A Rare Opportunity:

A Case for Rare Plant Conservation at Matthaei Botanical Gardens & Nichols Arboretum

by

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Contents

Introduction

The rate of biodiversity loss caused by humans has increased over the last century, and the current rates of species extinction are twice as high as the expected background extinction rates, creating what is known as the Sixth Mass Extinction (M.E.A., 2005, Ceballos et al., 2015). Not only are we seeing increases in biodiversity loss, but we are also experiencing biotic homogenization, where endemic species are lost to widespread species (McKinney & Lockwood, 1999). This loss in biodiversity can result in the removal of functional traits and functional groups of an ecosystem, leading to a loss of ecosystem resilience (Folke et al., 2004, Cardinale et al., 2012).Resilience, as Holling (1973) describes, is the ability of an ecosystem to absorb changes and still maintain its state and function. Furthermore, in the context of plant communities, increases in plant biodiversity are linked to decreases in plant pathogens and increases in wood production, resistance to plant invasion, carbon sequestration and storage, soil organic matter, and soil nutrient mineralization (Cardinale et al., 2012).

Rare species contribute to plant biodiversity, and although they have been thought to play insignificant roles in ecosystem services (Dee et al., 2019), rare plants have been shown to be important in nutrient availability and cycling, providing critical resources to pollinators (Jolls et al., 2018), and preventing new species invasions (Lyons et al., 2005). Mouillot et al. (2013) found that rare species in alpine ecosystems provided important functional traits to support insects and that a rare tree species in French Guiana may be able to withstand increasing fire frequency and maintain forest function and structure in future climate states. In addition to ecosystem services, rare species provide important cultural services (Dee et al., 2019), an example being Michigan's state wildflower, Dwarf Lake Iris (*Iris lacustris*), a Threatened

species endemic to the Great Lakes Region. Despite their ecological and cultural importance a growing number of rare plant species face the threat of extinction.

In response to the growing threat of extinction to plant species around the globe, the Convention on Biological Diversity (CBD) developed the Global Strategy for Plant Conservation (GSPC) in 2002 (*Background and Consultations,* n.d.). In fact, approximately 36.5% of all land plants are rare (Enquist et al., 2019). The United States and Michigan are not immune to plant extinction; one third of U.S. native flora is threatened, including 11-16% of tree species (Havens et al., 2014, Carrero et al., 2022), and in Michigan, approximately 24% (441) of native plant species are considered rare (i.e., Special Concern [114], Threatened [202], Endangered [78], or Extirpated [48]) (Michigan Flora Online, n.d.; Michigan's Rare Plants - Michigan Natural Features Inventory, n.d.). One of the goals of the GPSC to help address plant extinctions, is Target 8, which calls for "at least 75% of threatened plant species to be represented in ex-situ collections" and "at least 20% of those threatened species to be available for recovery and restoration programs by 2020."

Ex-situ conservation refers to conservation methods in which a species is conserved in a place other than where it naturally occurs (in-situ). While in-situ conservation or protecting species in their natural habitats is the ultimate goal of conservation, this approach is not without drawbacks. In general, in-situ conservation is more costly, and in an ecosystem approach to conservation, plant populations are still susceptible to natural disasters and anthropogenic threats, such as invasive species, pests, and climate change (Falk, 1990, Heywood & Iriondo, 2003, Li & Pritchard, 2009, Mounce et al., 2017, Soulé & Mills, 1992). To demonstrate the cost difference between in- and ex-situ conservation, it has been estimated that ex-situ seed conservation costs as little as 1% of that of in-situ conservation (Li & Pritchard, 2009). However,

ex-situ conservation is not without its own issues. Specifically, ex-situ conservation efforts that involve cultivating plant species must deal with genetic drift, artificial selection, and in/out-breeding depression, all of which can render a collection useless as a source for conservation purposes (Volis & Blecher, 2010). Overall, however, botanical gardens and seed banks maintain samples of plant diversity that are believed to be lost from the wild, which has prevented or delayed extinctions for many species (Raven, 2004). Organizations such as botanical gardens are ideally situated to support both ex-situ and in-situ conservation efforts.

Currently, botanic gardens are performing plant conservation with networks of botanic gardens facilitating the work (Havens et al., 2014). Botanical gardens having an active role in conservation is not new and can be traced back to the International Congresses for Nature Protection in 1923 and 1931 (Volis & Blecher, 2010). With infrastructure such as greenhouses and irrigation already in place and horticulturists with skills applicable for in-situ conservation, botanic gardens are ideal sites for plant conservation (Blackmore et al., 2011). Worldwide they host millions of visitors each year (Havens et al., 2006, Westwood et al., 2021, Blackmore et al., 2011), and they are sites of critically important research (see: Primack & Miller-Rushing, 2009, Norstog et al., 1986). Botanic gardens have also done significant research in understanding how plants will respond to climate change and have instituted citizen science programs that help monitor threatened species populations (Chen & Sun, 2018, Havens et al., 2006).

Even though there is a history of botanical gardens having a role in plant conservation, Mounce et al. (2017) report that only 41% of all threatened species are accounted for in ex-situ collections and comprise only 10% of total collections. Additionally, Westwood et al. (2021) have argued that “gardens will not be able to achieve the results needed to avert the plant extinction crisis without a revolution in the way resources, funding, and public attention are

focused." This indicates that there is still progress to be made in plant conservation at botanic gardens.

Matthaei Botanical Gardens and Nichols Arboretum (MBGNA) is positioned perfectly to step into a role of rare plant conservation. The mission of MBGNA is as follows:

"Matthaei Botanical Gardens and Nichols Arboretum is a transformative force for social and ecological resilience through the waters and lands we steward. We turn this commitment into action by:

- ***Positioning** humans as active participants within the natural world and compelling the university community and our publics to negotiate the full complexity that entails*
- ***Advancing** partnerships, programs, user experience, and all that we steward to catalyze equity and justice in a radically changing world*
- ***Emerging** as University of Michigan's premier partner for research, teaching, and public impact in sustainability, climate-forward practices, and biocultural diversity*
- ***Promoting** healthier communities, cultures, and ecosystems through active care and cultivation of the gardens, fields, natural habitats, and dynamic systems that sustain our world"*

Having a robust rare plant conservation program would enable MBGNA to fulfill its mission in promoting healthier ecosystems and advancing partnerships. In addition, across its four properties and conservatory, MBGNA holds approximately 93 species of plants that have legal protection or are species of special concern, which may need legal protection in the future. Despite this number of rare plants, MBGNA has no specific, focused program or person dedicated to the conservation of rare plants. The goals of this report are:

1) to outline reasons why it is possible for MBGNA to have such a program

2) to address what species MBGNA should initially focus on

3) to demonstrate what forms the conservation program could take

4) identify who the program could engage with.

Methods

The project included three primary activities. First, a list of all rare plant occurrences on MBGNA properties was compiled, physiognomy was recorded, and all species conservation ranks and statuses were compiled from multiple sources (see Table 2). Four classifications of physiognomy were used to categorize species, including Graminoid, Forb, Shrub, and Tree. For this report, Graminoid refers to plants that are grass-like, such as grasses, sedges, and rushes while Forbs are those that are herbaceous, and non-graminoid. Following the Global Tree Assessment initiative (Barstow et al., 2021) for defining shrubs and trees, Shrubs are woody plants, potentially multi-stemmed or less than 2 meters in height and includes subshrubs such as cacti, while Trees are woody plants that are single-stemmed or more than 2 meters in height and, following Carrero et al. (2022), includes palms, yuccas, and aloes that fall within those qualifiers. Shrub and tree determination were aided using Kew's Plants of the World Online (*Kew Science,* n.d.). Five different listing metrics were used to categorize species rarity, including the IUCN Red List, NatureServe Global Rank, NatureServe State Rank, Federal status, and State status. Continent and country of origin for rare species was determined using IUCN Red List geographic range information and NatureServe. The IUCN Red List Categories considered here are as follows: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU). IUCN considers the rankings of Critically Endangered, Endangered, and Vulnerable to be 'Threatened Categories' and species assigned to these categories have a higher risk of extinction

(IUCN 2022). NatureServe rankings only address species native to the United States and Canada. NatureServe's global (G) and subnational (state, S) rankings range from Critically Imperiled (G1, S1), Imperiled (G2. S2), Vulnerable (G3, S3), Apparently Secure (G4, S4), and Secure (G5, S5) (Charts 4). NatureServe's subnational rankings are assigned by each state, and in this paper's case, are provided by Michigan Natural Features Inventory (MNFI). Federally listed species are given two categories; Endangered (E) or Threatened (T) (Chart 5). The State of Michigan recognizes three categories of rarity; these include Endangered (E), Threatened (T), and Special Concern (SC) (Chart 5). Species listed by the State of Michigan as Endangered or Threatened are afforded legal protection, while species that are Special Concern are thought to be declining and worthy of tracking.

Secondly, a wide range of conservation organizations were consulted or reviewed. The consultations included email exchanges, Zoom meetings, and phone calls with directors, curators, researchers, and rare plant conservation program staff. Reviews of conservation organizations also consisted of reviewing organizational websites.

Third, a literature review was done for the following rare species that MBGNA could choose to focus on to begin its rare plant conservation program: *Tetraneuris herbacea* (Lakeside Daisy), *Iris lacustris* (Dwarf Lake Iris), *Cirsium pitcheri* (Pitcher's Thistle), *Betula murrayana* (Murray Birch), and *Panax quinquefolius* (American Ginseng). These species were selected due to their indigeneity to Michigan, with three species being endemic to the Great Lakes Region, and their current or previous presence at MBGNA. The aim of the literature review was to understand the species' biology and ecology, current threats, research that has already been done, existing knowledge gaps, and opportunities for conservation action.

Compiling a list of rare plants occurrences

A list of rare plant occurrences on MBGNA properties was compiled from multiple sources to help assess the current role of the organization in conserving rare plants. This was completed by communicating with staff, reviewing past survey and planting records, and conducting surveys throughout the growing season of 2021. Rare plant surveys were conducted at the following three properties managed by MBGNA: Matthaei Botanical Gardens; Nichols Arboretum; and Horner-McLaughlin Woods. Information on previously known rare plant occurrences from these properties was gained through several sources: A 2011-2012 survey of natural communities and flora of MBGNA (Walters et al., 2012) provided the locations of some rare flora on the properties; relevant planting maps at Matthaei Botanical Gardens were consulted for spaces that potentially had rare plants planted in them; rare plant occurrences were ascertained through consulting with current MBGNA staff and those with past association.

Rare Plant Conservation Organization Overview

In order to better understand how various organizations engage in plant conservation and to assess the potential for an expanded role for MBGNA, we corresponded and met with staff from several conservation organizations and reviewed the websites of multiple rare plant conservation programs. Several types of organizations were consulted to determine the following: work being done to conserve rare plants; steps needed to develop a rare plant conservation program; and whether or not a rare plant conservation program at MBGNA would be valued by other conservation organizations. The organizations consulted can be categorized in the following way: botanical gardens/arboreta, government agencies, local land conservancies, and other botanical related non-profit organizations (see Table 1).

Two organizations, the Center for Plant Conservation (CPC) and Botanic Gardens Conservation International (BGCI), track which organizations maintain in-situ collections of which rare species. These collections lists were consulted and compared with MBGNA's rare plant list.

Table 1. Organizations consulted.

Botanical Gardens/Arboreta	**Government Agencies**	**Local Land Conservancies**	**Botanical Non-profit Organizations**
Mt. Cuba Botanical Garden	City of Ann Arbor Natural Areas Preservation	Legacy Land Conservancy	Center for Plant Conservation
Holden Arboretum	Washtenaw County Parks Natural Areas Preservation Program	Southeast Michigan Land Conservancy	Botanic Gardens Conservation International
Minnesota Landscape Arboretum	Oakland Township Parks and Recreation		North American Orchid Conservation Center
Chicago Botanical Garden	Michigan Department of Natural Resources		MBGNA Campus Farm
Missouri Botanical Garden	Toledo Metroparks		
Atlanta Botanical Garden	Springfield Township Parks and Recreation		

Literature Review of Rare Plants

Beginning a rare plant conservation program requires knowing which plants or group of plants should be the initial focus of the program. Five plant species were selected as possible candidates to be the initial focus of a conservation program. The plants include: *Tetraneuris herbacea*, *Iris lacustris*, *Cirsium pitcheri*, *Betula murrayana*, and *Panax quinquefolius*. These plants were chosen for this report due to their current occurrences at MBGNA, endemism to the Great Lakes Region (except for *Panax quinquefolius*), and global rarity.

