 8 of the GSPC calls for at least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs by 2020 (Oldfield 2012). A report by Oldfield (2010) states that only 30% of the world’s threatened plants are represented in botanic garden’s living collections still far short of Target 8. Another study revealed that while
more than 39% of North American threatened plants are held in ex situ collections globally, the majority of these taxa are only represented in only one or two collections (Kramer et al. 2011). Studies have shown that most ex situ collections in botanic gardens are limited in their use for in situ applications for a variety of reasons including lack of genetic diversity (Hurka 1994, Maunder et al. 2001a, Maunder et al. 2001b). The current lack of species diversity and the inadequate knowledge about genetic representation in ex situ collections does not bode well if Target 8 is to be realized by 2020.

1.2 Why Magnoliaceae?

Magnoliaceae is one of three unrelated Angiosperm plant groups (namely Cactaceae, Hydrangea and Magnoliaceae) identified by BGCI and its research partners as top priorities for conservation and genetic research. The focus for these flagship groups is to compare genetic diversity between in situ populations and ex situ collections, to inform and prioritize integrated plant conservation efforts (Cires et al. 2013). Magnoliaceae taxa are also often utilized for timber, food, and ornamental uses as well as their medicinal properties (Hahm et al. 2008, Cutierrez and Vovides 1997, Moerman 1986), further supporting their conservation priority.

For Magnoliaceae essential baseline research has also been conducted. The Red List of Magnoliaceae (Cicuzza et al. 2007) and the Global Survey of Ex Situ Magnoliaceae Collections (BGCI 2008) were released in 2007 and 2008, respectively. It has also received much attention in taxonomic research, including the use of molecular systematics (Azuma et al. 2001; Kim et al. 2001, Nie et al. 2008) as well as more traditional morphological analysis techniques (Li and Conran 2003, Figlar and Nootenboom 2004). More recently a
gap analysis was completed that provides a critical overview of recent conservation and research activities carried out in the genus *Magnolia* throughout the world, focusing on genetic diversity analyses of different taxa (Cires et al. 2013).

According to *The Red List of Magnoliaceae* (Cicuzza et al. 2007), 89 taxa are listed as Critically Endangered or Endangered and more than half of the current known taxa are threatened globally. During BGCI’s 2008 survey of global *ex situ* Magnoliaceae collections, 2,274 records from 238 institutions in 47 countries were identified. However, only 362 records representing 37 of the most threatened Magnoliaceae taxa could be located. This means that more than half of the Critically Endangered or Endangered Magnoliaceae taxa are not found in cultivation (BGCI 2008). More recently a study found that just over 30% of the most threatened Magnoliaceae taxa (CR, EN and VU categories, Table 2) are found in at least one at least one collection (Cires et al. 2013). Despite these studies, relatively little information exists about the source and size of existing *ex situ* Magnoliaceae collections and their potential value to restoration and recovery action (BGCI 2008). Many threatened Magnoliaceae taxa are located in countries with limited capacity to initiate and sustain conservation projects (Figure 1). The regions of most concern are Latin America and the Caribbean, which have the greatest number of threatened *Magnolia* taxa not currently represented in *ex situ* collections (BGCI 2008). This distribution of threatened Magnoliaceae taxa highlights the need to build international collaborative efforts to support conservation. Some of the current threats to the survival of these taxa in the wild include habitat destruction, low natural regeneration, and overharvesting for timber and medicinal uses (Cires et al. 2013).
Several studies have shown that Magnoliaceae taxa are not considered ideal for long-term seed banking efforts, as the seed is generally considered recalcitrant (Fernando et al. 2011, Kha et al. 2005). The inability to currently preserve seed of Magnoliaceae emphasizes the importance of creating and maintaining ex situ living collections that can support in situ applications.

Several stakeholders such as the Magnolia Society International (MSI), Botanic Gardens Conservation International (BGCI), dozens of botanic gardens, conservation organizations and other interest groups are currently discussing the formation of a Global Consortium for the Conservation of Magnoliaceae. This seems an ideal platform to promote integrated plant conservation efforts. The aim of the proposed Consortium will be to engage, build and utilize ex situ collections of Magnoliaceous germplasm to support research, education and outreach, and in situ conservation efforts (Bunting 2012).

In order to support the possible creation of a Global Consortium for the Conservation of Magnoliaceae, the objectives of the current study were to: assess the current contributions of botanic gardens for the integrated conservation of Magnoliaceae and to inform future collaborative plant conservation efforts.
Figure 1. Magnoliaceae taxa in the Red List per country. CR: Critically Endangered; EN: Endangered; VU: Vulnerable; NT: Near Threatened; LC: Least Concern; DD: Data Deficient; NE: Not Evaluated (Adapted from Cires et al. 2013)
1.3 **Integrated Plant Conservation**

The traditional idea that botanic gardens simply act as repositories for cultivated specimens of threatened species is no longer appropriate (Havens *et al.* 2006). With the intensifying need for conservation of threatened species and the growing social, economic and legal complexities surrounding conservation efforts, botanic gardens are slowly moving away from the so-called “ark paradigm”. It is now clearer than ever that integrated models for plant conservation need to be employed for successful species recovery to occur (Havens *et al.* 2006, Maunder *et al.* 2004).

Integrated plant conservation acknowledges that a single approach such as legal protection for a species or the acquisition of land is unlikely to be successful, given the variety of threats to biodiversity (Falk 1990). International policies, combined with the growing understanding of the limitations of more traditional conservation techniques, are bringing about changes in how botanic gardens approach conservation. It is now considered vital that conservation efforts:

- address all levels of biological organization and not just species diversity,
- be developed with all threats or impacts taken into consideration,
- employ the full spectrum of conservation resources both *in situ* and *ex situ* (Falk 1990, Maunder *et al.* 2004).

Integrated plant conservation therefore includes both *in situ* and *ex situ* actions, linked by restoration and collection, to support long-term species survival (Figure 2). Feeding into this process and in so doing increasing the success of conservation are research, horticulture and education efforts (Oldfield and Newton 2012, Kramer *et al.* 2011). Integrated plant conservation addresses all aspects related to plant conservation and touches each of the 16 GSPC targets.
1.3.1 *Ex situ conservation*

It is recognized that *ex situ* conservation resources are becoming increasingly important for habitat and ecosystem preservation, as opportunities for extensive *in situ* preservation are decreasing (Maunder *et al.* 2004). Another aspect that has been highlighted by the GSPC and the Convention on Biological Diversity (CBD) is the disparity in capacity for conservation between countries from the Global North and Global South\(^1\). For example, only six percent of the world’s scientists live in economically poor countries that house more than 80 percent of our planet’s biodiversity (Sarukhan and Dirzo 2001). Some have also argued that the common *ex situ* model of collections held in remote foreign locations can weaken the link between people and their local plant resources

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\(^1\) The Global North–South divide is a term used to describe the socio-economic division that exists between richer more developed countries and poorer less developed countries.
(Burgess 1994, Müller 1994). The above-mentioned, combined with factors such as complex international policies (e.g., the Convention on Biological Diversity) have further motivated the drive to develop in-country *ex situ* conservation efforts with greater financial and technical support from institutions in countries from the Global North (Maunder *et al.* 2004, Maunder *et al.* 2000). *Ex situ* conservation in the country of origin also makes it logistically easier to connect *ex situ* collections with *in situ* applications.

Four approaches to *ex situ* germplasm conservation are commonly used: living plant collections, seed banking, cryopreservation and tissue culture. These four are briefly introduced below and discussed in terms of their usefulness with regard to the conservation of Magnoliaceae.

### 1.3.1.1 Living plant collections

Maintaining and curating collections of living plants is particularly valuable for species with recalcitrant seed (Oldfield 2009). Managing living collections is, however, costly: requiring land, materials, labor and technical expertise (Engelmann and Engels 2002). Living collections are also vulnerable to natural disasters (Bergquist 2009), pest and pathogens (Gapinski 2010), and loss/theft.

Studies have shown that most *ex situ* collections in botanic gardens are limited in their use for *in situ* applications for a variety of reasons; including:

- low genetic diversity due to limited diversity (both intra-population and inter-population diversity) within individuals collected for a specific taxon,
- phenomena such as genetic drift,
- bias toward cultivation of horticulturally amenable taxa, and
• varying horticultural and curatorial capacity leading to plant and information loss (Hurka 1994, Mauder et al. 2001a, Mauder et al. 2001b).

The current lack of genetic diversity and information about genetic diversity in *ex situ* living collections does not bode well if Target 8 of the GSPC is to be realized by 2020. *Ex situ* living collections in botanic gardens conversely provide boundless opportunities for education, awareness-building and research; aspects that play a crucial role in integrated plant conservation.

Magnoliaceae living plant collections must play a crucial role in *Magnolia* conservation efforts because the other options for *ex situ* germplasm conservation are not considered viable at the this point in time.

1.3.1.2 Seed banking

Orthodox seed is seed that can be dehydrated to low moisture content and stored at very low temperatures (approximately -20°C) and low humidity (approximately 15%) for years or decades (Roberts 1973). Conversely, recalcitrant seeds stay metabolically active, and are intolerant of desiccation (Berjak and Pammenter 2008). Seed banking is one of the most efficient *ex situ* conservation options for plants with orthodox seed, costing as little as 1% of the cost of *in situ* conservation while representing much of the genetic diversity of a species (Li and Pritchard 2009).

Magnoliaceae germplasm conservation has little to benefit from existing seed banking technology, as the seed is considered recalcitrant (Fernando et al. 2011, Kha et al. 2005)
1.3.1.3 Tissue culture

Tissue culture is an important tool the preservation of threatened taxa when few seeds are available and growing plants asexually from cuttings is problematic. Challenges with using tissue culture include the cost and technical expertise needed to maintain a number of genetic lines and development protocols for different species, and managing somaclonal variation (the mutation or epigenetic changes in plants maintained in tissue culture) (Pence 2010).