Results

Rare Plant Occurrences at MBGNA

The surveys across MBGNA properties and collections revealed the presence of 93 unique, rare plant species (Table 2). Rare plants currently make up 6.2% of the approximately 1500 species held in MBGNA collections.

Considering first the distribution of plant physiognomy (Chart 1), the majority of the rare plants are either forbs or trees, 46% and 30% respectively. Sixty percent of the rare plants in the MBGNA collection are native to North America, while 35% are from Central America, Europe, Africa, Asia, and the Middle East (Chart 2). Most rare species in the MBGNA collection are native to the United States and Canada, 55 and 56 respectively, and Mexico is a distant third with 10 species. Natural populations are known from 61 countries, with some species native to multiple countries, for example, *Prunus africana* (African Cherry) is native to 22 countries in Africa (Chart 3).

Despite 93 rare species being identified, comparisons with past surveys (Walters et al., 2012) and planting maps revealed that several intentionally planted and three naturally occurring species are no longer present or could not be located. Naturally occurring species that had previously been observed and could no longer be located, despite multiple surveys at different points throughout the growing season included *Hydrastis canadensis* at Horner Woods and *P. quinquefolius* and *Cypripedium candidum* (White Lady-Slipper) at Matthaei Botanical Gardens.

Looking at the IUCN Red List, species listed as Endangered (EN) make up the largest proportion with 26 species, followed by Vulnerable (VU) with 17 species, and Critically Endangered with 11 (Chart 3). 53 species of rare plants at MBGNA are included in the IUCN

Red List ranging from Critically Endangered (CR) to Vulnerable (VU). NatureServe's global ranking shows that 14 species are Critically Imperiled (G1), Imperiled (G2) and Vulnerable (G3); most of which being G3 (8) (Chart 4). However, MNFI's state ranking assigns 38 species as Critically Imperiled (S1), Imperiled (S2) and Vulnerable (S3), with 31% percent Critically Imperiled (S1), 45% Imperiled (S2), and 24% Vulnerable (S3) (Chart 4).

Five species in the collection have a federal listing of either Endangered (E) or Threatened (T) (Chart 5). Meanwhile, there are 30 species considered to be Endangered (E) or Threatened (T) in Michigan, while 9 species are considered to be Special Concern (SC) (Chart 5). MBGNA collections include roughly 8.5% of the 441 plants classified as Endangered, Threatened, Special Concern, or Extirpated in the state of Michigan.

Rare Plant Conservation Organization Overview

The Center for Plant Conservation

The Center for Plant Conservation (CPC) is a network of organizations committed to plant conservation in the United States. The 65 participating institutions share information and data and have access to funding opportunities through CPC grants and opportunities to store seeds with the USDA-ARS National Laboratory for Genetic Resources Preservation or the Millennium Seed Bank at Kew Gardens. Membership with the CPC would cost $1,550 annually (*Become A Conservation Partner*, 2022). Currently, no other botanical garden or conservation organization within the state of Michigan is a member of the CPC.

Joyce Maschinski, the past President of the CPC, was consulted to ascertain how the CPC operates and how a membership may help a rare plant conservation program at MBGNA.

The CPC has what it calls its "National Collection," which is a collection of globally threatened species held in the collections of participating institutions and is considered a backup for plants that may go extinct in the wild. Currently, MBGNA has seven species that are already represented in the National Collection. However, a key part of a collection qualifying to be part of the National Collection is that 1) it is a viable population, 2) the provenance (i.e., place of origin) of the individuals is known, and 3) a voucher specimen has been deposited in an herbarium. If MBGNA were to apply for any of its rare plants to become part of the CPC national collection, it would need to be able to ensure those qualifiers.

The CPC provides considerable resources for best practices for plant conservation. This includes best practices for seed banking, alternatives to seed banking, genetic guidelines, horticulture, reintroduction/translocations, and documentation. Beyond guidelines for these practices, the CPC also provides template forms for monitoring and collecting (*CPC Best Practices: Why Conserve Rare Plants?*, 2021). Their annual conference is well attended by plant conservation scientists from botanical gardens across North America.

Botanic Gardens Conservation International

Botanic Gardens Conservation International (BGCI) is a global network of botanic gardens across more than 100 countries that works to connect botanical gardens for plant conservation (*Our Organisation,* 2019). Correspondence with the Executive Director of BGCI US, Abby Meyer, and the Membership and Conservation Services Officer, Patricia Malcolm, yielded information regarding member benefits and other topics. Annual cost of joining this network would be $1,175 for MBGNA.

BGCI states that in developing a rare plant conservation program, a clear link between the program and MBGNA's mission must be established. It also must be clear how the program will further the goals of the organization.

BGCI offers accreditation schemes that can be used to measure program success within the organization and has grants available to their members to aid in funding their plant conservation programs.

For plants in collections that have unknown provenance, BGCI recommends using these specimens for education and awareness. Plants of unknown provenance are usually not useful for other conservation efforts like outplanting.

North American Orchid Conservation Center

The North American Orchid Conservation Center (NAOCC) is the only nationwide collaborative effort working to conserve North American Orchid species. It was established by the Smithsonian Environmental Research Center and the United States Botanic Garden and works to preserve naturally occurring orchids, develop protocols for growing orchids, and educate the public about orchids native to North America (*About Go Orchids*, n.d.). Currently, NAOCC has 25 collaborators across North America. NAOCC supports its collaborators with grants ranging from $20,000-50,000 per year.

Native Plant Network

The Native Plant Network is a network created to provide technical and practical information on the growing and planting of North American native plants (*Native Plant Network — Reforestation, Nurseries and Genetics Resources*, n.d.). The Network has created a database of propagation protocols for North American plant species. This database was cross-referenced

with MBGNA's list of rare plants to see which species already have propagation protocols and which do not. In total, 24 rare species on MBGNA properties have propagation protocols in the Native Plant Network (Table 5 in Appendix B).

Minnesota Landscape Arboretum

The Minnesota Landscape Arboretum (MLA) has a dedicated plant conservation program, the Native Orchid Conservation Program. MLA has projects dedicated to orchid seed storage, orchid seed germination, extraction of fungal associates, and orchid displays. David Remucal, the Curator of Endangered Plants and Program Director, has assisted MBGNA already by germinating orchid seed and sending protocorms and seedlings to MBGNA.

The Curator of Endangered Plants position was developed in 2013 and was tasked with figuring out what a conservation program would look like at MLA. The position was part time, and the program had little funding starting out, however, grants from the Minnesota Lottery eventually allowed Remucal to become full time. In order to have a very directed program, orchids native to Minnesota were chosen to be the focus. A relationship with the Minnesota Department of Natural Resources (DNR) was developed, which has resulted in MLA working with the DNR on translocation projects. This work has involved collecting orchid seeds in the wild, propagating them at MLA, and planting young orchids back into sites where they had formerly occurred.

In addition to native orchids, MLA also manages 12 other rare species of plants for the CPC as part of their National Collection. Remucal feels that the CPC has been extremely useful for MLA's plant conservation due to sharing of information between organizations that are part of the CPC network.

Seeds for plant conservation have been sent to the National Seed Bank (NSB), however, NSB does not accept orchid seeds due to the difficulty associated with their storage. MLA also has their own seed bank.

Remucal noted that MLA is one of the more active groups within NAOCC.

Holden Arboretum

Holden Arboretum is located in Kirtland, OH. It is a partner with the CPC and holds seven plant species that are part of the CPC National Collection and that also are in the MBGNA collection (Table 3 in Appendix B). To understand how the Holden Arboretum addresses plant conservation, an interview was held with the Curator of Living Collections, Tom Arbour, and Natural Areas Biologist, Becah Troutman.

Historically, Holden has had a close relationship with the Ohio Department of Natural Resources, which was progressive about including rare plants in Holden's collections. The Myrtle S. Holden Wildflower Garden is now the home to species that Holden refers to as "vanishing flora of the Great Lakes Region." This garden was practically covertly installed, but now is a significant display garden of native flora.

For plants that are part of the CPC National Collection, Holden used to have signage discussing their rarity, however, the advent of social media seems to have resulted in plant theft from the gardens.

In the future, Holden is looking to expand its role in plant conservation. Currently, they have a collection of plants from Madagascar, for example. However, they would like to focus primarily on Ohio. This is resulting in a review of which plants might be a better fit elsewhere. For example, looking at *Cirsium pitcheri*, they are questioning whether it makes sense for them

to have a collection of this species even though it is not found in Ohio and considerable effort is needed to obtain new seed.

Holden suggests that MBGNA examine its mission and consider whether or not a rare plant conservation program aligns with it. In addition, it stressed that relationships with land managers outside of the organization must be built.

Mt. Cuba Center

Mt. Cuba Center is a botanical garden located in Delaware that began working with native plants 50 years ago, however, a focus on native plants threatened with extinction began approximately 10 years ago. Speaking with the Director of Collections and Conservation Lead, Amy Highland, I was able to better understand Mt. Cuba's path to where it is now and receive her recommendations for beginning a rare plant conservation program. They have recently hired a Conservation Fellow who will be responsible for increasing the level of conservation storytelling, presenting internally and externally, reinvigorating their citizen science program, and starting a Mid-Atlantic Plant Conservation Alliance.

Mt. Cuba is a partner with both the CPC and BGCI, although they have been partners for a relatively short time, 1 year and 4 years, respectively.

Highland stressed that a plant conservation program is an iterative process; they are still figuring things out themselves. For example, measuring the success of their conservation program is difficult and still something that they struggle with. Two of the questions they ask themselves are: 1. How is this program making people conservation-minded? 2. How to measurably assess that the program is improving habitat. In addition, Highland has observed that plant conservation is not a particularly diverse field in terms of the race and ethnicity of its practitioners.

For MBGNA, Highland suggests performing a Strengths, Weaknesses, Opportunities, Threats (SWOT) Assessment before pursuing such a program and to also consider the mission and vision of the organization and where a rare plant conservation program fits in; connections must be made with collections policies.

Atlanta Botanical Garden

The Atlanta Botanical Garden (ABG) contains a Conservation & Research department that employs 20 staff members. This department is actively performing in-situ conservation with eight rare plant species native to the Southeastern United States. They are responsible for maintaining a database that holds information on rare plant collections in Georgia and on material that has been reintroduced into the wild. Beyond work within the United States, they are also active in the Caribbean, Colombia, and Ecuador, where they are involved with in-country capacity building, collaboration, research, and outreach.

ABG's Micropropagation Lab, Conservation Greenhouse, Safeguarding Nursery, Seedbank, and CryoBank are all facilities that are dedicated to plant conservation. The Micropropagation Lab is used to develop propagation protocols, especially for orchids. The Conservation Greenhouse is used to grow plants to maturity before transplanting into the field, and the Seedbank and CryoBank are used specifically for long-term storage of imperiled plant seeds and tissue.

Internships in plant conservation are available to students, and they collaborate with community science programs to help monitor rare plant occurrences.

Chicago Botanical Garden

The Chicago Botanic Garden's Negaunee Institute for Plant Conservation Science and Action is made up of 30 staff, including faculty at Northwestern University. One of the program's main focuses is preventing plant extinctions; this is done by working to develop a greater understanding of threats to plant species. The Negaunee Institute contains a seed bank, which is host to 11 of the rarest species in the Upper Midwest, including *Cirsium pitcheri*.

Advocacy is also part of the work of the Negaunee Institute. For example, they are actively involved in supporting 'The Botany Bill', which aims to employ and train botanists in the federal government, fund botanical research, and promote the use of native plants (*The botany bill,* n.d.).

Student and community engagement are also a focus of the Negaunee Institute. They are partners with the community science program, 'Plants of Concern', which aims to monitor the rarest native plants in the Midwest. For students, there are accredited graduate and undergraduate degree programs, internships, workshops, and seminars all aimed at plant conservation.

Missouri Botanical Gardens

The Missouri Botanical Garden Plant Conservation department consists of 27 staff members and is committed to the goals and principles of the Global Strategy for Plant Conservation (GSPC). Thirty-three species at Missouri Botanical Garden are in the CPC's National Collection, primarily as frozen seed. Beyond their work with North American plant species, Missouri is also involved in plant conservation in Asia, South America, Meso-America, and Africa. Their work includes conservation genetics, effects of climate change on vulnerable

plant species, assessing plant species distributions, reintroduction, and plant conservation capacity building.

University of Michigan Campus Farm

The University of Michigan Campus Farm (UMCF) at MBGNA is a student driven, learning lab for food systems. An interview with Farm Management Fellow, Becca Harley, and Campus Farm Program Manager, Jeremy Moghtader was held to learn more about the significant student engagement at UMCF and what has allowed it to be successful in engaging a large number of students. As stated previously, but reiterated by Moghtader, UMCF is staff directed, but student driven. This enables students to manage and perform the work necessary to UMCF while providing opportunities for leadership development. In addition, there are several areas of focus within UMCF that give it the ability to engage with a wider audience. UMCF allows students to continue to work in the same position throughout the year giving continuity to their work. This is a unique structure compared to other student positions at MBGNA, which are tied to the academic calendar. Further, UMCF generates revenue through produce sales to support student workers, whereas support for other student workers at MBGNA is limited to donations and federal student aid.

UMCF has outside pressure in the form of collaborators such as MDining, a condition that Moghtader says ensures that UMCF meets deliverables.

Natural Areas Preservation

The City of Ann Arbor Parks and Recreation department has 161 parks, of which approximately 75 are natural areas or contain natural areas. Their Natural Areas Preservation (NAP) department manages these areas and has a robust volunteer program. Working with NAP

could consist of assisting them with any rare plants that may occur on their properties and performing translocations (e.g., population reinforcement, reintroductions, and introductions).

Consultation with NAP's Stewardship Specialist, Becky Gajewski, yielded a statement of support for the creation of a rare plant conservation program at MBGNA (Image 1 in Appendix A). In summary, NAP believes that a rare plant conservation program at MBGNA "would be vital to preserving the genetic integrity and diversity of Michigan's rarest plants, and could potentially help bring their populations away from the brink of extirpation."

NAP also provided a list of rare plants found on their properties (see Table 1 of Appendix B). MBGNA and NAP share a total of 17 rare plant species.

Washtenaw County Parks

Under the auspices of Washtenaw County are approximately 28 natural areas and preserves that may also harbor rare plants. Like the natural areas and preserves of the City of Ann Arbor, Washtenaw County Parks may serve as reservoirs for rare plants, with which MBGNA may be able to help safeguard or use as sources for seed for reintroductions. The Stewardship Manager (Allison Krueger) for Washtenaw County Parks Natural Areas Preservation Program (NAPP), was confident in NAPP's support of a rare plant conservation program but was going to be consulting the NAPP team before issuing a final statement.

Oakland Township Parks and Recreation

Approximately 1500 acres of natural area are included within Oakland Township Parks and Recreation properties. Dr. Benjamin VanderWeide, the Natural Areas Stewardship Manager issued a statement of support for the creation of a rare plant conservation program at MBGNA (Image 2 in Appendix A). From the statement of support: "Natural areas in our park system

contain various uncommon and rare plants that would benefit from concerted conservation efforts…Matthaei Botanical Gardens & Nichols Arboretum would be uniquely positioned to work on rare plant conservation because they have access to resources or would be able to form partnership to address plant propagation, population genetics, seed banking, rare species reintroductions, and other unique considerations of rare plant conservation."

Springfield Township Natural Resources

Mike Losey of Springfield Township Natural Resources was made aware of this potential program via correspondence with Dr. VanderWeide of Oakland Township Parks and Recreation. He was interested in the project but did not explicitly state an interest in working with a future program. However, Losey raised legitimate questions regarding the ease of working with Threatened and Endangered Species due to having to apply for permits for them. Losey referenced his own desire to work with state Threatened species purple milkweed (*Asclepias purpurascens*), Sullivant's milkweed (*A. sullivantii*), and tall green milkweed (*A. hirtella*) and the Toledo Metropark's Blue Creek Native Plant Nursery. Due to potential administrative hurdles, he proposed that it might be easier to initially work with species listed as Special Concern in the state or to work with species that may not be listed but may be highly conservative and restricted or species that have low recruitment due to deer browse.

Michigan Department of Natural Resources

Meeting with Dan Kennedy, the former Michigan DNR Endangered Species Coordinator, and Phyllis Higman, MNFI Botanist and Invasive Species Lead yielded interest in a rare plant conservation program at MBGNA, and they could see the DNR being a partner. However, they suggested that a framework for the program would need to be developed and then reviewed by

the Division Chiefs from Forestry, Parks and Recreation, and Wildlife before the DNR would consider actively supporting such a program.

Toledo Metroparks

Located in Northwest Ohio, the Toledo Metroparks maintains 19,000 acres of natural areas across 19 properties. While located directly south of Michigan, the continuity of ecosystems across jurisdictional boundaries (such as Oak Openings) necessitates interaction among organizations from multiple states. The Toledo Metropark's Blue Creek Nursery is the largest publicly-owned nursery in Ohio and specializes in growing native plants of the region. While the nursery does not do research on listed species or focus specifically on growing listed species, 12 of the 58 species they do grow are listed as rare in Ohio. An interview with Penny Niday, the Seed Nursery Coordinator, was held to understand the Toledo Metroparks' role in plant conservation.

The Toledo Metroparks is a member of the Green Ribbon Initiative (GRI), a group of conservation organizations focused on protecting the Oak Openings region. This group also includes conservation organizations in Southeast Michigan.

Overall, the Toledo Metroparks believes there is a need for rare plant conservation in the region.

Southeast Michigan Land Conservancy

The Southeast Michigan Land Conservancy (SMLC) is a non-profit land trust located in Superior Township, MI. SMLC works to conserve 17 preserves across six counties. SMLC's past Stewardship and Outreach Manager, Julie McLaughlin, stated that she could see a potential collaboration with a rare plant conservation program at MBGNA for their West Prairie Nature

Preserve in Wayne County, MI. This property contains three Michigan state-listed species, none of which are represented in MBGNA's collection. A species list was provided by McLaughlin (see Table 2 of Appendix B).

Legacy Land Conservancy

Legacy Land Conservancy is a non-profit land trust and was Michigan's first local land trust. Seven preserves make up their collection of protected lands. Legacy's Executive Director, Diana Kern, stated that they do not currently have the bandwidth to be a collaborator with MBGNA, but that in the future, Legacy would be interested in collaborating with a rare plant conservation program at MBGNA.

Literature Review of Rare Plants

A literature review of *Tetraneuris herbacea* (Lakeside Daisy), *Iris lacustris* (Dwarf Lake Iris), *Cirsium pitcheri* (Pitcher's Thistle), *Betula murrayana* (Murray Birch), and *Panax quinquefolius* (American Ginseng) was completed to understand the species' biology and ecology, current threats, research that has already been done, existing knowledge gaps, and opportunities for conservation action.

Tetraneuris herbacea

Tetraneuris herbacea (Lakeside Daisy) is an herbaceous perennial plant that primarily occupies alvar communities in the Great Lakes region (Penskar & Higman, 2002). *Tetraneuris herbacea* is listed as Endangered in Michigan, ranked Imperiled (S2) in the state, and Vulnerable (G3) globally (Table 2). Michigan has one known population (Penskar & Higman, 2002), while

at least 94% of the plant's populations are accounted for in Canada; on the Bruce Peninsula and Manitoulin Island Regions of Ontario (Ontario Ministry of Natural Resources, 2013). Populations also exist on Ohio's Marblehead Peninsula (DeMauro, 1990), while all populations that had naturally occurred in Illinois have been destroyed (Ault, 2002). *Tetraneuris herbacea* is characterized by self-incompatibility, which prevents self-fertilization and cross-fertilization between plants that are in the same mating group, or have identical genotypes (McClain & Ebinger, 2008). This can make a small population very vulnerable, and there is evidence that genetic stochasticity caused one population to go extinct (*DeMauro*, 1990). In addition, the plant has a low seed set, averaging about 42.6% viable seeds per inflorescence (Ontario Ministry of Natural Resources, 2013). Although this plant is difficult to reproduce sexually, asexual reproduction can be easily accomplished through its creeping root, and it has also been successfully propagated through tissue culture (Ault, 2002). Overall, *T. herbacea*'s greatest threat is destruction of its globally rare alvar habitat (Ontario Ministry of Natural Resources, 2013). *Tetraneuris herbacea* also has scored as 'Highly Vulnerable' on a Climate Change Vulnerability Index (Penskar & Derosier, 2012). Understudied areas for *T. herbacea* include the following: reason for low seed set, genetic isolation as a potential threat, impact of fire suppression, and limits of temperature and drought tolerance (Ontario Ministry of Natural Resources, 2013). Currently, MBGNA, Holden Arboretum, and Cincinnati Zoo have collections of *T. herbacea* (Table 3 in Appendix B).

Iris lacustris

Iris lacustris (Dwarf Lake Iris) is an herbaceous perennial that forms clonal colonies and is endemic to the Great Lakes Region (Penskar et al., 2001). *Iris lacustris* is listed as Threatened in Michigan, and ranked Vulnerable (S3, G3) in the state and globally (Table 2). About 94% of

the all known populations of this plant occur in Michigan (Ostlie, 1990). *Iris lacustris* readily reproduces clonally, has sparse flower production, low fruit set, and low seed set (Penskar et al., 2001). Little is known about its pollination biology; insects have been observed at the flowers, but have not been observed to be carrying pollen (Parks Canada Agency, 2011; Ostlie, 1990; Penskar et al., 2001). However, this plant has been shown to be self-compatible (Parks Canada Agency, 2011), but limitations of the breeding system are believed to be a significant reason for its rarity (Ostile, 1990). Habitat development is considered the greatest threat to *I. lacustris* (Ostlie, 1990). *Iris lacustris* has been scored as Highly Vulnerable to climate change on a Climate Change Vulnerability Index (Penskar & Derosier, 2012). Research needed for *I. lacustris* includes pollination biology, seed dispersal, management techniques on canopy removal, impact and prevalence of collection for horticulture trade, impacts of burning, impact of invasive species, seed germination, and offspring survival (Parks Canada Agency, 2011; Ostlie, 1990; Penskar et al., 2001). MBGNA and the Holden Arboretum hold *I. lacustris* in their collections (Table 3 in Appendix B).

Cirsium pitcheri

Cirsium pitcheri (Pitcher's Thistle) is an herbaceous, monocarpic perennial endemic to open, active beach dunes and stabilized dunes of the western Great Lakes shorelines (Hamze & Jolls, 2000; Loveless, 1984). In Michigan, where the majority of populations exist (Havens et al., 2012), it is listed as Threatened, it is Federally Threatened, and is Vulnerable (S3, G3) in the state and globally (Table 2). Outside of Michigan, populations exist in Wisconsin and Indiana, although of the 12 known populations found in Indiana, only 8 are extant. (Fant et al., 2013). Populations had occurred in Illinois, however, it has been extirpated from that state for more than 100 years (Fant et al., 2013). Loss of habitat from shoreline development, introduced weevils,

recreation, and climate change are all threats faced by *C. pitcheri* (Fant et al., 2013; Loveless, 1984; Havens et al., 2012). It is possible that it was historically common for populations to shrink, disappear, and re-establish over decades, but this necessitates large habitat patches (Loveless, 1984). Because this species cannot reproduce vegetatively, its sexual reproduction, survival, and seed germination requirements have been studied. Approximately 23 insects have been documented visiting *C. pitcheri* flowers, and moths may be nocturnal visitors (Loveless, 1984). Populations also likely have different pollinators, and pollinators probably vary between seasons and between years (Loveless, 1984). *Cirsium pitcheri* seeds and flowers are predated by a number of native insects and animals, but also introduced weevils, which in combination could severely impact a small population (Havens et al., 2012). Hamze & Jolls (2000) found that seeds that germinated were heavier than seeds that did not germinate, and seeds buried at 2 cm provided the greatest probability of emergence compared to those buried at 4 cm and 8 cm.