Although some Magnoliaceae species and hybrids have been successfully propagated using tissue culture techniques (Zeng et al. 2002, Merkle and Wiecko 1990, Biedermann 1987), it is currently not widely utilized for conservation purposes for species in this family. Studies done on Magnolia fraseri var. pyramidata, however, demonstrate that is possible to successfully propagate magnolias using tissue culture techniques (Merkle and Watson-Pauley 1994, Merkle and Wiecko 1990).

1.3.1.4 Cryopreservation

Cryopreservation offers an alternative solution when seed bank storage is not possible. This process involves the storage of seed, pollen or vegetative tissue in liquid nitrogen at ultra-low temperatures (as low as -196°C). The rapid freezing causes no interference in cell metabolism or structure, which ensures that the cells remain viable after a long period of storage (Engelmann 2004, Fuller 2004). Cryopreservation is particularly useful for storing recalcitrant seed, however, its success is dependent on sound knowledge of tissue culture protocols and seed biology, storage behavior and propagation protocols for each species (Engelmann 2004).
For Magnoliaceae, additional research is still needed to develop protocols on cryopreservation before it could be considered a viable, *ex situ* conservation technique for threatened Magnolia taxa.

### 1.3.2 *In situ* conservation

Maintaining viable populations in a species’ native environment is generally considered the most effective way to ensure long-term survival of a species (Kramer *et al.* 2011). In many cases *in situ* conservation work involves studying and protecting critical habitats as well as undertaking management activities to ensure ecological processes and species survival (Garcia-Dominguez and Kennedy 2003). Restoration and reintroduction are increasingly important tools to help maintain healthy future *in situ* populations but is only possible when suitable *ex situ* collections are available (Kramer *et al.* 2011). Despite the fact that protected areas are continuing to increase, and now covering almost 12% of the Earth’s terrestrial surface (Butchard *et al.* 2010), the growing threats of habitat loss, climate change and the spread of invasive species means that *in situ* conservation is increasingly becoming inadequate to conserve plant diversity (Maunder *et al.* 2004).

### 1.3.3 Research, horticulture and education

Research, horticulture and education critically support both *in situ* and *ex situ* conservation efforts (Figure 2). BGCI estimates that 200 million people visit botanic gardens every year. If collections are effectively interpreted and incorporated into programing, botanic gardens can be vital to not only educate the public but also generate support for both *in situ* and *ex situ* plant conservation efforts (Kramer *et al.* 2011).
1.4 Magnolia Taxa Studied

Three closely related Magnolia taxa with different conservation statuses were used as case studies in this research, namely Magnolia macrophylla var. ashei, Magnolia macrophylla var. dealbata and Magnolia fraseri var. pyramidata.

1.4.1 Magnolia macrophylla var. ashei (Ashe’s magnolia)

Magnolia macrophylla var. ashei (Figure 3 and Figure 4) is currently considered the most threatened Magnolia taxon in the USA (NatureServe 2012, Cicuzza et al. 2007, FNA 1993). According to NatureServe (2012) the global conservation status of this taxon is G2-Imperiled (Table 1) while the The Red List of Magoliaceae (Cicuzza et al. 2007) lists its global conservation status as VU – Vulnerable (Table 2). Although literature sources agree that M. macrophylla var. ashei’s distribution is limited to the Florida panhandle (NatureServe 2012, FNA 1993, Kral 1983), sources differ for specific counties where it can be found. According to the Flora of North America (1993), the distribution of M. macrophylla var. ashei is limited to only six counties in the Florida panhandle while NatureServe (2012) lists ten counties (Table 3). About 95 occurrences have been mapped for M. macrophylla var. ashei in total, with about one third of all occurrences being last confirmed in the 1980s (NatureServe 2012). Individual plants also tend to occur in a scattered fashion making delimitation of occurrences troublesome. The most recent assessment cites only about ten occurrences with more than 100 individual plants (all sizes) and only 12 occurrences were rated as having excellent viability. Therefore, there are likely to be only a few thousand individual plants remaining in the wild (NatureServe 2012).
Table 1. NatureServe conservation status ranks (adapted from NatureServe 2012)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX</td>
<td>Presumed Extinct</td>
</tr>
<tr>
<td>GH</td>
<td>Possibly Extinct</td>
</tr>
<tr>
<td>G/S1</td>
<td>Critically Imperiled - At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors</td>
</tr>
<tr>
<td>G/S2</td>
<td>Imperiled - At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors</td>
</tr>
<tr>
<td>G/S3</td>
<td>Vulnerable - At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors.</td>
</tr>
<tr>
<td>G/S4</td>
<td>Apparently Secure - Uncommon but not rare; some cause for long-term concern due to declines or other factors</td>
</tr>
<tr>
<td>G/S5</td>
<td>Secure - Common; widespread and abundant</td>
</tr>
<tr>
<td>G</td>
<td>Global rank</td>
</tr>
<tr>
<td>S</td>
<td>State rank</td>
</tr>
<tr>
<td>NR</td>
<td>Global rank not yet assessed.</td>
</tr>
<tr>
<td>G#G#</td>
<td>Range rank indicates the range of uncertainty about the exact status of a taxon</td>
</tr>
</tbody>
</table>

Table 2. IUCN conservation status ranks (adapted from IUCN 2012)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EX</td>
<td>Extinct - No known individuals remaining.</td>
</tr>
<tr>
<td>EW</td>
<td>Extinct in the Wild - Known only to survive in ex situ collections, or as a naturalized population outside its historic range.</td>
</tr>
<tr>
<td>CR</td>
<td>Critically Endangered - Extremely high risk of extinction in the wild.</td>
</tr>
<tr>
<td>EN</td>
<td>Endangered - High risk of extinction in the wild.</td>
</tr>
<tr>
<td>VU</td>
<td>Vulnerable - High risk of endangerment in the wild.</td>
</tr>
<tr>
<td>NT</td>
<td>Near Threatened - Likely to become endangered in the near future.</td>
</tr>
<tr>
<td>LC</td>
<td>Least Concern - Lowest risk. Common; widespread and abundant.</td>
</tr>
<tr>
<td>DD</td>
<td>Data Deficient - Insufficient data to make an assessment of its risk of extinction</td>
</tr>
<tr>
<td>NE</td>
<td>Not Evaluated - Has not yet been evaluated against the criteria.</td>
</tr>
</tbody>
</table>
*M. macrophylla* var. *ashei* normally grows in the sandy loam soils of woodlands, ravines, bluffs and coastal plains (Riefler 1984, Kral 1983). It typically grows as a shrub or small tree and can reach a height of up to 12 m (FNA 1993), and normally flowers from April to June. Associated species include *Magnolia grandiflora*, *M. virginiana*, *Acer barbatum*, *A. leucoderme*, *Asimina parviflora*, *Fagus* spp., *Ilicium floridanum*, *Ilex* spp., *Persea* spp., *Pinus taeda* and *P. glabra*. Habitat disturbance such as logging and the subsequent increase of weedier species and erosion pose considerable threats to this taxon’s long-term survival (Kral 1983). According to Self (1988) a long-term rare plant monitoring and prescribed burning program was initiated in the Apalachicola Bluffs and Ravines Preserve in the late 1980s. However, this program has been inactive for years with little or no data being available (Printiss 2013).

Figure 3. Flowers of *Magnolia macrophylla* var. *ashei* in the female phase (left) and male phase (right)
M. macrophylla var. ashei has become a popular plant in the nursery trade in recent years and it thrives well north of its natural range (Riefler 1984). Seed viability is generally low (15 to 20%) because of poor pollination and it also does not propagate well from cuttings (Riefler 1984). Although no ethnobotanical uses are known for M. macrophylla var. ashei, the bark of the closely related M. macrophylla var. macrophylla was traditionally used as an analgesic, antidiarrheal, gastrointestinal aid, respiratory aid, and toothache remedy (Moerman 1986).

Figure 4. Magnolia macrophylla var. ashei in the University of Delaware Botanic Gardens (left), seed with arils (top right) and ripe fruit (bottom right, photo: Jen Kettell, Arnold Arboretum of Harvard University)
Table 3. *M. macrophylla* var. *ashei*; Natural history records for counties in the USA (adapted from NatureServe 2012)

<table>
<thead>
<tr>
<th>State</th>
<th>County Name (FIPS Code)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>Bay (12005), Gadsden (12039), Jackson (12063), Leon (12073),</td>
</tr>
<tr>
<td></td>
<td>Liberty (12077), Okaloosa (12091), Santa Rosa (12113),</td>
</tr>
<tr>
<td></td>
<td>Wakulla (12129), Walton (12131), Washington (12133)</td>
</tr>
</tbody>
</table>

Table 4. *M. macrophylla* var. *ashei*; Distribution by Watershed (based on available natural heritage records) in the USA (adapted from NatureServe 2012)

<table>
<thead>
<tr>
<th>Watershed Name (Watershed Code)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Ochlockonee (03120003), Apalachicola (03130011), Chipola (03130012), St.</td>
</tr>
<tr>
<td>Andrew-St. Joseph Bays (03140101), Choctawhatchee Bay (03140102),</td>
</tr>
<tr>
<td>Yellow (03140103), Pensacola Bay (03140105), Lower Choctawhatchee (03140203)</td>
</tr>
</tbody>
</table>
There is some debate in the scientific community about the correct placement for this taxon. Figlar (2012), a Magnoliaceae taxonomy expert, places it as *Magnolia macrophylla* var. *ashei*. This taxon is distinguished from *M. macrophylla* var. *macrophylla* by being a smaller, multi-trunked tree with smaller leaves, having fewer stamens and pistils, smaller seeds, smaller stipules, filiform trichomes, and smaller, nearly glabrous, cylindric follicetums. Although purple blotching at base of the innermost whorl of tepals is mentioned as a typical characteristic for both *M. macrophylla* var. *ashei* and *M. macrophylla* var. *macrophylla* (FNA 1993), the purple blotching seems to be highly variable in both species (Figlar 2012, Riefler 1984). *M. macrophylla* var. *ashei* also flowers at an early age (three to four years from seed) and often bears flowers in pairs (FNA 1993). Floral odor is also reported to be chemically distinct from *M. macrophylla* var. *macrophylla* (Thien et al. 1975) with patterns of pollinators also differing significantly between these two taxa (Thien 1974). These two taxa are also allopatric with no overlap occurring within their natural ranges (FNA1993, Figure 5).