Restoration of Pitcher's thistle populations has been attempted and is under study. The most successful method has been transplanting of greenhouse-grown plants (Rowland & Maun, 2001), and two reintroduction events seem to have been successful in creating genetic diversity within those sites (Fant et al., 2013). A Climate Change Vulnerability Index score for *C. pitcheri* considers this species as Moderately Vulnerable (Penskar & Derosier, 2012). A study done on the predicted climatic suitability of *C. pitcheri* suggests that seed collection should be done in the southeastern edge of Lake Michigan due to predicted shifting of the climatic envelope out of this area; using seeds from this area in existing northern populations may integrate potentially adaptive traits (Vitt et al., 2010). Due to risks from habitat destruction, flower and seed predation, and climate change, it has been suggested that the following actions be done: long-term seed storage, monitoring of threats, invasive vegetation management, and the status of the

plant be uplisted to Endangered (Havens et al., 2012). The Holden Arboretum, Cincinnati Zoo, and The Morton Arboretum currently have collections of this species (Table 3 in Appendix B), while MBGNA has one plant.

Betula murrayana

Betula murrayana (Murray Birch) is a species of birch tree described by Barnes and Dancik and discovered on the shores of Third Sister Lake in Washtenaw County, MI (Barnes & Dancik, 1985). *Betula murrayana* is a species of Special Concern in Michigan and is ranked Critically Imperiled (S1, G1) in the state and globally, although this ranking may change depending on changes to taxonomy (Table 2). This species is a hybrid of *Betula x purpusii* and *Betula alleghaniensis* and has only been found to be naturally occurring in two sites; the aforementioned site in Michigan and a site in Ontario, Canada, which are approximately 320 km apart (Barnes & Dancik, 1985; Shaw et al., 2014). It has been suggested that other populations exist in the Great Lakes Region and St. Lawrence Valley, but as of now it is thought that there are fewer than 25 individuals in total (Shaw et al., 2014). There is disagreement as to whether this species should be considered an independent taxonomic lineage, and further genetic work could be done to elucidate its state (Shaw et al., 2014; Taylor pers. comm., 2021). This species is considered Extremely Vulnerable to climate change (Penskar & Derosier, 2012). *Betula murrayana* is held in collections at MBGNA, Holden Arboretum, and Ness Botanical Garden (Table 3 in Appendix B, Shaw et al., 2014).

Panax quinquefolius

Panax quinquefolius (American Ginseng) is an herbaceous perennial that occurs in deciduous forests of North America and needs moist soils and areas of low evapotranspiration

(Anderson et al., 1993). This species is Threatened in Michigan and ranked Imperiled/Vulnerable (S2S3) in the state and Vulnerable (G3) globally (Table 2). This species has a long history of being used for medicinal purposes, which generally require destruction of the plant for use because the root is the target of harvest. While the cultivation of *P. quinquefolius* has decreased the harvesting of wild populations, there is still a preference for wild specimens in some markets due to distinctive root morphology and its perceived medicinal superiority to that of cultivated specimens (Case et al., 2007). A rough estimate of this species' age can be ascertained from the number of prongs (type of leaf) and number of prong leaflets (Anderson et al., 1993). Annual scars on rhizomes can also be used to estimate a plant's age, however, this may require destruction of the individual (Lewis & Zenger, 1982). Although it develops a rhizome, it rarely reproduces asexually, even though it faces high seed mortality when reproducing sexually (Lewis & Zenger, 1982). Despite the low probability of a seed reaching maturity (0.55%), the probability of a seedling reaching maturity is high, (97%), resulting in seed development being the most precarious stage in its life cycle (Lewis & Zenger, 1982, Charron & Gagnon, 1991). Plants only produce fruit after three growing seasons (Anderson et al., 1993). Beyond life-history traits, habitat destruction and widespread collection have contributed to the disappearance of *P. quinquefolius*, with moderate timber harvest and grazing being impactful and collection potentially driving some populations to extinction (Anderson et al., 1993; Charron & Gagnon, 1991). In one study, the presence of a footpath was found to have a negative impact on the population (Charron & Ganon, 1991). A study done in Nebraska looking at risk posed to rare plants by invasive species demonstrated that *P. quinquefolius* had the highest risk score, and that the invasive plants Garlic mustard (*Alliaria petiolata*) and Amur honeysuckle (*Lonicera maackii*) contributed significantly to the high risk score (Miller et al., 2010). *Panax quinquefolius* has a

climate change vulnerability index score of Extremely Vulnerable (Penskar & Derosier, 2012). This species is currently in MBGNA collections.

Table 2. Rare plants in MBGNA collections. Federal and State conservation status listing categories are as follows: Endangered (E); Threatened (T); and Special Concern (SC). Global and State Ranks are assigned by NatureServe (Global Rank) and Michigan Natural Features Inventory (State Rank) and are as follows: Critically Imperiled (G1/S1); Imperiled (G2/S2); Vulnerable (G3/S3); Apparently Secure (G4, S4); and Secure (G5, S5). IUCN Red List Ranks are as follows: Critically Endangered (CR); Endangered (EN); and Vulnerable (VU).

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Abeliophyllum distichum	Abeliophyllum distichum	Shrub	-	-	-	-	EN
Abies fraseri	Fraser fir	Tree	-	-	-	G2	EN
Adansonia grandidieri	Renala	Tree	-	-	-	-	EN
Aechmea manzanaresiana	Aechmea manzanaresiana	Forb	-	-	-	-	EN
Aesculus hippocastanum	Horse Chestnut	Tree	-	-	-	-	VU
Agrimonia rostellata	Beaked Agrimony	Forb	-	T	S2	G5	-
Aloe dichotoma	Quiver Tree	Tree	-	-	-	-	VU
Amorpha canescens	Lead-plant	Shrub	-	SC	S3	G5	-
Amorphophallus titanum	Titan Arum	Forb	-	-	-	-	EN

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Arnoglossum plantagineum	Tuberous Indian Plantain	Forb	-	SC	S3	G4	-
Astrophytum ornatum	Liendrilla	Shrub	-	-	-	-	VU
Baptisia lactea	White False Indigo	Forb	-	SC	S3	G4	-
Beaucarnea recurvata	Stripy Ponytail	Tree	-	-	-	-	CR
Betula murrayana	Murray Birch	Tree	-	SC	S1	G1	CR
Betula uber	Virginia roundleaf Birch	Tree	T	-	-	G1	CR
Bouteloua curtipendula	Side Oats Grama	Graminoid	-	E	S1	G5	-
Carex scirpoidea subsp. convoluta	Bulrush sedge	Graminoid	-	T	S2	G5	-
Carex trichocarpa	Hairy-fruited sedge	Graminoid	-	SC	S2	G4	-
Castanea dentata	American Chestnut	Tree	-	E	S1	G3	CR
Cedrus libani	Cedar of Lebanon	Tree	-	-	-	-	VU

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Celtis tenuifolia	Dwarf Hackberry	Tree	-	SC	-	-	-
Ceratozamia hildae	Ceratozamia hildae	Shrub	-	-	-	-	CR
Ceratozamia mexicana	Tzalam-thipac	Shrub	-	-	-	-	CR
Cibotium glaucum	Hāpuʻu	Forb	-	-	-	G3	EN
Cibotium sp.	Cibotium	Forb	-	-	-	-	EN
Cirsium pitcheri	Pitcher's Thistle	Forb	T	T	S3	G3	-
Cleistocactus winteri	Cleistocactus winteri	Shrub	-	-	-	-	EN
Coffea arabica	Arabica Coffee	Tree	-	-	-	-	EN
Conophytum ficiforme	Conophytum ficiforme	Shrub	-	-	-	-	EN
Coreopsis palmata	Prairie Coreopsis	Forb	-	T	S2	G5	-
Cypripedium candidum	White Lady-Slipper	Forb	-	T	S2	G4	VU

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Dionaea muscipula	Venus Flytrap	Forb	-	-	-	-	VU
Dioon spinulosum	Coyolito de Cerro	Tree	-	-	-	-	EN
Dracaena draco	Dracaena draco	Tree	-	-	-	-	EN
Echinocactus grusonii	Golden Barrel	Shrub	-	-	-	-	EN
Encephalartos altensteinii	Encephalartos altensteinii	Tree	-	-	-	-	VU
Eryngium yuccifolium	Rattlesnake Master	Forb	-	T	S2	G5	-
Eupatorium sessilifolium	Upland Boneset	Forb	-	T	S1	G5	-
Euphorbia geroldii	Euphorbia geroldii	Shrub	-	-	-	-	CR
Euphorbia neohumbertii	Euphorbia neohumbertii	Shrub	-	-	-	-	EN
Fraxinus americana	White Ash	Tree	-	-	-	-	CR
Fraxinus nigra	Black Ash	Tree	-	-	-	G5	CR

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Fraxinus pennsylvanica	Green Ash	Tree	-	-	-	-	CR
Fraxinus profunda	Pumpkin Ash	Tree	-	T	S2	G4	CR
Gentiana alba	White Gentian	Forb	-	E	S1	G4	-
Gentianella quinquefolia	Stiff Gentian	Forb	-	T	S2	G5	-
Geum triflorum	Prairie Smoke	Forb	-	T	S2	G5	-
Ginkgo biloba	Ginkgo	Tree	-	-	-	-	EN
Guaiacum sanctum	Holywood Lignum Vitae	Tree	-	-	-	G2	NT
Helianthus mollis	Ashy Sunflower	Forb	-	T	S2	G4	-
Hydrastis canadensis	Goldenseal	Forb	-	T	S2	G3	VU
Iris lacustris	Dwarf Lake Iris	Forb	T	T	S3	G3	NT
Jeffersonia diphylla	Twinleaf	Forb	-	SC	S3	G5	-

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Kalanchoe beharensis	Kalanchoe beharensis	Shrub	-	-	-	-	VU
Lithops sp.	Lithops	Forb	-	-	-	-	VU
Magnolia stellata	Star Magnolia	Tree	-	-	-	-	EN
Mammillaria eichlamii	Mammillaria eichlamii	Shrub	-	-	-	-	EN
Melocactus matanzanus	Dwarf Turk's Cap Cactus	Shrub	-	-	-	-	EN
Mertensia virginica	Virginia Bluebells	Forb	-	E	S1	G5	-
Metasequoia glyptostroboides	Dawn Redwood	Tree	-	-	-	-	EN
Monadenium guentheri var. mammillare	Monadenium guentheri var. mammillare	Shrub	-	-	-	-	EN
Pachypodium brevicaule	Pachypodium brevicaule	Shrub	-	-	-	-	VU
Panax quinquefolius	American Ginseng	Forb	-	T	S2	G3	-
Paphiopedilum appletonianum	Appleton's Paphiopedilum	Forb	-	-	-	-	EN

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Parodia leninghausii	Parodia leninghausii	Shrub	-	-	-	-	EN
Plectranthus bipinnatus	Andriamborondrao	Forb	-	-	-	-	VU
Polemonium reptans	Jacob's-Ladder	Forb	-	T	S2	G5	-
Populus heterophylla	Swamp Cottonwood	Tree	-	E	S1	G5	LC
Primula meadia	Shooting-Star	Forb	-	E	S1	G5	-
Prunus africana	African Cherry	Tree	-	-	-	-	VU
Rhexia virginica	Meadow-Beauty	Forb	-	SC	S3	G5	LC
Ruellia humilis	Hairy Ruellia	Forb	-	T	S1	G5	-
Sanguisorba canadensis	American Burnet	Forb	-	E	S1	G5	-
Sarracenia alata	Yellow Trumpets	Forb	-	-	-	G4	NT
Sarracenia jonesii	Mountain Sweet Pitcherplant	Forb	E	-	-	G2	EN

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Sarracenia leucophylla	Whitetop Pitcherplant	Forb	-	-	-	G3	VU
Sequoiadendron giganteum	Giant Sequoia	Tree	-	-	-	-	EN
Silphium integrifolium	Rosinweed	Forb	-	T	S2	G5	-
Silphium laciniatum	Compass Plant	Forb	-	T	S1	G5	-
Silphium perfoliatum	Prairie Dock	Forb	-	-	-	G5	-
Sporobolus heterolepis	Prairie Dropseed	Forb	-	SC	S3	G5	-
Stangeria eriopus	Natal Grass Cycad	Shrub	-	-	-	-	VU
Tanacetum bipinnatum	Lake Huron Tansy	Forb	-	T	S3	G5	-
Tetraneuris herbacea	Lakeside Daisy	Forb	T	E	S1	G3	-
Trillium recurvatum	Prairie Trillium	Forb	-	T	S2	G5	LC
Trillium sessile	Toadshade	Forb	-	T	S2	G5	LC

Scientific Name	Common Names	Physiognomy	Federal Status	State Status	State Rank	Global Rank	IUCN Rank
Tsuga caroliniana	Carolina Hemlock	Tree	-	-	-	G2	NT
Valeriana edulis	Hairy Valerian	Forb	-	T	S2	G5	-
Vanilla planifolia	Vanilla	Forb	-	-	-	-	EN
Wollemia nobilis	Wollemi Pine	Tree	-	-	-	-	CR
Yucca treculeana	Spansih Bayonet	Tree	-	-	-	G5	VU
Zamia pumila	Guáyara	Shrub	-	-	-	-	VU
Zamia pygmaea	Yuquilla de Ratón	Shrub	-	-	-	-	EN

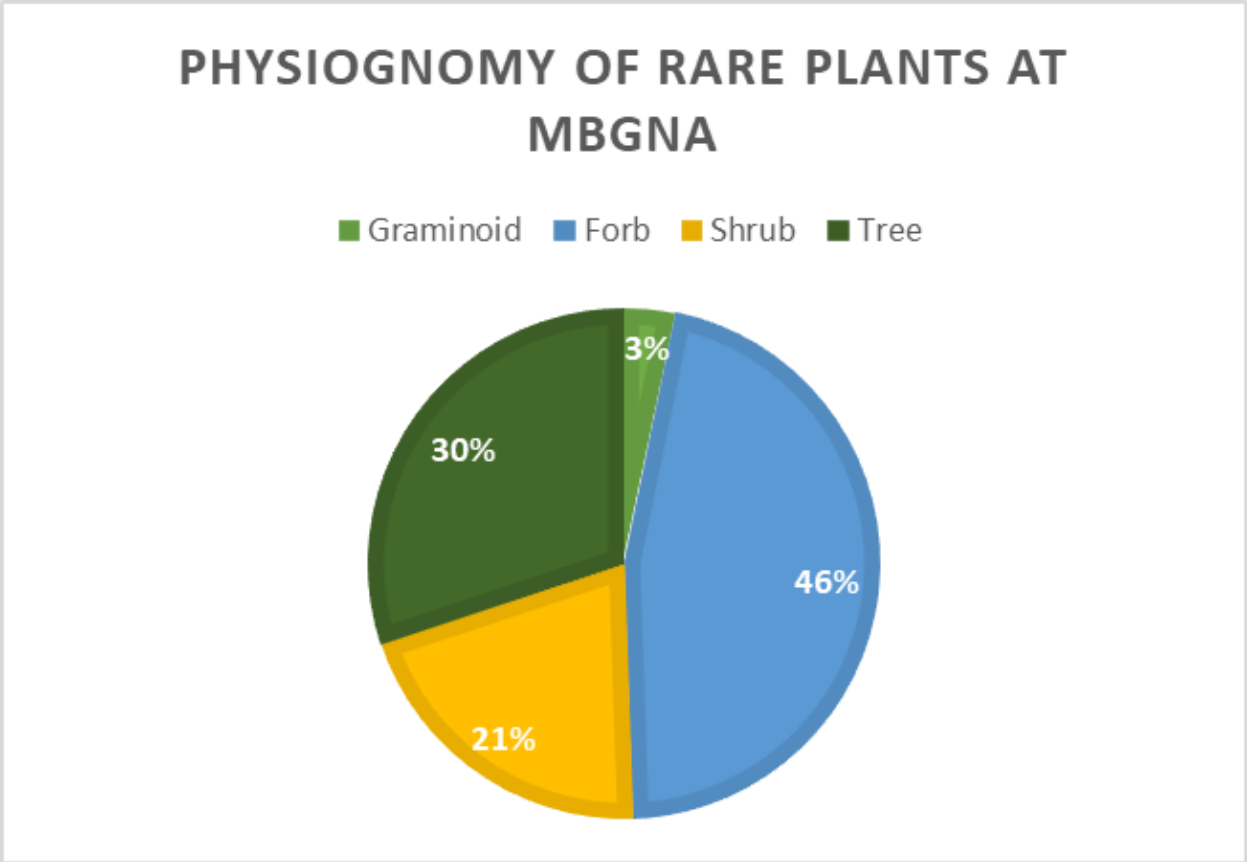

Chart 1. Distribution of Physiognomy of rare plants at MBGNA. Four classifications of physiognomy were used to categorize the species, including Graminoid, Forb, Shrub, and Tree. Graminoid refers to plants that are grass-like, such as grasses, sedges, and rushes. Forbs are those that are herbaceous, non-flowering, and non-graminoid. Shrubs are woody plants, potentially multi-stemmed or less than 2 meters in height and includes subshrubs such as cacti. Trees are woody plants that are single-stemmed or more than 2 meters in height and includes palms, yuccas, and aloes that fall within those qualifiers.

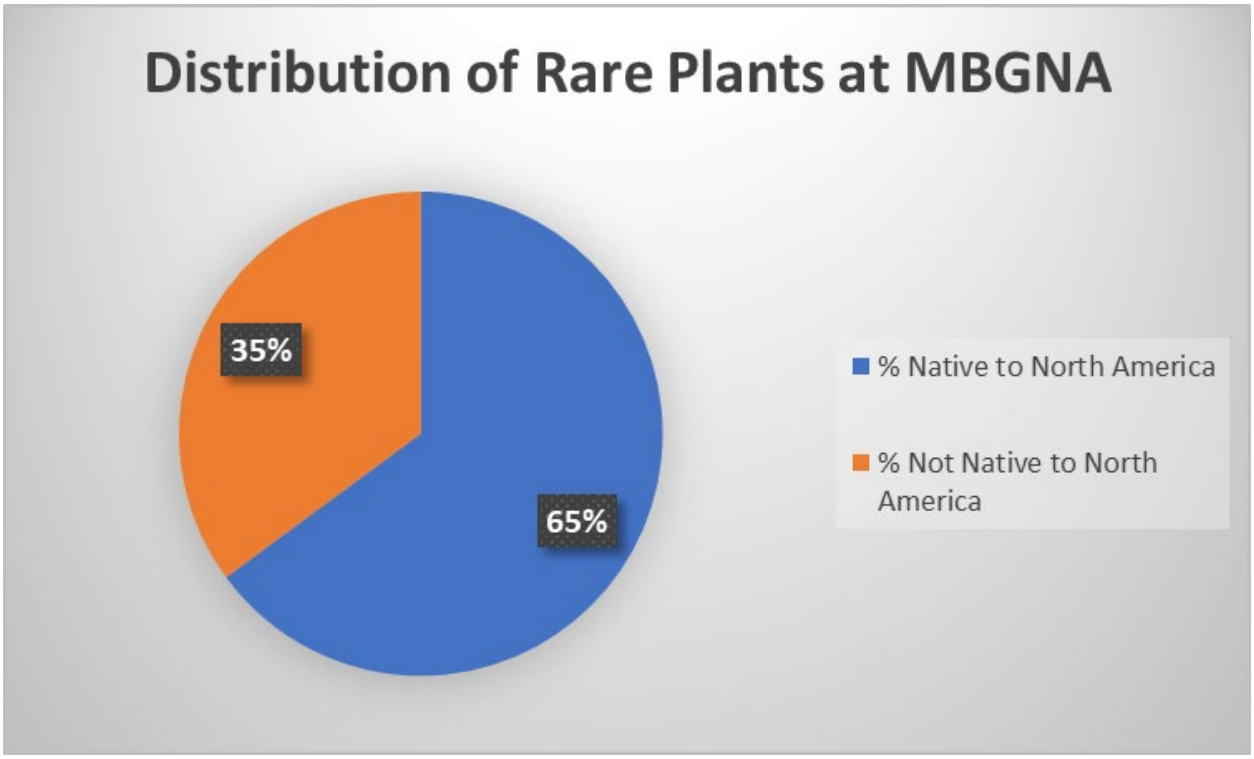

Chart 2. Geographic distribution of rare plants in MBGNA collections.

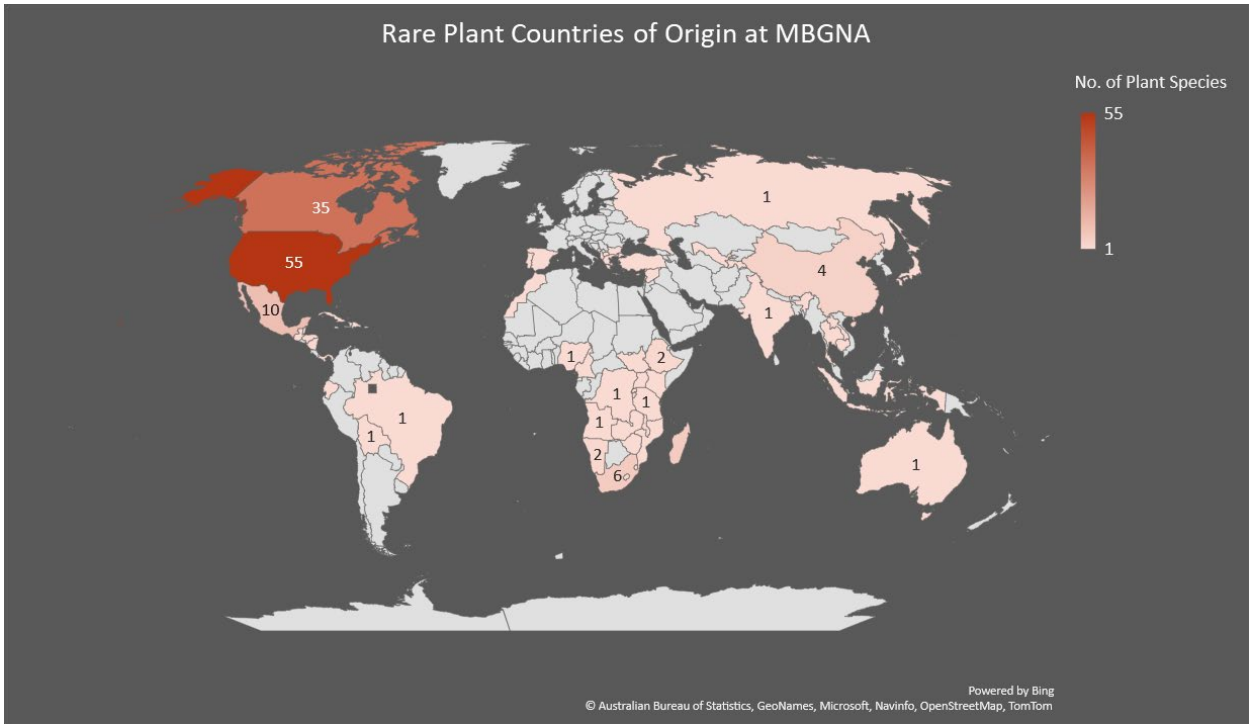

Chart 3. Distribution of rare species in MBGNA collections and their countries of origin. Plants native to the United States and Canada are best represented. Note that there is overlap in species ranges, with several occurring in both the United States and Canada.