- *Magnolia ashei* Weath., Rhodora 28: 35 (1926);

1.4.2 *Magnolia macrophylla* var. *dealbata* (Mexican bigleaf magnolia)

*M. macrophylla* var. *dealbata*, is a taxon native to Mexico that is closely related to *M. macrophylla* var. *ashei* and *M. macrophylla* var. *macrophylla*. The IUCN conservation status for *M. macrophylla* var. *dealbata* is EN – Endangered (Table 2). It was once thought to be extinct until it was rediscovered in the wild in 1977 (Cicuzza et al. 2007, Vovides and
Iglesias 1996). Only about four to five relic subpopulations exist in the Mexican states of Oaxaca, Hidalgo and Veracruz. Between 80 and 100 individuals of this taxon can be found in a disturbed cloud forest at Ixhuacan de los Reyes, Veracruz while very few (4 to 10 individuals) remain in Oaxaca and Hidalgo (Vovides 1998, Cutierrez and Vovides 1997). The decline in numbers has been due to habitat destruction, timber production and poor natural regeneration (Vovides 1998). Some ex situ conservation efforts have been made with saplings grown and planted at Jardín Botánico Francisco Javier Clavijero (Cutierrez and Vovides 1997).

*Magnolia macrophylla* var. *dealbata* is used for timber while flowers and bark are used as a traditional medicine to treat heart disease (Cutierrez and Vovides 1997, Vovides and Iglesias 1996). Flowers are also harvested and used ornamentally, especially during Easter celebrations (Cutierrez and Vovides 1997). Flowering usually occurs between March and April. An in situ study by Cutierrez and Vovides (1997) it is suggests that *Magnolia macrophylla* var. *dealbata* can survive in disturbed secondary succession forests as long as clear-cutting is not allowed.

*M. macrophylla* var. *dealbata* can be fairly easily cultivated from seed (Vovides and Eglesias 1996) using the standard technique for ornamental magnolias of Dirr and Heuser (1987). Vovides and Eglesias found that the best germination rate, was achieved using fresh non-stratified or 5°C stratified seed of which the aril was removed and soaked in warm water for 24 hours before sowing. The warm water is believed to stimulate germination by removing the chemical germination inhibitor still remaining on the seedcoat after the fleshy arils were removed (Vovides and Eglesias 1996, Dirr and Heuser
Reduction in germination rate was observed for seed stratified at 0°C and seed stored at 5°C for longer than six months (Vovides and Eglesias 1996).

A synonym for *Magnolia macrophylla var. dealbata* (Zucc.) D.L.Johnson, Baileya 23: 56 (1989) is (WCSP 2012):


### 1.4.3 *Magnolia fraseri* var. *pyramidata* (Pyramid magnolia)

*Magnolia fraseri* var. *pyramidata* naturally occurs in the deciduous forests of slopes, bluffs, and uplands along the Apalachicola, Ochlockonee, and Escambia Rivers in the states of Texas, Louisiana, Alabama, Arkansas, Mississippi, Kentucky, Georgia, South Carolina and Florida (NatureServe 2012, Table 5, Table 6, Figure 6). It typically grows as a small tree and can reach a height of nearly 12m bearing large, with white flowers in spring (FNA 1993). According to NatureServe (2012), the global conservation status of this taxon is G4 - Apparently Secure (Table 1). Its conservation status, however, varies in the states where it occurs: Alabama (SNR – Not Assessed), Arkansas (SNR – Not Assessed), Florida (S3 – Vulnerable), Georgia (S3 - Vulnerable), Kentucky (SH – Possibly Extirpated), Louisiana (S2 - Imperiled), Mississippi (S4 – Apparently Secure), South Carolina (S1 – Critically Imperiled) and Texas (S1 - Critically Imperiled) (Table 5).
Table 5. *M. fraseri* var. *pyramidata*; Natural history records for counties in the USA (from NatureServe 2012)

<table>
<thead>
<tr>
<th>State</th>
<th>County Name (FIPS Code)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>Bay (12005), Calhoun (12013), Escambia (12033), Gadsden (12039), Jackson (12063), Leon (12073), Liberty (12077), Okaloosa (12091)*, Santa Rosa (12113), Walton (12131), Washington (12133)</td>
</tr>
<tr>
<td>Kentucky</td>
<td>Fulton (21075)*</td>
</tr>
<tr>
<td>Louisiana</td>
<td>Sabine (22085), Washington (22117), West Feliciana (22125)</td>
</tr>
<tr>
<td>South Carolina</td>
<td>Aiken (45003), Calhoun (45017), Lexington (45063), Newberry (45071), Richland (45079)</td>
</tr>
</tbody>
</table>

*Extirpated/possibly extirpated*
Table 6. *M. fraseri* var. *pyramidata*; Distribution by Watershed (based on available natural heritage records) in the USA (adapted from NatureServe 2012)

<table>
<thead>
<tr>
<th>Watershed Name (Watershed Code)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Broad (03050106), Congaree (03050110), North Fork Edisto (03050203), Middle Savannah (03060106), Lower Ochlockonee (03120003), Apalachicola (03130011), Chipola (03130012), St. Andrew-St. Joseph Bays (03140101), Choctawhatchee Bay (03140102), Lower Choctawhatchee (03140203), Escambia (03140305), Lower Pearl. Mississippi (03180004), Lower Mississippi-Memphis (08010100), Obion (08010202), Bayou Sara-Thompson (08070201), Lower Sabine (12010005)</td>
</tr>
</tbody>
</table>

*Magnolia fraseri* var. *pyramidata* differs from *M. fraseri* var. *fraseri* in being a smaller tree with a narrower, pyramidal habit and having no overlap in its natural range. *M. fraseri* var. *pyramidata* also differs from *M. fraseri* var. *fraseri* in having pandurate leaf blades, smaller flowers and stipules, fewer stamens and pistils, and smaller follicetums (FNA 1993).

*Magnolia fraseri* var. *pyramidata* is occasionally found in cultivation, but it is less hardy than *M. fraseri* var. *fraseri* (FNA 1993). It is a desirable landscape tree due to its compact, pyramidal habit; fragrant white flowers; and large, auriculate leaves (Treseder 1978). The seed viability of *M. fraseri* var. *pyramidata* is much higher than *M. macrophylla* var. *ashei* suggesting different pollen vectors (Riefler 1984). Studies on the use of tissue culture techniques to cultivate *Magnolia fraseri* var. *pyramidata* found that it was possible to initiate embryogenic cultures with somatic embryo-derived plantlets grown on in a humidifying chamber showing higher survival rates compared to those kept in plantlet development medium in test tubes (Merkle and Watson-Pauley 1994, Merkle and Wiecko 1990).

- *Magnolia pyramidata* Bartram, Travels Carolina: 408 (1791);
- *Magnolia auriculata* var. *pyramidata* (Bartram) Nutt., Gen. N. Amer. Pl. 2: 18 (1818);
Chapter 2
MATERIALS AND METHODS

2.1 Survey of Magnoliaceae Currently Found in Ex Situ Collections Globally

BGCI’s PlantSearch database (BGCI 2012) was used to access data on global Magnoliaceae collections, with special focus on to the representation of threatened taxa in ex situ collections. The data was analyzed with regard to number of known records and institutions for each species and compared to the results of previous work, Global survey of Ex Situ Magnoliaceae Collections (BGCI 2008).

2.2 Global Survey to Assess Support for Conservation Efforts of Selected North American Magnolia Taxa

An online survey (Appendix A) of three North American magnolia species of varying conservation concern, Magnolia macrophylla var. ashei, M. macrophylla var. dealbata, M. fraseri var. pyramidata was conducted using the Qualtrics Research Suite, Version 12.018 (Qualtrics Labs Inc. 2005). Survey recipients included botanic gardens growing these species as identified using BGCI’s PlantSearch database (BGCI 2012) and through Magnolia Society International (MSI). Data collected in the survey included the following:

- All ex situ germplasm, with regard to origin and use of accessions
- All collections of herbarium specimens and other preserved specimens, with regard to origin and use of specimens
- The current involvement of institutions in in situ conservation and monitoring efforts for these species and their natural habitats
2.2.1 Follow-up data collection

After the survey was completed, various institutions were contacted for clarification of technicalities or to obtain additional information where needed. For plant material obtained from commercial nursery sources, further investigation was conducted to establish the actual origin of the material in the case of *Magnolia macrophylla* var. *ashei*. Current *in situ* status was also further studied using herbarium specimens, *ex situ* accessioned material (of known wild-origin) and reported field observations for this specific taxa.

2.2.2 Ethical considerations and validation of survey

Prior to distribution, the online survey was validated for content and technical quality via the researcher’s graduate committee and other subject experts who would not ordinarily participate in the study. The survey incorporated display logic, whereby participants only saw relevant questions depending on the answers of preceding questions. Consequently, the survey was significantly shorter for institutions that had less information to share, and thus encouraged survey completion.

The University of Delaware Human Subjects Review Board reviewed all survey questions and protocols before the surveys were distributed (Appendix B). Potentially sensitive information, such as *in situ* location details, will also be managed with the necessary consideration so this information will only be shared with those directly involved in conservation efforts of relevant taxa.

2.3 Sources of Literature and Nomenclature

Many sources were consulted regarding the status of the selected magnolia species, including the Flora of North America (FNA 1993) and NatureServe (NatureServe 2012), but the World Checklist for Selected Plant Families (WCSP 2012) was used as the definitive nomenclature source, as advised by a Magnoliaceae taxonomy expert (Figlar 2012). With regard to global conservation status, NatureServe (NatureServe 2012) and *The Red List of Magnoliaceae* (Cicuzza et al. 2007) were used.
2.4 Statistical Analysis

Data were first tested for normality; subsequently, Chi-square ($X^2$) test and Students T-test were used to identify statistically significant differences among variables in both the survey results using IBM SPSS Statistics software, Version 20 (IBM Corp. 2011).
Chapter 3
RESULTS, DISCUSSION AND CONCLUSION

3.1 Magnoliaceae Currently Known in Collections Globally

Through BGCI’s PlantSearch database, 7,025 records\(^2\) for Magnoliaceae were found. Of these records, 3,522 (50\%) were linked with currently accepted nomenclature or synonyms and the remaining records represented Magnoliaceae hybrids, cultivars and ambiguous records. The identifiable records represented 122 taxa of the approximately 247 recognized Magnoliaceae taxa found globally (BGCI 2008) and were located in 358 institutions located in 52 countries.