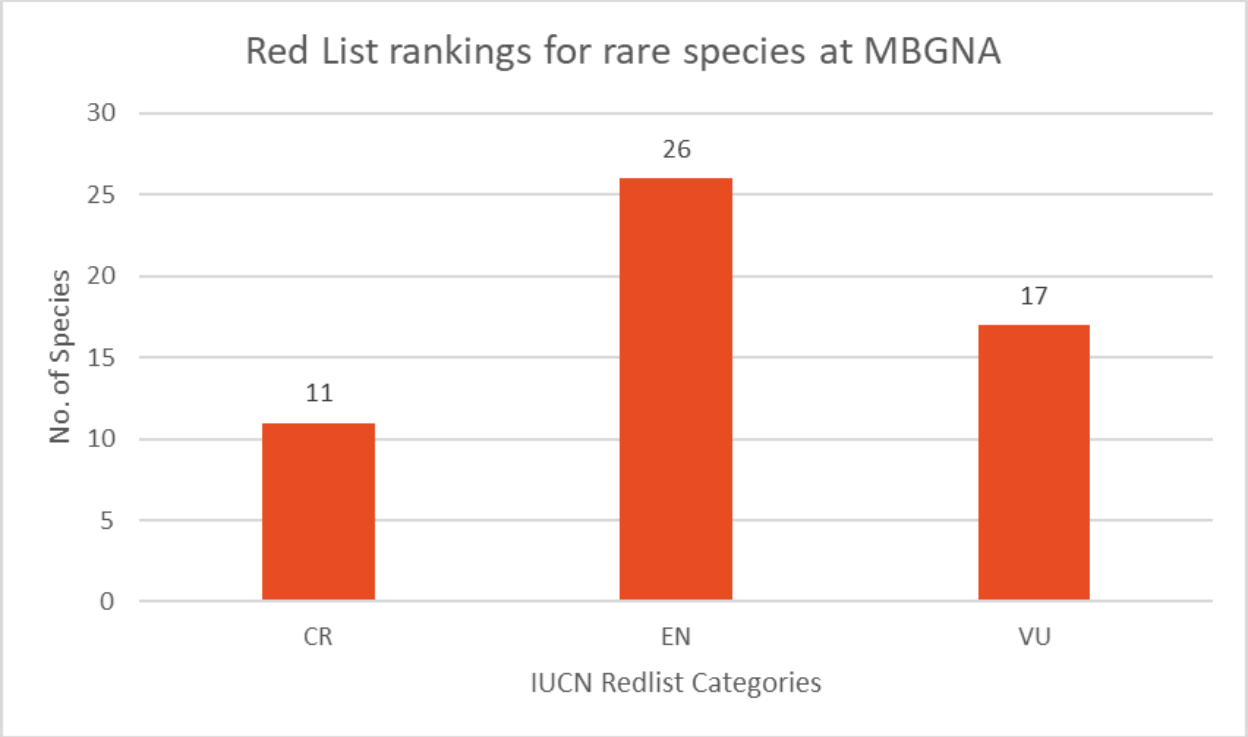

Chart 3. Red List categories for rare plants in MBGNA collections. Rare species Red List categories are as follows: Critically Endangered (CR); Endangered (EN); and Vulnerable (VU).

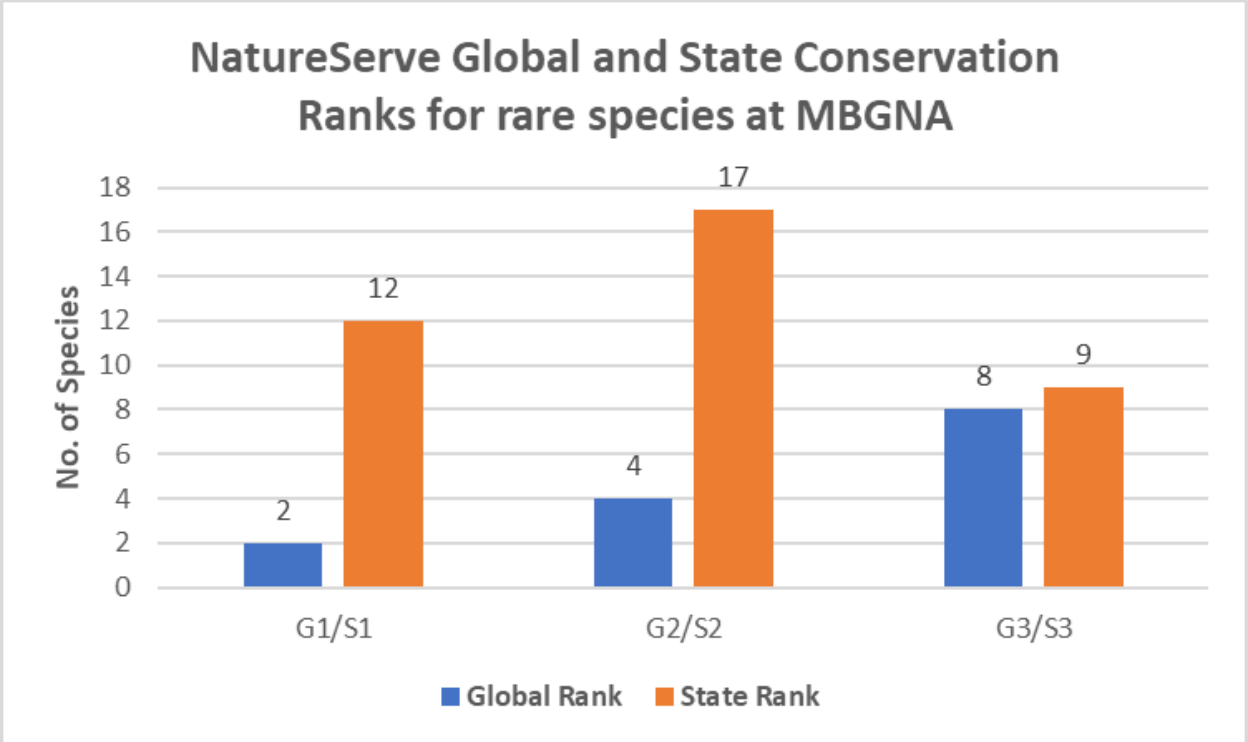

Chart 4. NatureServe Global Ranks for rare plants in MBGNA collections. NatureServe Global and State Ranks are as follows: Critically Imperiled (G1/S1); Imperiled (G2/S2); Vulnerable (G3/S3).

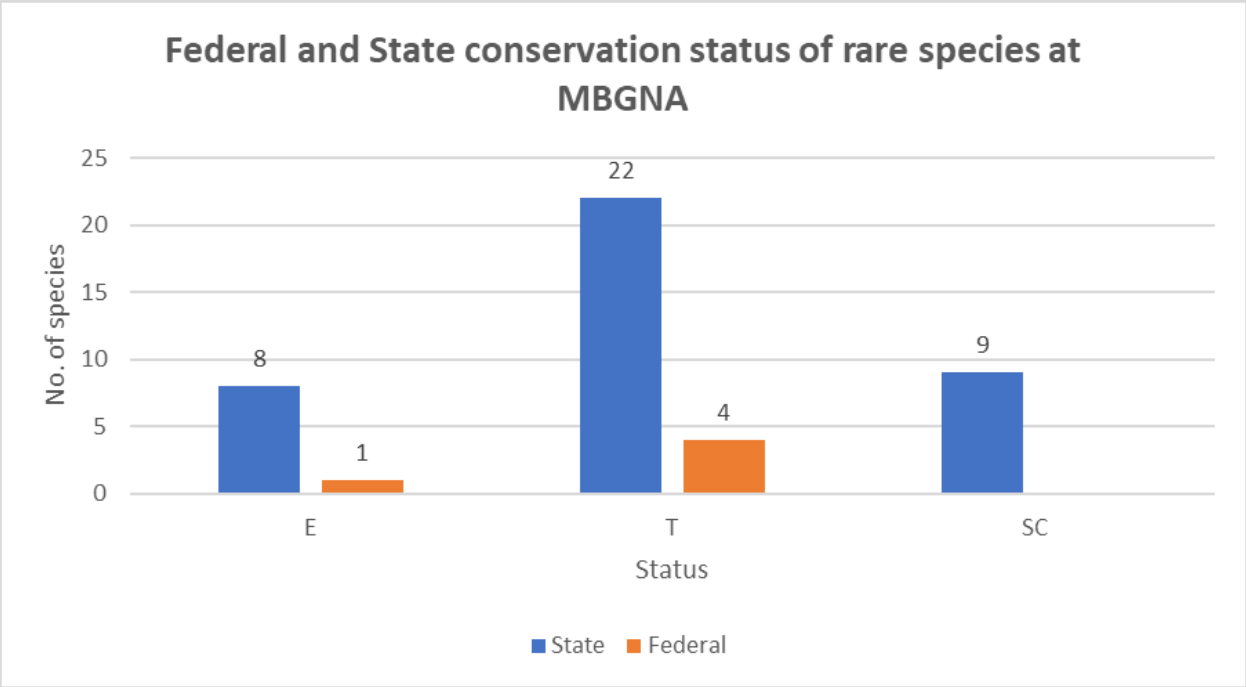

Chart 5. State and Federal Conservation Status for rare plants in MBGNA collections. Listing categories are as follows: Endangered (E); Threatened (T); and Special Concern (SC). Species on the Federal list receive legal protection through the Endangered Species Act, while species on the state list receive legal protection through the state's Natural Resources and Environmental Protection Act.

Discussion

MBGNA has, in some ways, been doing rare plant conservation. This is evident with the fact that there are at least 93 rare plants found on its properties, *P. quinquefolius* is actively propagated, and invasive species management occurs throughout MBGNA properties, including in areas where *P. quinquefolius* and other rare plants grow. However, there is opportunity for MBGNA to expand its role in rare plant conservation. By looking at the five species discussed in the literature review (*Tetraneuris herbacea, Iris lacustris, Cirsium pitcheri, Betula murrayana, Panax quinquefolius*), it is evident where a rare plant conservation program could begin.

Currently, *T. herbacea, I. lacustris*, *B. murrayana,* and *P. quinquefolius* are all part of ex-situ collections at MBGNA, and *C. pitcheri* has been grown previously and attempts to re-establish an ex-situ population are currently underway. Because *B. murrayana* is of known provenance (*P. quinquefolius*' provenance is questionable), it would be possible to have this plant used for conservation purposes and included in the CPC's National Collection. The *C. pitcheri* that is currently being grown, could then be included as well since its provenance is known.

Regardless of known provenance, all five species present opportunities for MBGNA to engage in critical research. Rare plants, generally, are lacking information regarding their biology, genetics, and ecology, and studies looking into interactions and dynamics need to be undertaken (Falk, 1990, Maschinski et al., 2012). Climate change, for example, is a direct threat to populations of plant species (Blackmore et al., 2011), and research into how it will affect populations of rare plants are important in determining management strategies moving forward (Havens et al., 2012; Vincent et al., 2020). All five species reviewed at MBGNA, scored from Moderately Vulnerable to Extremely Vulnerable to climate change (Penskar & Derosier, 2012).

To cope with climate change, plants will have to adapt and/or migrate (Davis & Shaw, 2001). However, emerging research is illuminating situations in which migration and adaptation will not be enough to protect them from the effects of climate change. Rare plants in Switzerland showed less plasticity in their response to changing precipitation and temperature than more widespread plants (Vincent et al., 2020); under climate change rare plants in Alberta, Canada are expected to be locally extirpated due to a decrease in fitness (Barber et al., 2016). While models have predicted that species will shift their ranges in response to climate change, this assumes that a given species has the ability to move. Plants with poor dispersal capabilities are likely to be susceptible to migration stress as a result of climate change (Barber et al., 2016), while plants that disperse by wind or animals may stand a better chance to migrate (Corlett, 2011). However, Fricke et al. (2022) predict that even among animal-aided dispersed plants, the current and future loss of animal species will inhibit the abilities of these plants to shift their ranges, and Davis & Shaw (2001) do not view the necessary range shifts as plausible.