When comparing representation of IUCN conservation status ranks of Magnoliaceae taxa in global institutions to the total Magnoliaceae taxa in each rank, a $X^2$ test for homogeneity refuted the null hypothesis that the two groups are homogeneous (P<0.001). Expected values were higher for CR, EN, VU, NT and NE ranked taxa and lower for LC and NE ranked taxa (Figure 7). Of the 3,522 records that could be matched with known Magnoliaceae taxa only 74 records (2\% of all records) represented six CR ranked taxa, a rank which actually represents 13\% of the taxa in this family. This trend was also observed for other ranks with 381 records representing 17 EN ranked taxa (11\% of all records), 239 records representing eight VU ranked taxa (7\% of all records), 277 records representing eight NT ranked taxa (8\% of all records) and 1,073 records representing 47 NE ranked taxa (30\% of all records). For the conservation status ranks of lesser conservation concern there was a greater than expected representation in collections, namely 1,188 records.

\(^2\) A record is the presence of a single Magnoliaceae taxon within a collection a given institution and may include multiple accessions and/or individuals.
representing 15 LC ranked taxa (34% of all records) and 292 records representing six DD ranked taxa (8% of all records). The number of taxa found in collections was also compared to the total number of recognized taxa. Only 50% of all known taxa were located in collections. The taxa ranked CR (2%) again had the lowest representation in collections. The taxa with ranks NT (3%) and LC (6%) showed a significantly smaller reduction in overall representation of Magnoliaceae taxa in collections possibly because these ranks represents a large number of records for relatively few taxa.

Figure 7. Distribution of Magnoliaceae taxa, known records and current taxa in collections per IUCN conservation rank category.
The Magnoliaceae taxa per IUCN conservation rank represented in collections globally were also compared to the total Magnoliaceae taxa in each rank (Figure 8). The conservation ranks with the lowest representation in collections globally were CR (19%), EN (29%) and VU (35%). The conservation ranks that had the largest representation in collections were NT (89%) and LC (75%), were also the groups of least conservation concern; the ranks DD (60%) and NE (50%), both ranks of slightly more conservation concern, were not as well represented. The data show a clear positive correlation for institutions globally to cultivate Magnoliaceae taxa from conservation status ranks of lesser conservation concern, which has also been reported for other plant groups (Toppila et al. 2012, Aplin 2008, Maunder et al. 2001).

Although a 35% increase in total records for Magnoliaceae was observed, from 2,274 (BGCI 2008) to 3,522, there was little increase of species with a high conservation priority in collections as per the Global Survey of Ex Situ Magnoliaceae Collections (BGCI 2008). The increase in the number of Magnoliaceae records is most likely due to an increase in the number of botanic gardens uploading their collections in the last four years rather than as an actual increase in collections due to a response to the 2008 survey. Kramer et al. (2011) reported a 575% increase in number of contributors to PlantSearch database for North American institutions in 2010 alone.
Since approximately 92% of all Magnoliaceae taxa are found in the Global South, collection records for Magnoliaceae were analyzed according to their distribution in the Global North and Global South (Figure 10). Of the estimated 247 Magnoliaceae taxa found globally, only approximately 20 taxa (8% of all taxa) can be found in the Global North. However, 367 (10%) Magnoliaceae records could be located for countries in the Global South (Figure 10). When comparing representation of IUCN conservation status ranks (Table 2) of Magnoliaceae taxa in Global North and Global South, a $X^2$ test indicated that the two groups are heterogeneous ($P<0.001$). Twenty-eight countries in the Global North

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3 Global South refers to the countries still in development or transition with regard to socio-economic factors.
held 3,155 records (90% of all known records) representing 106 taxa, while 24 countries in the Global South only had 367 (10%) records representing 89 taxa.

According to BGCI’s GardenSearch database, more than two thirds of the world’s botanic gardens are located in the Global North. Data from this research, as well as from others (Burgess 1994, Müller 1994, Sarukhan and Dirzo 2001, Maunder et al. 2004, Maunder et al. 2000), combined with complex international policies (e.g. CBD), motivates the necessity to develop in-country ex situ conservation efforts with greater financial and technical support from institutions in developed countries.

Figure 9. Distribution of countries of the Global North (blue) and Global South (grey) with the regions with the highest Magnoliaceae diversity circled in red.
Figure 10. Distribution of Magnoliaceae records per IUCN conservation rank category and between countries from the Global North and Global South

Since *Magnolia* taxa native to both the USA and Mexico were used as case studies, Magnoliaceae collections in these two countries and indigenous *Magnolia* species were analyzed in more depth (Figure 11). According to Cires *et al.* (2013), ten taxa are listed as native to the USA (Table 7) and 11 in Mexico (Table 8). However, the World Checklist of Selected Plant Families (WCSP 2013) that lists eleven taxa native to the USA and 17 taxa native to Mexico. For Magnoliaceae taxa indigenous to the USA, 100% were represented
in collections in the USA and other countries. For Mexico, however, only 22% of their native taxa were represented in collections in Mexico with 33% of taxa in collections in other countries. The number of taxa records in collections, with the exception of *Magnolia grandiflora*, was also significantly less than the number of records for other Magnoliaceae taxa indigenous to the USA. All Mexican Magnoliaceae taxa records represented indigenous taxa compared to only 39% for the USA.

![Distribution of Magnoliaceae records of Mexico and the USA per IUCN conservation rank category](image)

**Figure 11.** Distribution of Magnoliaceae records of Mexico and the USA per IUCN conservation rank category
Table 7. Threatened Magnoliaceae taxa found in the USA, their IUCN conservation rank categories and representation in collections in the country of origin or abroad according to 2013 PlantSearch and the 2013 World Checklist of Selected Plant Families (WCSP 2013).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>IUCN conservation rank</th>
<th>Number of records in country</th>
<th>Number of records outside country</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Liriodendron tulipifera</em></td>
<td>LC</td>
<td>95</td>
<td>121</td>
</tr>
<tr>
<td><em>Magnolia acuminata</em> var.</td>
<td>LC</td>
<td>99</td>
<td>77</td>
</tr>
<tr>
<td>acuminata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Magnolia acuminata</em> var.</td>
<td>NE</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>subcordata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Magnolia fraseri</em> var. fraseri</td>
<td>LC</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td><em>Magnolia fraseri</em> var. pyramidata</td>
<td>LC</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td><em>Magnolia grandiflora</em></td>
<td>LC</td>
<td>72</td>
<td>97</td>
</tr>
<tr>
<td><em>Magnolia macrophylla</em> var.</td>
<td>VU</td>
<td>41</td>
<td>10</td>
</tr>
<tr>
<td>macrophylla</td>
<td></td>
<td>63</td>
<td>40</td>
</tr>
<tr>
<td><em>Magnolia tripetala</em></td>
<td>LC</td>
<td>66</td>
<td>67</td>
</tr>
<tr>
<td><em>Magnolia virginiana</em> var.</td>
<td>LC</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td><em>Magnolia virginiana</em> var.</td>
<td>LC</td>
<td>92</td>
<td>39</td>
</tr>
<tr>
<td>virginiana</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8. Magnoliaceae taxa found in Mexico, their IUCN conservation rank categories and their representation in collections in the country or abroad according to 2013 PlantSearch and the 2013 World Checklist of Selected Plant Families (WCSP 2013).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>IUCN Conservation Rank</th>
<th>Number of records in country</th>
<th>Number of records outside country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnolia grandiflora</td>
<td>LC</td>
<td>4</td>
<td>165</td>
</tr>
<tr>
<td>Magnolia guerrerensis</td>
<td>NE*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia ilitisisana</td>
<td>VU</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia krusei</td>
<td>VU</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia lacandonica&lt;sup&gt;4&lt;/sup&gt;</td>
<td>NE*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia macrophylla var. dealbata</td>
<td>EN</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Magnolia mayae</td>
<td>NE*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia mexicana</td>
<td>NE</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia pacifica subsp. pacifica</td>
<td>EN</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Magnolia pacifica subsp. tarahumara</td>
<td>VU</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia poasana</td>
<td>NE*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia pugana</td>
<td>CR</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia schiedeana</td>
<td>EN</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Magnolia sharpii</td>
<td>EN</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Magnolia sororum subsp. sororum</td>
<td>EN</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia tamaulipana</td>
<td>EN</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Magnolia vazquezii</td>
<td>NE*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnolia yoroconte</td>
<td>VU</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NE* = assumed NE (not evaluated) conservation status as it is not listed in the current Red List of Magnoliaceae (Cicuzza et al. 2007).

<sup>4</sup> Newly described Magnolia species from the rainforest of Chiapas in Mexico (Vazquez-Garcia et al. 2013) not yet recognized by the World Checklist of Selected Plant Families (2013)
3.2 Support for Integrated Plant Conservation Efforts of Selected Threatened North American *Magnolia* Taxa

3.2.1 *Magnolia macrophylla* var. *ashei*

3.2.1.1 *Ex situ* living plant collections

The PlantSearch database indicated that 51 institutions (41 inside the USA) had *M. macrophylla* var. *ashei* in their collections as of August 2012. Of these, four did not respond to the survey, corresponding to a 98% response rate within the USA and a 73% response rate outside the USA. Six institutions lost specimens from their collections, with most citing severe winters or unsuitable clay soils as possible reasons. Institutions as far north as Quebec, Canada maintained *M. macrophylla* var. *ashei* with relative success.

The survey was also sent out to the Magnolia Society International members and other gardens that were believed to have this taxon in their collections. Forty-five sites\(^5\) were subsequently identified with living accessions of *M. macrophylla* var. *ashei*, including 43 public gardens and two private collections (Figure 12). An overwhelming majority (87%) of collection sites were located in the USA.

Two institutions initially reported growing plants of known wild origin but with follow-up investigation they could not produce any specific origin records. Only six institutions (13%) maintained plants that were grown from wild collected seeds (two institutions, four accessions) or that were originally grown from open pollinated seed of parent plants that were grown from wild collected material (four institutions, five accessions). These six institutions kept at least nine different accessions representing 27 individual plants, of which 11 were still seedlings (Figure 13). Of these six institutions, one garden was not aware that its plant had a known wild origin, which only became apparent

---

\(^5\) Collection sites is used to refer to sites where accessions are cultivated which can be either private collectors or botanic gardens and public gardens
after follow-up contact with the nursery that supplied the plants to the institution. As mentioned above, only four individual accessions grown at two institutions could be found that were grown from truly wild collected material. These four accessions only represented 18 plants (of which 11 were seedlings) from Florida’s Liberty, Santa Rosa and Walton counties. The remaining four institutions obtained their material from the same nursery source where the parent plants were originally collected in Liberty County. Therefore, the known ex situ collections represent just a handful of individuals from only three of the ten counties where this taxon occurs naturally. All institutions that kept material of known wild origin were located in the USA. Very few accessions of known (two) or unknown origin (four) were also linked to herbarium specimens.

---

Figure 12. Distribution of number of collection sites that cultivate *Magnolia macrophylla* var. *ashei* inside and outside the USA
3.2.1.2 Other ex situ germplasm collections

Only two seed bank records were located for Magnolia macrophylla var. ashei with only one record being of known wild origin and recently collected (Table 9). The other seed bank record was of open pollinated seed from a plant of unknown origin; the seeds were almost ten years old and almost certainly non-viable (Vovides 1996). No other forms of germplasm were located.

Table 9. Representation of Magnolia macrophylla var. ashei in other germplasm collections

<table>
<thead>
<tr>
<th>Type of germplasm collection</th>
<th>Number of collections sites with known wild origin accessions</th>
<th>Number of collections sites with unknown origin accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryopreservation facilities</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
3.2.1.3 Magnolia macrophylla var. ashei ex situ collections use

Four institutions used their plants for propagation, citing collecting the seed for propagation or collecting pollen for plant breeders (Table 10). Five institutions used their accessions in displays and/or shared them with other institutions. Other uses included gathering phenological data, using plants for botanical illustration classes, and conducting research on reproductive biology, propagation and cultivation, as their collection matures. This represented only 9 different collection sites, representing 20% of institutions that completed the survey.

Table 10. Use of Magnolia macrophylla var. ashei germplasm collections

<table>
<thead>
<tr>
<th>Accession use</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive biology</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Propagation</td>
<td>4</td>
<td>9%</td>
</tr>
<tr>
<td>Cultivation</td>
<td>5</td>
<td>11%</td>
</tr>
<tr>
<td>Genetic analysis</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

Only five institutions (11%) indicated that Magnolia macrophylla var. ashei specimens were interpreted for visitors (Table 11), using such techniques as interpretive signs, brochures, guided tours and/or docents. Only one institution (2%) interpreted the conservation status of this taxon (Figure 14).
Table 11. Interpretation techniques and incidences for *Magnolia macrophylla* var. *ashei* collections

<table>
<thead>
<tr>
<th>Accession interpretation</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretive signs/labels</td>
<td>5</td>
<td>11%</td>
</tr>
<tr>
<td>Guided tours or docents</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Conservation status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interpreted</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2%</td>
</tr>
</tbody>
</table>

Figure 14. One example of interpretive signage developed for *Magnolia macrophylla* var. *ashei* as part of BGCI’s Care for the Rare initiative.
3.2.1.4 Institutional involvement in in situ efforts

Only one institution (2%) reported monitoring wild populations but no institutions were involved in habitat preservation or restoration activities where *Magnolia macrophylla* var. *ashei* occurs naturally. Six institutions (13%) reported their involvement in wild collecting efforts for this taxon (Table 12).

Table 12. Institutional activities in in situ efforts for *Magnolia macrophylla* var. *ashei*

<table>
<thead>
<tr>
<th>Involvement</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild population monitoring</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>preservation/restoration</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Wild collecting efforts</td>
<td>6</td>
<td>13%</td>
</tr>
</tbody>
</table>

Sixteen institutions (39%) indicated an interest to become involved with integrated conservation efforts for *Magnolia macrophylla* var. *ashei*; 21 institutions (51%) answered to be uncertain to do so (Figure 15); and four institutions (10%) were not interested in building an involvement in these efforts. Reasons for their lack of interest included limited space available for additional accessions and being primarily concerned about preservation of their landscape instead of plant conservation. Of all the institutions with *Magnolia macrophylla* var. *ashei*, only eight (20%) indicated that conservation was not seen as part of their mission (Figure 16).

When institutions maintaining living collections or germplasm collections of *Magnolia macrophylla* var. *ashei* were surveyed, 16 institutions were found to have conservation programs and 20 had ex situ programs. Four had medicinal programs and five
institutions had reintroduction programs (Table 13). While 15 institutions interpreted threatened species in their collections, only one institution interpreted the conservation status of this taxon in their collection. Even though many institutions (42%) had active programs or had been involved in other research with Magnoliaceae, *Magnolia macrophylla* var. *ashei* mostly did not officially form part of these programs or of Magnoliaceae research.

Figure 15. Response of institutions to become involved in integrated plant conservation efforts for *Magnolia macrophylla* var. *ashei*
Figure 16. Reported conservation as part of mission of institutions with *Magnolia macrophylla var. ashei*

Table 13. Reported activities present at institutions maintaining living collections or other germplasm collections of *Magnolia macrophylla var. ashei*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Yes</th>
<th>No</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation programs</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicinal plants program</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex situ program</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reintroduction program</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interpret threatened species in collections</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.2 *Magnolia macrophylla* var. *dealbata*

3.2.2.1 *Ex situ* living plant collections

Initially, 17 institutions (two in Mexico) were identified with *Magnolia macrophylla* var. *dealbata* in their collections according to BGCI’s PlantSearch database as of December 2012. One of these institutions did not respond to the survey, corresponding to a 100% response rate within Mexico and a 93% response rate outside Mexico. Of these responses, only one institution reported no longer having the specimens in their collections anymore. Fifteen collection sites were identified with living accessions of *M. macrophylla* var. *dealbata*, all of which were publicly accessible gardens (Figure 17). The overwhelming majority of institutions or private collectors with this taxon were located outside Mexico (87%).

One of the gardens surveyed initially reported plants of known wild origin but follow-up investigation did not produce any specific records of plant collection details. Only four institutions (26%) were finally identified as maintaining plants grown from wild collected material. These four institutions kept at least five different accessions representing at least 12 individual plants (Figure 18). Very few accessions of known (three accessions) or unknown origin (none) were also linked to herbariums specimens.
Figure 17. Distribution of number of collection sites that cultivate *Magnolia macrophylla* var. *dealbata* inside and outside Mexico

<table>
<thead>
<tr>
<th>Inside Mexico</th>
<th>Outside Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
</tr>
</tbody>
</table>

Total number of collection sites (n=15)

Figure 18. Origin of *Magnolia macrophylla* var. *dealbata* represented in collections

<table>
<thead>
<tr>
<th>Know wild origin</th>
<th>Unknown origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>11</td>
</tr>
</tbody>
</table>

Total number of collection sites (n=15)
3.2.2.2 Other *ex situ* germplasm collections

Only one seed bank record was located with seed of *Magnolia macrophylla* var. *dealbata* (Table 14). For this institution, three different accessions were recorded of which two represented seed from known origin and one from unknown origin.

Table 14. Representation of *Magnolia macrophylla* var. *dealbata* in other germplasm collections

<table>
<thead>
<tr>
<th>Type of germplasm collection</th>
<th>Number of collections sites with known wild origin accessions</th>
<th>Number of collections sites with unknown origin accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryopreservation facilities</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seed bank</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gene bank and/or Tissue culture</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

3.2.2.3 *Magnolia macrophylla* var. *dealbata* *ex situ* collections use

Four institutions responded that their *Magnolia macrophylla* var. *dealbata* plants have been used for propagation including germination trials and testing propagation techniques (Table 15).

Table 15. Use of *Magnolia macrophylla* var. *dealbata* germplasm collections

<table>
<thead>
<tr>
<th>Accession use</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive biology</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Propagation</td>
<td>4</td>
<td>27%</td>
</tr>
<tr>
<td>Cultivation</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Genetic analysis</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
With regard to the interpretation of *Magnolia macrophylla* var. *dealbata*, only one institution reported doing so, corresponding to 7% of the total survey responses (Table 16). Only one institution reported interpreting the conservation status of this taxon, corresponding to 7% of the total responses.

Table 16. Interpretation of *Magnolia macrophylla* var. *dealbata*

<table>
<thead>
<tr>
<th>Accession interpretation</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretive signs/labels</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Guided tours or docents</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Conservation status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interpreted</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

3.2.2.4 Institutional involvement in *in situ* efforts

Only one institution (7%) was involved in wild population monitoring efforts while none were involved in habitat preservation or restoration where *Magnolia macrophylla* var. *dealbata* naturally occurs. Three institutions (20%) responded that they are or were involved in wild collecting efforts for this taxon.

Table 17. Institutional involvement in *in situ* efforts

<table>
<thead>
<tr>
<th>Involvement</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild population monitoring</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>preservation/restoration</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Wild collecting efforts</td>
<td>3</td>
<td>20%</td>
</tr>
</tbody>
</table>
Seven institutions (47%) expressed an interest to become involved with integrated plant conservation efforts for *Magnolia macrophylla* var. *dealbata*, with 7 institutions (47%) answering that they were not sure if they were interested in becoming involved in such efforts (Figure 19). One participant (7%) answered that its institution was not interested in becoming involved in integrated conservation efforts. Of all the institutions keeping *Magnolia macrophylla* var. *dealbata* only one institution responded that conservation was not seen as part of its mission (Figure 20).