In Michigan, climate change will lead to temperatures increasing by 5-20° F by the end of the century; winters have been getting shorter, and changes in the amount and timing of precipitation have been occurring (Lee et al., 2011, Notaro et al., 2015). Lee et al. (2011) anticipates that the shorelines and coastal zones of the Great Lakes region will be most affected by climate change, due to predicted changes in water levels. While there is uncertainty in climate models forecasting the changes in water levels, with some anticipating higher water levels and others lower, there is general consensus that there will be more variation in the extreme highs and lows of water level (Kayastha et al., 2022, Seglenieks et al., 2022). This may affect rare species that are generally restricted to coastal areas. Plants in Michigan also face difficulties in the ability to shift their ranges. Plant communities in the southern Lower Peninsula are

embedded in a matrix of agricultural land. Land cover change that impedes gene flow is suggested to reduce adaptation to a degree that will not keep pace with predicted climate change (Davis & Shaw, 2001). The effects of habitat loss coupled with climate change may require assisted movement of plants to ensure their preservation (Vitt et al., 2010). Although current research indicates negative outcomes for rare plants, Dee et al. (2019) note that some rare species may emerge from climate change as important providers of ecosystem services and that research into this possibility should be undertaken. The potential outcomes and uncertainties associated with climate change coupled with the climate vulnerability scores, necessitate continued research into how these plants may respond to climate change in different future climate scenarios.

Temperature and drought tolerance were both areas of needed research for *T. herbacea*, and although collecting seeds from MBGNA's collection might be difficult considering *T. herbacea*'s self-incompatibility and low seed set, Ault (2012) provided protocols for its micropropagation. Mastering these protocols would create consistent stock for research of this species' temperature and drought tolerances.

Despite *C. pitcheri*'s climate change vulnerability score of Moderately Vulnerable, its climatic envelope is still predicted to shift out of the southeastern edge of Lake Michigan. Because of this, it has been suggested that seed be collected from these areas and stored to preserve genetic diversity and to potentially be used for introduction into northern populations for adaptive traits. This is an effort MBGNA could be a part of as MBGNA has had success in growing this species. In addition, it has been shown that green-house grown plants have been the most successful method of reintroduction of this plant, potentially giving MBGNA a path towards assisting in reintroduction of this species.

Pollination biology and seed dispersal are two areas of research needed for *I. lacustris*. At MBGNA it has been reported that this species has spread, non-vegetatively, beyond the areas it was initially planted (Grese, pers. comm., 2022), indicating that flowers are being successfully pollinated and seeds are being dispersed. Observational studies of the flowers would give insight into insects visiting the flowers and carrying pollen, or results would further confirm this plant's ability to self-pollinate. Following pollination, seed dispersal could also be observed. In addition to pollination and seed dispersal, research into canopy management techniques would uncover what amount of canopy removal may be necessary to maintain populations of this species. Because of *I. lacustris'* small size, it would be feasible to propagate small populations of this plant and place them under differing canopy types to ascertain how they might be affected.

Because of *B. murrayana'*s uncertainty as an independent taxonomic lineage, genetic work could be done using the individuals growing at MBGNA. This would help either establish its need for conservation or downgrade its ranking if it is determined that it is not an independent lineage. Regardless of the result, this research would help fill knowledge gaps surrounding a species that is currently Critically Imperiled in the state and globally.

Literature review of *P. quinquefolius* offers insight into what can be done to protect MBGNA's current populations. Because of the impact that both Garlic mustard and Amur honeysuckle have on *P. quinquefolius,* the prioritization of the removal of these species in the vicinity of the population should be maintained. Currently, two footpaths border the population. Because footpaths have been shown to be detrimental to *P. quinquefolius* populations, these footpaths should be reviewed to determine their necessity to exist. To better understand the population at MBGNA, the population should be surveyed to obtain estimates of age classes via the number of leaves on an individual. Although this population exists on protected land, Falk

(1990) suggests that decreasing over-collection of harvestable species may not be as simple as land protection. Because of the possibility of collection and the likelihood of collectors harvesting plants with 3 or more leaflets, determining which areas of the population has a high proportion of this age class would be important to prioritizing protection measures. Consistent monitoring of the populations would also reveal whether or not collecting is occurring. Because of the low seed survival probability, but high seedling survival probability, seed should continue to be collected and propagated.

The above is just one pathway for rare plant conservation action, however, alternatives do exist. For example, 32% of the rare species that constitute MBGNA's collection are trees, this is the second highest physiognomy represented. The Global Tree Assessment revealed that 30% of tree species around the globe are threatened with extinction (Barstow et al., 2021). This suggests that a possible pathway for plant conservation at MBGNA could be solely tree focused. Regardless of the form a conservation program may take, there will always be opportunities for rare plant conservation in the form of education and outreach.

Public-facing discussion and education about rare plants should be a constant theme at MBGNA. However, with Holden Arboretum as evidence, this must be carefully done so as not to endanger the plants at MBGNA. If signage is to be placed indicating specific rare plants, the species should be chosen with consideration of its location (e.g., display garden vs. natural area), rarity, ease of propagation, utility (e.g., medicinal, horticultural, etc.), and parts used (e.g., root, leaves, fruit, etc.). This will allow MBGNA to make well-informed decisions about which species to promote or conceal. In lieu of species-specific signage, it is encouraged that general information about rare plants be provided to visitors such as, what they can do to protect them, what MBGNA is doing, and how they can help MBGNA work towards rare plant conservation.

As a botanic garden, MBGNA is a museum with living collections (Sanders et al., 2018), and museums have been transitioning towards centers of education rather than solely preservation of collection (Crowley et al., 2014). As such, MBGNA should be providing a level of education regarding rare plants to its visitors.

Becoming advocates for rare plant conservation is recommended as well. The Chicago Botanical Garden's Negaunee Institute is politically active in promoting the Botany Bill. This demonstrates that it is possible for a botanical garden to advocate for their ideals beyond their borders. The Recovering America's Wildlife Act (RAWA) is an example of legislation that MBGNA could advocate for. RAWA would address gaps in funding for rare plant conservation as it aims to provide funding for "wildlife and plant species of greatest conservation need" (Recovering America's Wildlife Act of 2021, 2022). Despite the relatively high percentage of rare plants in the U.S. and the fact that plants make up 57% of total species on the federal Endangered Species List, plants receive surprisingly little in the way of funding (Negron-Ortiz, 2014). The U.S. Fish and Wildlife service provides funding for species recovery, but these funds are disproportionately directed towards mammals, birds, and fishes; in 2011 for example, plant species received less than 3.86% of federal endangered species expenditures (Havens et al., 2014). Negron-Ortiz (2014) found that states spend on average only 0.1% of their federally listed species recovery budget on plants. Overall, Maunder et al. (2004) do not believe that the current amount of investment into ex-situ conservation will reduce expected extinction loss. Advocating for legislation that increases funding for conservation is an essential component of combatting future plant extinction.

Advocacy for legislation that would aim to reduce habitat destruction is also recommended for MBGNA. Habitat loss, either through land-use change or habitat

fragmentation is widely recognized as the greatest threat to plants (Falk, 1990). Land-use change is considered a dominant cause of biodiversity loss in terrestrial ecosystems, and it is one of the main reasons behind projected species extinctions (Pereira et al., 2010). Habitat fragmentation and reduction in habitat size result in small, isolated populations for many species (Saunders et al., 1991) and can be particularly detrimental to rare species already existing in small, isolated populations. Small, isolated populations are prone to reduced genetic variation (Frankham, 1996, Pimm, 1991). The effects of lower genetic variation can result in increased seedling mortality, which leads to reduced recruitment and thus pushes these populations toward extinction (Aguilar et al., 2019). As was shown, the biggest threat to the existence of the five species discussed earlier is habitat destruction. Advocating for land protection in the areas associated with these species would advance rare plant conservation.

Comparing species for which there are propagation protocols already developed through the Native Plant Network (Table 5 in Appendix B), CPC, BGCI, and NAOCC would inform MBGNA of gaps in knowledge that may be able to be met through work done at MBGNA. MBGNA can take the information regarding the lack of protocols and focus attention on propagation of those plant species. This would reduce unnecessary time developing protocols for species that already exist. For those species that do already have protocols, MBGNA should be using these as a way to increase the population of each species already present. Current experience growing rare plants demonstrates that MBGNA could support plant conservation efforts of other organizations by growing rare plants from seed collected on their own properties. Joining the networks mentioned above (i.e., CPC, BGCI) and reengaging with NAOCC, would give greater access to other organizations' propagation protocols that may not be available elsewhere.

As stated by Penny Nidal of the Toledo Metroparks, there is a need for rare plant conservation. Further, several area organizations support the creation of a rare plant conservation program at MBGNA. These organizations believe that MBGNA is well suited to help address the needs of rare plant conservation and would consider partnering with MBGNA if such a program were to be developed. In discussions with Campus Farm, it was evident that if an organization has collaborators, it will help hold the organization accountable and enable them to meet deliverables. Similarly, MLA has outside partnerships with the Minnesota DNR, which has enabled them to build credibility and resulted in plant translocations. If MBGNA is to have a rare plant conservation program, collaborators are a must. Collaborators would allow for MBGNA to be working beyond the confines of its property, it would allow MBGNA staff and students to work with new species that collaborators may need help propagating that are not already at MBGNA, and it would allow student staff and volunteers to build professional relationships.

Campus Farm has demonstrated that a robust program can be developed with use of student volunteers and student staff. Due to MBGNA's attachment to the University of Michigan, use of students in the development of a rare plant program is highly recommended. Existing student groups could be the initial work force to run this program. The student group Botany Undergrads Doing Stuff (BUDS) is one such group that would be able to direct aspects of a rare plant conservation program. The student group is made up of undergraduates, graduates, PhD, and post-doctoral students from a wide range of backgrounds. The group has already participated in native plant seed collection and seed cleaning events for MBGNA. In addition, the group has created an iNaturalist project to contribute to citizen science, sharpen identification skills, and assist others with identification skills. The project currently has over 2,100 plant observations (iNaturalist, n.d.), indicating the skill and interest in plant identification and

documentation among its members. The group's abilities could be put to use by collecting seed, cleaning seed, propagating plants, surveying existing populations of rare plants, and eventually guiding the program in much the same way that students do for Campus Farm.

Plant conservation is the norm for many botanical gardens, and it would not be unusual for a botanical garden such as MBGNA to have a rare plant conservation program. Such a program does not need to have state-of-the-art equipment and facilities nor a large team of staff to begin. MLA began its conservation efforts with one part-time curator and a refrigerator. MBGNA has a significant amount of infrastructure at its disposal already in the form of greenhouses, refrigerators, and other space for growing plants.

Although there are 93 rare plants within MBGNA's properties, and other organizations indicate that a rare plant conservation program is possible, MBGNA's mission must first be examined to determine if a program for rare plant conservation aligns with it.

A rare plant conservation program aligns well with the mission of MBGNA. The mission calls for advancing partnerships. A rare plant conservation program would help achieve this aspect of the mission by developing partnerships with other conservation organizations, locally, nationally, and globally. Locally, MBGNA would have the opportunity to partner with organizations that have already stated their interest in a rare plant conservation program. MBGNA has 56 rare species native to the United States, these are species that are also listed in other states. Partnerships can be developed with other botanic gardens and conservation organizations in other states; this would be facilitated by joining organizations such as the CPC and reengaging with NAOCC. While most of the rare plants are from the United States, MBGNA also has plants that from other countries, especially Canada and Mexico. MBGNA has an opportunity to develop partnerships internationally, which can be facilitated by BGCI. The

Global Strategy for Plant Conservation "calls for at least 75% of threatened plant species to be represented in in-situ collections, preferably in the country of origin." Because MBGNA has plants that are native to countries outside of the United States, it should work to ensure that plants in its holdings are being conserved in their country of origin, and if not, work with local organizations to develop plans to conserve them there, with MBNGA contributing genetic material if of the specimens are known. This may be especially relevant to the conservation of *T. herbacea* in Canada, where 95% of its population occurs.