When institutions maintaining living plant or germplasm collections of *Magnolia macrophylla* var. *dealbata* were surveyed about institutional activities it was found that six institutions reported conservation and *ex situ* programs. Only three institutions had medicinal programs and three institutions reported reintroduction programs (Table 18). While eight institutions responded that they interpreted threatened species in collections only one institution interpreted this taxon in its collection. Even though many institutions reported active programs or had been involved in other research on Magnoliaceae (40% of institutions), *Magnolia macrophylla* var. *dealbata* did not seem to officially form part in the majority of these programs or of Magnoliaceae research done at these institutions.
Figure 19. Reported interest of institutions to become involved in integrated plant conservation efforts for *Magnolia macrophylla* var. *dealbata*

Figure 20. Reported conservation as part of mission of institutions keeping *Magnolia macrophylla* var. *dealbata*
Table 18. Reported activities present at institutions maintaining living collections or other germplasm collections of *Magnolia macrophylla* var. *dealbata*

<table>
<thead>
<tr>
<th>Does your institution have any of the following activities?</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation program</td>
<td>6</td>
</tr>
<tr>
<td>Medicinal plants program</td>
<td>3</td>
</tr>
<tr>
<td>Ex situ program</td>
<td>6</td>
</tr>
<tr>
<td>Reintroduction program</td>
<td>3</td>
</tr>
<tr>
<td>Interpret threatened species in collections</td>
<td>8</td>
</tr>
</tbody>
</table>

3.2.3 *Magnolia fraseri* var. *pyramidata*

3.2.3.1 *Ex situ* living plant collections

Initially, 20 institutions (17 inside the USA) were identified with *M. fraseri* var. *pyramidata* in their collections through data from BGCI’s PlantSearch database collected in December 2012. Of these 20 institutions only four institutions did not respond to the survey corresponding to an 88% response rate within the USA and a 66% response rate outside the USA. Of these responses only one institution reported no longer having a specimen in their collections anymore. Fifteen collection sites were identified that had living accessions of *M. fraseri* var. *pyramidata*, all of which were publicly accessible collections (Figure 21). The overwhelming majority of institutions with this taxon in their collections where located in the USA (80%).

One of the institutions surveyed initially reported to have plants of known wild origin but with follow-up investigation could not produce any specific records on the origin of the plants. Six institutions (40%) were finally identified as maintaining plants that had a known wild origin. These six institutions kept at least eleven different accessions
representing at least 17 individual plants (Figure 22). Very few accessions of known wild (three accessions) or unknown origin (none) were also linked to herbariums specimens.

Figure 21. Distribution of number of collection sites reporting Magnolia fraseri var. pyramidata inside and outside the USA

Figure 22. Origin of Magnolia fraseri var. pyramidata known in collections
3.2.3.2 Other ex situ germplasm collections

Only one institution reported storing seed of *Magnolia fraseri* var. *pyramidata* (Figure 21). For this institution three different accessions were recorded of which all three accessions represented seed of plants from known wild origin.

Table 19. Reported representation of *Magnolia fraseri* var. *pyramidata* in other germplasm collections

<table>
<thead>
<tr>
<th>Type of germplasm collection</th>
<th>Number of collections sites with known wild origin accessions</th>
<th>Number of collections sites with unknown origin accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryopreservation facilities</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seed bank</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Gene bank and/or Tissue culture</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

3.2.3.3 *Magnolia fraseri* var. *pyramidata* ex situ collections use

One institution reported that their plants had been used for propagation with the institutions citing that seed had been collected from their specimens for propagation purposes (Table 20). One institution reported that plants were used to record floral phenology data. These abovementioned responses only represent two different collection sites representing 13% of institutions that completed the survey. With regard to the interpretation of *Magnolia fraseri* var. *pyramidata* only four institutions (27%) indicated that specimens were interpreted (Table 21). Only two institutions (13%) reported interpreting the conservation status of this taxon.
Table 20. Use of *Magnolia fraseri* var. *pyramidata* germplasm collections

<table>
<thead>
<tr>
<th>Accession use</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive biology</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Propagation</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>Cultivation</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Genetic analysis</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 21. Interpretation of *Magnolia fraseri* var. *pyramidata*

<table>
<thead>
<tr>
<th>Accession interpretation</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretive signs/labels</td>
<td>4</td>
<td>27%</td>
</tr>
<tr>
<td>Guided tours or docents</td>
<td>2</td>
<td>13%</td>
</tr>
<tr>
<td>Conservation status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interpreted</td>
<td>2</td>
<td>13%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

3.2.3.4 Institutional involvement in *in situ* efforts

No institutions reported being involved in wild population monitoring or habitat preservation efforts in natural areas where *Magnolia fraseri* var. *pyramidata* occurs. Three institutions (20%) responded that they are or were involved in wild collecting efforts for this taxon.
Table 22. Reported institutional involvement in *in situ* efforts

<table>
<thead>
<tr>
<th>Involvement</th>
<th>Number of collection sites</th>
<th>% Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild population monitoring</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Habitat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>preservation/restoration</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Wild collecting efforts</td>
<td>3</td>
<td>20%</td>
</tr>
</tbody>
</table>

Nine institutions (60%) expressed an interest to become involved with integrated conservation efforts for *Magnolia fraseri* var. *pyramidata*, with 5 institutions (33%) answering that they were not sure if their institutions were interested in becoming involved in such efforts (Figure 23). One responded (7%) answered that its institution was not interested in becoming involved in integrated conservation efforts. Of all the institutions keeping *Magnolia fraseri* var. *pyramidata* only one institution responded that conservation was not seen as part of its mission (Figure 20).

When institutions maintaining living plant or germplasm collections of *Magnolia fraseri* var. *pyramidata* were surveyed about institutional program activities it was found that seven institutions reported conservation programs and six reported *ex situ* programs. Only two institutions reported medicinal plant programs (Table 23). While six institutions responded that they interpreted threatened species in collections only four institutions interpreted this taxon in its collections. Even though many institutions had active programs or had been involved in other research on Magnoliaceae (40% of institutions), *Magnolia fraseri* var. *pyramidata* did not seem to officially form part of these programs or of Magnoliaceae research done at these institutions.
Figure 23. Reported interest of institutions to become involved in integrated plant conservation efforts for *Magnolia fraseri* var. *pyramidata*

Figure 24. Reported conservation as part of mission of institutions keeping *Magnolia fraseri* var. *pyramidata*
Table 23. Reported activities present at institutions maintaining living collections or other germplasm collections of *Magnolia fraseri* var. *pyramidata*

<table>
<thead>
<tr>
<th>Does your institution have any of the following activities?</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation program</td>
<td>7</td>
</tr>
<tr>
<td>Medicinal plants program</td>
<td>2</td>
</tr>
<tr>
<td><em>Ex situ</em> program</td>
<td>6</td>
</tr>
<tr>
<td>Reintroduction program</td>
<td>0</td>
</tr>
<tr>
<td>Interpret threatened species in collections</td>
<td>6</td>
</tr>
</tbody>
</table>

### 3.3 Other Observations

*Magnolia macrophylla* var. *ashei*, *Magnolia macrophylla* var. *dealbata* and *Magnolia macrophylla* var. *macrophylla* were observed flowering at the same time at the University of Delaware Botanic Gardens during May 2013 (Figure 25). *Magnolia macrophylla* var. *dealbata* is known to flower much earlier even far north of its natural range (Figlar 2013). Bees were observed at flowers of all three plants making the chances of cross-pollination a possibility between these plants a possibility (Figure 26). The scent of *Magnolia macrophylla* var. *ashei* is also distinctly different from both *Magnolia macrophylla* var. *dealbata* and *Magnolia macrophylla* var. *macrophylla*, with the former having a distinctly stronger sweeter smell.

The correct identification these taxa especially of *Magnolia macrophylla* var. *dealbata* needs to be critically evaluated by gardens as this taxon is known to have been grafted onto *Magnolia macrophylla* var. *macrophylla* rootstock. It is believed that some of the plants currently in collections could have potentially died back leaving the rootstock to resprout as *Magnolia macrophylla* var. *macrophylla*. As a result open pollinated seed of
these plants may have been passed on to other gardens as *Magnolia macrophylla* var. *dealbata* (Figlar 2013).

Figure 25. *Magnolia macrophylla* var. *ashei* (left) and *Magnolia macrophylla* var. *macrophylla* (right) flowering at the same time at the University of Delaware Botanic Gardens. Photo taken May 2013.
3.4 In Situ Status *Magnolia macrophylla* var. *ashei*

3.4.1 Herbarium and locality data

Data of 178 herbarium specimens were collected from 15 different herbaria including several digitized specimens (Figure 27, Table 24). Of these specimens 170 (96%) were documented as collected in the wild and eight (4%) represented specimens of unknown or garden origin. The wild collected specimens represented ten different counties in the Florida panhandle.
The *Magnolia macrophylla* var. *ashei* herbarium specimens included several duplicate specimens. Even though no herbarium specimens could be physically studied, several digitized specimens and notes were accessed online. Several specimens described flower color as white or cream making no mention of purple blotching therefore corroborating the reports by several experts that the purple blotching is highly variable for this taxon.
Figure 27. Isolectotype herbarium specimen of *Magnolia macrophylla* var. *ashei* (Photo: University of North Carolina Herbarium)
Locality data from the FNAI (Florida Natural Areas Inventory) listed at least 95 occurrences for *Magnolia macrophylla* var. *ashei* from ten counties (Table 25). As mentioned by NatureServe (2012) the data confirmed that most occurrences for this taxon were last confirmed in the 1980s. Even though at least 12 different management areas are known for *Magnolia macrophylla* var. *ashei* it appears not to form part of any active rare species monitoring programs.

The stewardship overview of *Magnolia macrophylla* var. *ashei* simply states that the communities needs to be left alone by avoiding activities such as logging, clearing, and burning directly in the slope forests (Chafin 2000). It is also recommended that activities in adjacent upslope communities should be monitored so that excessive erosion can be avoided. It is also noted that prescribed burning of adjacent upland communities might actually be beneficial by creating some beneficial natural openings and reduce the spread of competing vines and shrubs.

<table>
<thead>
<tr>
<th>Florida counties</th>
<th>Number of occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay</td>
<td>1</td>
</tr>
<tr>
<td>Clarke</td>
<td>0</td>
</tr>
<tr>
<td>Gadsden</td>
<td>2</td>
</tr>
<tr>
<td>Jackson</td>
<td>2</td>
</tr>
<tr>
<td>Leon</td>
<td>2</td>
</tr>
<tr>
<td>Liberty</td>
<td>24</td>
</tr>
<tr>
<td>Okaloosa</td>
<td>21</td>
</tr>
<tr>
<td>Santa Rosa</td>
<td>7</td>
</tr>
<tr>
<td>Wakulla</td>
<td>3</td>
</tr>
<tr>
<td>Walton</td>
<td>18</td>
</tr>
<tr>
<td>Washington</td>
<td>13</td>
</tr>
</tbody>
</table>
3.5 Summative Conclusions

Globally, botanic gardens and other institutions can play essential roles in conservation efforts for Magnoliaceae. These conservation efforts are not just limited to maintaining *ex situ* collections but include all aspects of integrated plant conservation, such as interpretation of threatened species, research, monitoring of native habitats and reintroduction.

For Magnoliaceae, living plant collections can fulfill an especially crucial role in *ex situ* conservation efforts since other methods such as seed banking and cryopreservation are not considered viable conservation methods at this time. Results from the analysis of the global PlantSearch records for Magnoliaceae showed that botanic gardens exhibit a great bias in cultivating hybrids and cultivars rather than species. Global records also showed that of the taxa kept, the majority was from IUCN conservation status ranks of lower conservation concern.

Survey response rates for these taxa were higher from institutions located in the country of origin. This might be partly due to an increased interest in or awareness of the conservation needs of these taxa in the country of origin. This further highlights the logic for building *ex situ* collections in the county of origin, close to potential reintroduction or restoration programs as suggested by Target 8 of the GSPC and previous research (Maunder *et al.* 2001).

The data show that the global trend of disparity between resources and diversity between countries from the Global North and Global South was also true with regard to Magnoliaceae diversity and *ex situ* Magnoliaceae collections. According to BGCI’s GardenSearch (2013) database, approximately 1,105 gardens (approximately 231 BGCI members) are in the Global South compared to 1,990 gardens (approximately 379 BGCI members) in the Global North. Even if the numbers were potentially skewed by the number of botanic gardens and BGCI members in the Global South uploading data to BGCI’s
PlantSearch database, the differences in these numbers itself is directly connected with the resources available to institutions in these countries.

Analysis of *ex situ* collections from the USA and Mexico were further analyzed as countries from the Global North and Global South with comparable Magnoliaceae diversity. Great disparities were again evident in the number of records and the number of native taxa maintained in collections. While the USA had all its native Magnoliaceae taxa represented in *ex situ* collections with a relatively large number of records per taxa, Mexico had fewer than a quarter of its native taxa represented in *ex situ* collections within its borders. About a third of Mexico’s native Magnoliaceae taxa were represented in collections outside Mexico, more taxa than within the country itself. The total number of known records per taxa was also significantly fewer for Mexican native taxa than for taxa native to the USA.

The results also exposed some weaknesses in record keeping at botanic gardens. At least two gardens believed that their *Magnolia macrophylla* var. *ashei* plants were wild collected but lacked any specific records supporting this claim. Conversely, at least one garden did not record the fact that the plants it bought from a nursery were grown from seed of plants originally collected in the wild. While the Magnolia Society International has distributed seed of this taxon to a substantial number of botanic gardens, it could not produce any records of the origin of seed distributed in past seed exchanges. Further, very few gardens had systems to assess and verify correct identification of their *Magnolia* taxa; most relied on the identification provided by their suppliers. Very few herbarium specimens existed to document material in *ex situ* collections. Therefore, substantial uncertainty on the real identity of the accessions studied exists and, unfortunately, time constraints prevented identity verification. For all three *Magnolia* taxa used as case studies, a very small number of accessions in botanic gardens had a known wild origin. The above-mentioned results for these North American taxa corroborate previous studies that found
that botanic gardens’ collections are dominated by non-wild collected accessions that are often inadequately documented and often representing conservation status ranks of lesser conservation concern (Aplin 2008, Maunder et al. 2001).

Target 8 of the GSPC aims to have at least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs by 2020 (Oldfield 2012). If Target 8 of the GSPC is to be reached by 2020, *ex situ* collections of known wild origin need to increase dramatically because they are considered preferred material for restoration and recovery programs. Only between 4% and 27% of botanic gardens maintained wild-collected material of the taxa studied. Very few records could also be located for seed in seed banks, which probably is correlated with the fact that *Magnolia* seed cannot currently be successfully stored for long time periods.

Commercial nurseries could also play a crucial role in the conservation of these threatened taxa as most botanic gardens in this study purchased their material from nurseries. Even though most nurseries provided origin information for the plants they sold, some nurseries refused to divulge the sources thereof. Botanic gardens should avoid nurseries that refuse to provide this information to ensure ethical collecting practice. For *Magnolia macrophylla* var. *ashei*, most nurseries obtained material from only a few sources. So the plant material sold in nurseries, like the material in botanic gardens, was probably not genetically representative. This thesis research did not conduct genetic analysis of *ex situ* collections versus natural populations to confirm or deny this suspicion. Some nurseries and botanic gardens also commented on how difficult it was to obtain permits to collect material of these taxa in the wild. A closer collaboration between conservation agencies and botanic gardens interested in responsible collecting can also help the overall conservation of these threatened taxa.
In the case of all three taxa studied, very few were interpreted to visitors in gardens reporting them in their collections. Even fewer gardens interpreted the conservation status of these taxa, which does not bode well for creating awareness and ultimately action for habitat conservation or rehabilitation.

Only in a few cases were living collections of these taxa used for research or propagation; most gardens maintained these plants solely for display purposes. No evidence was found that _ex situ_ collections of these taxa were used for more collaborative research or conservation projects. Very few gardens were involved with wild collecting efforts or wild populations monitoring for these taxa. While the vast majority of botanic gardens stated that conservation was within their mission, fewer expressed interest in becoming involved in integrated conservation efforts.

All three _Magnolia_ taxa used as case studies could be considered best-case scenarios; there are relatively large numbers of known records in multiple _ex situ_ collections and the trees considered attractive and horticulturally amenable. The data, however, demonstrated that even these _Magnolia_ taxa are probably not as secure as previously thought. The data also indicated that these _ex situ_ collections are hardly used to support integrated plant conservation efforts and there seems to be no change in this regard since researchers began publishing on this topic a little more than a decade ago.

There are many resources to guide the involvement of botanic gardens in integrated conservation efforts, notably Oldfield and Newton (2012) _Integrated conservation of tree species by botanic garden: a reference manual_. It has now become crucial for botanic gardens to take action in this regard in the following ways:

- Interpret threatened species to create awareness
- Prioritize collecting plants of known wild origin
- Improve recordkeeping standards
o Make data available to other stake-holders by uploading and updating data to databases like BGCI’s PlantSearch database
o Conduct more targeted collecting, especially of species and populations not yet in cultivation and of conservation status ranks of conservation concern
o Support in-country *ex situ* conservation where possible
o Integrate institutional research with conservation needs for specific plant families or taxa.
REFERENCES


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Appendix A

EXAMPLE OF SURVEY USED TO ASSES INSTITUTIONAL INVOLVEMENT IN CONSERVATION OF MAGNOLIA TAXA
Assessing global support for integrated conservation of *Magnolia macrophylla* var. *ashei* (Synonyms *Magnolia ashei; Magnolia macrophylla* subsp. *ashei*)

Dear Colleague,

Please take 20 minutes to complete this survey about how your institution contributes to integrated conservation efforts for *Magnolia macrophylla* var. *ashei* (Synonyms *Magnolia ashei; Magnolia macrophylla* subsp. *ashei*). *Magnolia macrophylla* var. *ashei* is restricted to scattered sites on the Florida Panhandle and its conservation status is currently listed as G2 imperiled by NatureServe. The aim of this survey is to collect baseline data to better inform future integrated plant conservation efforts for *M. macrophylla* var. *ashei* within the botanical community.

This survey is being conducted by Martin Smit, a Fellow in the Longwood Graduate Program at the University of Delaware, in collaboration with Botanic Gardens Conservation International (BGCI) and Magnolia Society International (MSI).

Please note that participation in this survey is voluntary and you may exit at any time. Potentially sensitive information, such as location details, will be managed with the necessary consideration. Questions may be directed to Martin Smit (msmit@udel.edu).

**Ex situ**

What is the name of your institution?

---

Is *Magnolia macrophylla* var. *ashei* maintained in your institution’s living plant collection?

- Yes
- No
Which of the following categories of accessions are represented in your institution's living collection for *Magnolia macrophylla* var. *ashei*?

- [ ] Known wild origin
- [ ] Non-wild or unknown origin
- [ ] Records lost/insufficient

How many accessions of *Magnolia macrophylla* var. *ashei* with **known wild origin** are present in your institution’s living collection?

How many accessions of *Magnolia macrophylla* var. *ashei* with **non-wild or unknown origin** are present in your institution’s living collection?

How many accessions of *Magnolia macrophylla* var. *ashei* with **records lost/insufficient** are present in your institution’s living collection?