The new mission also calls for promoting healthier ecosystems. Part of healthy ecosystems include sufficient habitat to provide for large populations, which in turn allows for higher genetic variability. Due to the mission of MBGNA, it could advocate for land preservation outside of ots property boundaries.

Conclusion

"In a hundred years botanic gardens will be judged not by the number of relictual species maintained as botanical 'living dead' but by the number of viable species and habitats surviving as a result of botanic garden intervention…" (Maunder, 1994).

We are currently in the midst of a biodiversity crisis, and botanical gardens have a role in helping to solve this issue. Botanical gardens are sites of research and public-facing education, making them uniquely positioned to bring attention to rare plants and the crises they face. MBGNA is perfectly situated to create a rare plants conservation program. By already having 93 rare plants representing 67 countries on its properties, MBGNA has the potential to have both a local and global impact. Discussions with local conservation organizations and similar-scale

botanical gardens demonstrate that a program such as this would be useful and is necessary. There are already established plant conservation networks that MBGNA would be able to join, eliminating the process of having to build such networks itself. MBGNA currently has a robust volunteer program and would be able to draw from students at the University of Michigan, existing volunteers, and new volunteers looking for additional conservation opportunities. In place already are infrastructure, rare plants, a pool of potential volunteers, and many research opportunities. Bringing these pieces together to develop a rare plant conservation would transform MBGNA into a local and global leader in rare plant conservation and make a positive impact on reducing global biodiversity loss.

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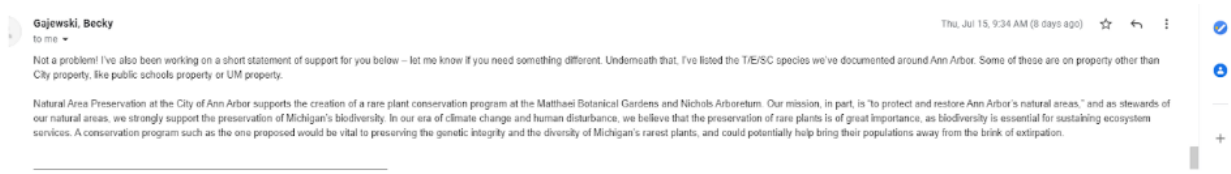
Appendix A



Gajewski, Becky
to me

Thu, Jul 15, 9:34 AM (8 days ago)

Not a problem! I've also been working on a short statement of support for you below – let me know if you need something different. Underneath that, I've listed the T/E/SC species we've documented around Ann Arbor. Some of those are on property other than City property, like public schools property or UM property.

Natural Area Preservation at the City of Ann Arbor supports the creation of a rare plant conservation program at the Matthaei Botanical Gardens and Nichols Arboretum. Our mission, in part, is "to protect and restore Ann Arbor's natural areas," and as stewards of our natural areas, we strongly support the preservation of Michigan's biodiversity. In our era of climate change and human disturbance, we believe that the preservation of rare plants is of great importance, as biodiversity is essential for sustaining ecosystem services. A conservation program such as the one proposed would be vital to preserving the genetic integrity and the diversity of Michigan's rarest plants, and could potentially help bring their populations away from the brink of extirpation.

"Natural Area Preservation at the City of Ann Arbor supports the creation of a rare plant conservation program at the Matthaei Botanical Gardens and Nichols Arboretum. Our mission, in part, is "to protect and restore Ann Arbor's natural areas," and as stewards of our natural areas, we strongly support the preservation of Michigan's biodiversity. In our era of climate change and human disturbance, we believe that the preservation of rare plants is of great importance, as biodiversity is essential for sustaining ecosystem services. A conservation program such as the one proposed would be vital to preserving the genetic integrity and the diversity of Michigan's rarest plants, and could potentially help bring their populations away from the brink of extirpation."

Image 1

Charter Township of Oakland
Parks and Recreation Commission
Mailing: 4393 Collins Road, Rochester, Michigan, 48306-1670
Office: 4480 Orion Road, Rochester, Michigan 48306-1670
*Telephone: (248) 651-7810 * Fax: (248) 601-0106 * www.oaklandtownship.org*

July 20, 2021

Chad Machinski
M.S. Candidate
School of Environment & Sustainability
University of Michigan
440 Church Street
Ann Arbor, MI 48109

Dear Mr. Machinski,

I am pleased to offer this letter supporting the proposed rare plant conservation program at Matthaei Botanical Gardens & Nichols Arboretum. Many plants which were once common in Michigan have declined or are rare due to habitat loss, invasive species, lack of pollinators, deer overabundance, and other factors. Understanding the reasons for decline and actively working to restore populations of rare plants are important pieces of ecological restoration efforts in Michigan. Herbaria and Michigan Natural Features Inventory document rare plant occurrences in the state, and many agencies manage their land to protect natural communities and the rare plants they contain. However, I am not aware of an effort focused on conservation of rare plants in southeast Michigan or the state.

Oakland Township Parks & Recreation currently has over 1500 acres of natural area within its park system. As parkland was acquired over the last four decades, the Park Commission focused on protecting high quality natural areas for the benefit of our local ecosystem and the enjoyment of township residents. Oakland Township Parks & Recreation is committed to the protection, management, and restoration of our natural areas, supported by a dedicated land preservation millage that was overwhelmingly renewed for its third 10-year term in 2018.

Natural areas in our park system contain various uncommon and rare plants that would benefit from concerted conservation efforts. We are very interested in collaboration with Matthaei Botanical Gardens & Nichols Arboretum for the proposed rare plant conservation program, including providing access to our parks for this work. Matthaei Botanical Gardens & Nichols Arboretum would be uniquely positioned to work on rare plant conservation because they have access to resources or would be able to form partnership to address plant propagation, population genetics, seed banking, rare species reintroductions, and other unique considerations of rare plant conservation. We heartily support creation of this program and look forward to collaborating in the future.

Sincerely,

Dr. Benjamin VanderWeide
Natural Areas Stewardship Manager
Oakland Township Parks & Recreation

Image 2

Appendix B

Table 1. NAP Rare Plant List

Scientific Name	Common Name	Status
Allium schoenoprasum var. sibiricum	WILD CHIVES	T
Angelica venenosa	HAIRY ANGELICA	SC
Asclepias purpurascens	PURPLE MILKWEED	T
Astragalus canadensis	CANADIAN MILK-VETCH	T
Bouteloua curtipendula	SIDE-OATS GRAMA	E
Carex squarrosa	SEDGE	SC
Carex trichocarpa	HAIRY-FRUITED SEDGE	SC
Castanea dentata	AMERICAN CHESTNUT	E
Chelone obliqua	PINK TURTLEHEAD	E
Cypripedium candidum	WHITE LADY-SLIPPER	T
Dichanthelium leibergii	LEIBERG'S PANIC GRASS	T
Echinacea purpurea	PURPLE CONEFLOWER	X
Endodeca serpentaria	VIRGINIA SNAKEROOT	T
Eryngium yuccifolium	RATTLESNAKE-MASTER	T
Euonymus atropurpureus	WAHOO; BURNING-BUSH	SC
Eupatorium sessilifolium	UPLAND BONESET	T
Eutrochium fistulosum	HOLLOW-STEMMED JOE-PYE-WEED	T
Gentiana alba	YELLOWISH GENTIAN	E
Hydrastis canadensis	GOLDENSEAL	T
Jeffersonia diphylla	TWINLEAF	SC
Justicia americana	WATER-WILLOW	T
Liparis liliifolia	LILY-LEAVED TWAYBLADE	SC
Lithospermum latifolium	BROAD-LEAVED PUCCOON	SC
Mertensia virginica	VIRGINIA BLUEBELLS	E
Morus rubra	RED MULBERRY	T

Panax quinquefolius	GINSENG	T
Polemonium reptans	JACOB'S-LADDER	T
Sanguisorba canadensis	AMERICAN BURNET	E
Scutellaria parvula	SMALL SKULLCAP	T
Silphium perfoliatum	CUP PLANT	T
Smallanthus uvedalia	LARGE-FLOWERED LEAFCUP	T
Smilax herbacea	CARRION-FLOWER	SC
Spiranthes ovalis	OVAL LADIES'-TRESSES	T
Sporobolus heterolepis	PRAIRIE DROPSEED	SC
Symphyotrichum praealtum	WILLOW ASTER	SC
Trillium recurvatum	PRAIRIE TRILLIUM	T
Trillium sessile	TOADSHADE	T
Valeriana edulis	COMMON VALERIAN	T
Viburnum prunifolium	BLACK-HAW	SC

Table 2. SMLC - Rare plant list

Scientific Name	Common Name	Status
Angelica venenosa	Venomous Angelica	SC
Betula populifolia	Gray Birch	SC
Juncus brachycarpus	Short-fruited Rush	T

Table 3. MBGNA species in the CPC National Collection

Scientific Name	Location in CPC National Collection
Abies fraseri	The Morton Arboretum
Cirsium pitcheri	Holden Arboretum, The Morton Arboretum, Chicago Botanic Garden
Cypripedium candidum	Minnesota Landscape Arboretum
Guaiacum sanctum	Marie Selby Botanical Gardens
Tetraneuris herbacea	Holden Arboretum, Cincinnati Zoo
Betula murrayana	Holden Arboretum
Iris lacustris	Holden Arboretum
Tsuga caroliniana	Atlanta Botanical Garden

Table 4. Rare species at MBGNA that are held in other botanic gardens according to BGCI. No. of Locations represents how many other organizations have reported their presence in their collection.

Scientific Name	**No. Locations**
Adansonia grandidieri	39
Aechmea manzanaresiana	6
Aloe dichotoma	77
Astrophytum ornatum	158
Beaucarnea recurvata	149
Ceratozamia hildae	56
Ceratozamia mexicana	101
Coffea arabica	197
Conophytum ficiforme	20
Dioon spinulosum	112
Dracaena draco	202
Echinocactus grusonii	231
Encephalartos altensteinii	78
Euphorbia geroldii	38
Guaiacum sanctum	44
Kalanchoe beharensis	167
Mammillaria eichlamii	8
Melocactus matanzanus	42
Pachypodium brevicaule	37
Paphiopedilum appletonianum	31
Plectranthus bipinnatus	3
Prunus africana	21
Vanilla planifolia	152
Wollemia nobilis	135
Yucca treculeana	43
Zamia pumila	94

Table 5. Rare species at MBGNA that have propagation protocols from the Native plant network

Native Plant Network Propagation Protocols	
Abies fraseri	Jeffersonia diphylla
Amorpha canescens	Mertensia virginica
Arnoglossum plantagineum	Panax quinquefolius
Baptisia lactea	Polemonium reptans
Bouteloua curtipendula	Primula meadia
Castanea dentata	Rhexia virginica
Coreopsis palmata	Sequoiadendron giganteum
Eryngium yuccifolium	Silphium integrifolium
Fraxinus nigra	Silphium laciniatum
Gentianella quinquefolia	Silphium perfoliatum
Geum triflorum	Sporobolus heterolepis
Helianthus mollis	Valeriana edulis

Appendix C

IUCN Rankings Definitions

Critically Endangered (CR): A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.

Endangered (EN): A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.

Vulnerable (VU): A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.

NatureServe & MNFI Ranks

Critically Imperiled (G1/S1): At very high risk of extinction or elimination due to very restricted range, very few populations or occurrences, very steep declines, very severe threats, or other factors.

Imperiled (G2/S2): At high risk of extinction or elimination due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.

Vulnerable (G3/S3): At moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.

Endangered Species Act of Michigan

Endangered - Any species of fish, plant life, or wildlife that is in danger of extinction throughout all or a significant part of its range, other than a species of Insecta determined by the department or the secretary of the United States department of the interior to constitute a pest whose protection under this part would present an overwhelming and overriding risk to humans.

Threatened - Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

MNFI

Special Concern - Indicates declining or relict species in the state. While not protected by law, these species need protection to prevent them from becoming Threatened or Endangered.

Federal Endangered Species Act of 1973

Threatened - Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Endangered - Any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man.