Known-wild origin
Living collections, **Known wild origin** accession details:
(Please try to complete all fields)
*Note that these fields will be repeated once for every accession reported in this category*

- [ ] Accession number
- [ ] Number of individual plants in collection for this accession
- [ ] GPS location of collection origin
- [ ] National grid reference of collection origin
- [ ] Origin location description of (Roads, town, county, etc.)
- [ ] Origin habitat description
- [ ] Collected as (seed, cutting, etc.)
- [ ] Date of original collection
- [ ] Name of collector
- [ ] Other relevant collection notes
- [ ] Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

**Non-wild origin**

Living collections, **Non-wild or unknown origin** accession details:
(Please try to complete all fields)
*Note that these fields will be repeated once for every accession reported in this category*

- [ ] Accession number
- [ ] Number of individual plants in collection for this accession
- [ ] Source of material
- [ ] Other relevant collection notes
- [ ] Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

**Records lost/insufficient**
Ex situ continued

Does your institution have preserved germplasm or specimens of *Magnolia ashei* represented in the following? (Please select relevant collections and categories)

<table>
<thead>
<tr>
<th>Collection</th>
<th>Known wild origin</th>
<th>Non-wild or unknown origin</th>
<th>Records lost/insufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryopreservation collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed bank collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbarium collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gene bank and/or tissue culture</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How many specimens with **known wild origin** of *Magnolia macrophylla var. ashei* are present in the cryopreservation collection?

How many specimens with **non-wild or unknown origin** of *Magnolia macrophylla var. ashei* are present in the cryopreservation collection?

How many specimens with **records lost/insufficient** of *Magnolia macrophylla var. ashei* are present in the cryopreservation collection?

How many accessions with **known wild origin** of *Magnolia macrophylla var. ashei* are present in the seed bank collection?
How many accessions with **non-wild or unknown origin** of *Magnolia macrophylla* var. *ashei* are present in the seed bank collection?

How many accessions with **records lost/insufficient** of *Magnolia macrophylla* var. *ashei* are present in the seed bank collection?

How many specimens with **known wild origin** of *Magnolia macrophylla* var. *ashei* are present in the herbarium collection?

How many specimens with **non-wild or unknown origin** of *Magnolia macrophylla* var. *ashei* are present in the herbarium collection?

How many specimens with **records lost/insufficient** of *Magnolia macrophylla* var. *ashei* are present in the herbarium collection?

How many specimens with **known wild origin** of *Magnolia macrophylla* var. *ashei* are present in the gene bank or tissue culture collection?

How many specimens with **non-wild or unknown origin** of *Magnolia macrophylla* var. *ashei* are present in the gene bank or tissue culture collection?
How many specimens with **records lost/insufficient** of *Magnolia macrophylla* var. *ashii* are present in the gene bank or tissue culture collection?

### Known wild-origin cryopreservation

Cryopreservation, accessions with **known wild origin**:  
(Please try to complete all fields)  
Note that these fields will be repeated once for every accession reported in this category

- [ ] Same information as previously supplied (No need to repeat data entry. Please describe which accessions/reference numbers)
- [ ] Database/Reference number
- [ ] Number of individual samples in collection for this accession
- [ ] GPS location of collection origin
- [ ] National grid reference of collection origin
- [ ] Origin location description (Roads, town, county, etc.)
- [ ] Origin habitat description
- [ ] Date of original collection
- [ ] Name of collector
- [ ] Other relevant collection notes
- [ ] Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

### Non-wild or unknown origin cryopreservation
Cryopreservation, accessions with **non-wild or unknown origin**:

(Please try to complete all fields)

**Note that these fields will be repeated once for every accession reported in this category**

- [ ] Database/Reference number
- [ ] Number of individual plants in collection for this accession
- [ ] Source of material
- [ ] Other relevant collection notes
- [ ] Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen number

**Records lost/insufficient cryopreservation**

Cryopreservation, accessions with **records lost/insufficient**:

(Please try to complete all fields)

**Note that these fields will be repeated once for every accession reported in this category**

- [ ] Please supply any relevant information

**Known wild-origin seed bank**
Seed bank, accessions with **known wild origin**:
(Please try to complete all fields)
*Note that these fields will be repeated once for every accession reported in this category*

- Same information as previously supplied (No need to repeat data entry. Please describe which accessions/reference numbers)
- Database/Reference number
- Number of individual samples in collection for this accession
- GPS location of collection origin
- National grid reference of collection origin
- Origin location description (Roads, town, county, etc.)
- Origin habitat description
- Date of original collection
- Name of collector
- Other relevant collection notes
- Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

Non-wild or unknown origin seed bank

Seed bank, accessions with **non-wild or unknown origin**:
(Please try to complete all fields)
*Note that these fields will be repeated once for every accession reported in this category*

- Database/Reference number
- Number of individual plants in collection for this accession
- Source of material
- Other relevant collection notes
- Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

Records lost/insufficient seed bank
Seed bank, accessions with records lost/insufficient:
(Please try to complete all fields)
Note that these fields will be repeated once for every accession reported in this category

☐ Please supply any relevant information

____________________________

Known wild-origin herbarium

Herbarium, specimens with known wild origin:
(Please try to complete all fields)
Note that these fields will be repeated once for every specimen reported in this category

☐ Same information as previously supplied (No need to repeat data entry. Please describe which accessions/reference numbers)

☐ Database/Reference number

____________________________

☐ Number of individual specimens in collection for this accession

____________________________

☐ GPS location of collection origin

____________________________

☐ National grid reference of collection origin

____________________________

☐ Origin location description (Roads, town, county, etc.)

____________________________

☐ Origin habitat description

____________________________

☐ Date of original collection

____________________________

☐ Name of collector

____________________________

☐ Other relevant collection notes

____________________________

☐ Is this specimen linked to any other herbarium specimens? If so please provide herbarium name and specimen ID number

____________________________

Non-wild or unknown origin herbarium
Herbarium, specimens with non-wild or unknown origin:
(Please try to complete all fields)
Note that these fields will be repeated once for every specimen reported in this category

- Database/Reference number
- Number of individual plants in collection for this accession
- Source of material
- Other relevant collection notes
- Is this accession linked to any other herbarium specimens? If so please provide herbarium name and specimen ID number

Records lost/insufficient herbarium

Herbarium, specimens with records lost/insufficient:
(Please try to complete all fields)
Note that these fields will be repeated once for every specimen reported in this category

- Please supply any relevant information

Known wild-origin gene bank
Gene bank and/or tissue culture collection, specimens with known wild origin:
(Please try to complete all fields)
Note that these fields will be repeated once for every specimen reported in this category

☐ Same information as previously supplied (No need to repeat data entry. Please describe which accessions/reference numbers)

☐ Database/Reference number

☐ Number of individual samples in collection for this accession

☐ GPS location of collection origin

☐ National grid reference of collection origin

☐ Origin location description (Roads, town, county, etc.)

☐ Origin habitat description

☐ Date of original collection

☐ Name of collector

☐ Other relevant collection notes

☐ Is this specimen linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

Non-wild or unknown origin gene bank and/or tissue culture collection

Gene bank and/or tissue culture collection, specimens with non-wild or unknown origin:
(Please try to complete all fields)
Note that these fields will be repeated once for every specimen reported in this category

☐ Database/Reference number

☐ Number of individual plants in collection for this accession

☐ Source of material

☐ Other relevant collection notes

☐ Is this accession linked to any herbarium specimens? If so please provide herbarium name and specimen ID number

Records lost insufficient gene bank and/or tissue culture collections
Gene bank and/or tissue culture collection, specimens with records lost/insufficient: (Please try to complete all fields)

Note that these fields will be repeated once for every specimen reported in this category

- Please supply any relevant information

Interpretation

Have any of your institution’s specimens of Magnolia ashei been used for research either on-site or off-site? (Select all that apply)

- Reproductive biology (Please describe)
- Propagation (Please describe)
- Cultivation (Please describe)
- Genetic analysis (Please describe)
- Other (Please describe)

Are any specimens of Magnolia macrophylla var. ashei interpreted at your institution?

- Yes
- No

Which of the following interpretation methods are used to interpret Magnolia macrophylla var. ashei?

- Accession label
- Interpretive signs/labels
- Guided tours or docents
- Other (Please describe)
Is the current conservation status of *Magnolia macrophylla* var. *ashei* interpreted?

- Yes (Please describe)
- No

**In situ conservation**

Is your institution involved in any wild population monitoring efforts for *Magnolia macrophylla* var. *ashei*?

- Yes
- No
- Other

Is your institution involved in any habitat preservation/restoration on sites where *Magnolia macrophylla* var. *ashei* is native?

- Yes
- No
- Other

Is your institution involved in any wild collecting efforts for *Magnolia macrophylla* var. *ashei*?

- Yes
- No
- Other

**General**

Has your institution been involved in any other research or conservation efforts on Magnoliaceae?

- Yes
- No
Please select the type of research that your institution is involved in for Magnoliaceae.

☐ Conservation efforts (please provide details)

☐ Taxonomic research (please provide details)

☐ Ecological research (please provide details)

☐ Reproductive biology (please provide details)

☐ Propagation protocols (please provide details)

☐ Other (please provide details)

Do you know of any other institutions doing research on Magnoliaceae?

☐ Yes (Please provide the institutions' names)

☐ No

Would your institution like to become involved in integrated conservation efforts for *Magnolia macrophylla* var. *ashei*?

☐ Yes

☐ No

☐ Not sure

Demographics

Is conservation seen as a part of the mission of your institution?

☐ Yes

☐ No

☐ Other
Does your institution have any of the following activities? (Check all that apply)

- Conservation Program
- Medicinal Plant Program
- Ex Situ Program
- Reintroduction Program
- Interpret threatened species in collections

Please provide your contact details:

- Name
- Position
- E-mail
- Telephone number

Additional comments here:
Appendix B

CERTIFICATION OF TRAINING HUMAN SUBJECTS IN RESEARCH

Certification of Training
Human Subjects in Research

The University of Delaware certifies that Martin Smit
(Name of researcher)

attended an institutional training session on the use of human subjects in research on

September 1, 2011,
(Date)

The session included the following topics:

• The Belmont Report
• Federal regulations for using humans in research (45 CFR 46)
• The University’s Federalwide Assurance
• Informed consent
• Institutional procedures
• Sources for additional information.

Cordell M. Overby, ScD
Associate Provost for Research

Research Office
University of Delaware
Newark DE 19716
302-831-2137