Journal of
Zoological and Botanical Gardens

MDPI

Article

BiodiverseCity St. Louis—An Initiative of the Missouri Botanical Garden

Jean Ponzi [1,*], Glenda Abney [1,*], Matthew A. Albrecht [2], Sean Doherty [3], Robbie Hart [4], Allison Joyce [1], Nisa Karimi [5], Daria Mckelvey [6], Mike Saxton [7] and Jen Sieradzki [7]

1 EarthWays Center, Missouri Botanical Garden, St. Louis, MO 63110, USA; ajoyce@mobot.org
2 Center for Conservation & Sustainable Development, Missouri Botanical Garden, St. Louis, MO 63110, USA; malbrecht@mobot.org
3 Education Division, Missouri Botanical Garden, St. Louis, MO 63110, USA; sdoherty@mobot.org
4 William L. Brown Center, Missouri Botanical Garden, St. Louis, MO 63110, USA; rhart@mobot.org
5 Africa and Madagascar Department, Science and Conservation Division, Missouri Botanical Garden, St. Louis, MO 63110, USA; nkarimi@mobot.org
6 Kemper Center for Home Gardening, Missouri Botanical Garden, St. Louis, MO 63110, USA; dmckelvey@mobot.org
7 Shaw Nature Reserve, Missouri Botanical Garden, St. Louis, MO 63110, USA; msaxton@mobot.org (M.S.); jsieradzki@mobot.org (J.S.)
* Correspondence: jponzi@mobot.org (J.P.); gabney@mobot.org (G.A.)

Abstract: Botanical gardens are addressing urgent biodiversity issues through plant-based capacities including botanical research and data-sharing, conservation horticulture, ecological restoration, seed banking, and more. The Missouri Botanical Garden initiative BiodiverseCity St. Louis, led by the Garden's sustainability division, adds broad community engagement to this mix. This work includes public and professional education, the demonstration and promotion of ecological landscaping and Green Infrastructure practices, citizen science programs, and coordinating communications for a regional network of partner organizations focused on biodiversity. Diverse activity engages businesses, local governments, elementary and secondary (K-12) schools, colleges, and community groups. Community biodiversity work at the Garden is informed by an institutional core of scientific rigor, provides opportunity for internal collaborations, and aligns with global strategies for plant conservation—to ground impactful local work. Missouri Botanical Garden's experience offers a model for public gardens: leveraging modes of community engagement, in concert with diverse institutional strengths, to address biodiversity needs.

Keywords: Missouri Botanical Garden; BiodiverseCity St. Louis; biodiversity; education; sustainability; community engagement

Citation: Ponzi, J.; Abney, G.; Albrecht, M.A.; Doherty, S.; Hart, R.; Joyce, A.; Karimi, N.; Mckelvey, D.; Saxton, M.; Sieradzki, J. BiodiverseCity St. Louis—An Initiative of the Missouri Botanical Garden. *J. Zool. Bot. Gard.* **2024**, *5*, 143–156. https://doi.org/10.3390/jzbg5020010

Academic Editors: Donald Rakow and Christopher P. Dunn

Received: 19 March 2024
Revised: 26 March 2024
Accepted: 1 April 2024
Published: 10 April 2024

1. Introduction

Worldwide, botanical gardens are intently, urgently focused on biodiversity in many ways, ranging from global efforts to advance the United Nations Convention on Biological Diversity and Sustainable Development Goals to localized collaborations between gardens and their state and regional native plant programs. Practices in conservation horticulture and conservation biology are increasingly merging gardens' hands-on and research resources to study, protect and restore biodiversity. Public gardens also have a vital capacity in education and sustainability to cultivate public biodiversity engagement.

As cultural institutions that both contribute to and are supported by our local communities, botanical gardens can lead diverse community partners in biodiversity initiatives, especially by partnering with colleagues at sister public institutions including zoos, insectariums, aquariums, libraries, and museums. Public gardens are powerfully positioned to engage the audiences we serve in biodiversity education, action, and advocacy.

In St. Louis, for over a decade, the Missouri Botanical Garden (Figure 1) has cultivated this capacity through a broad range of community partnerships. The Garden's own work in this area brings together the skills and programs of our locally focused Sustainability and Education teams with the global scope and reputation of research led by our Science and Conservation staff and the conservation and restoration expertise in our Horticulture division.

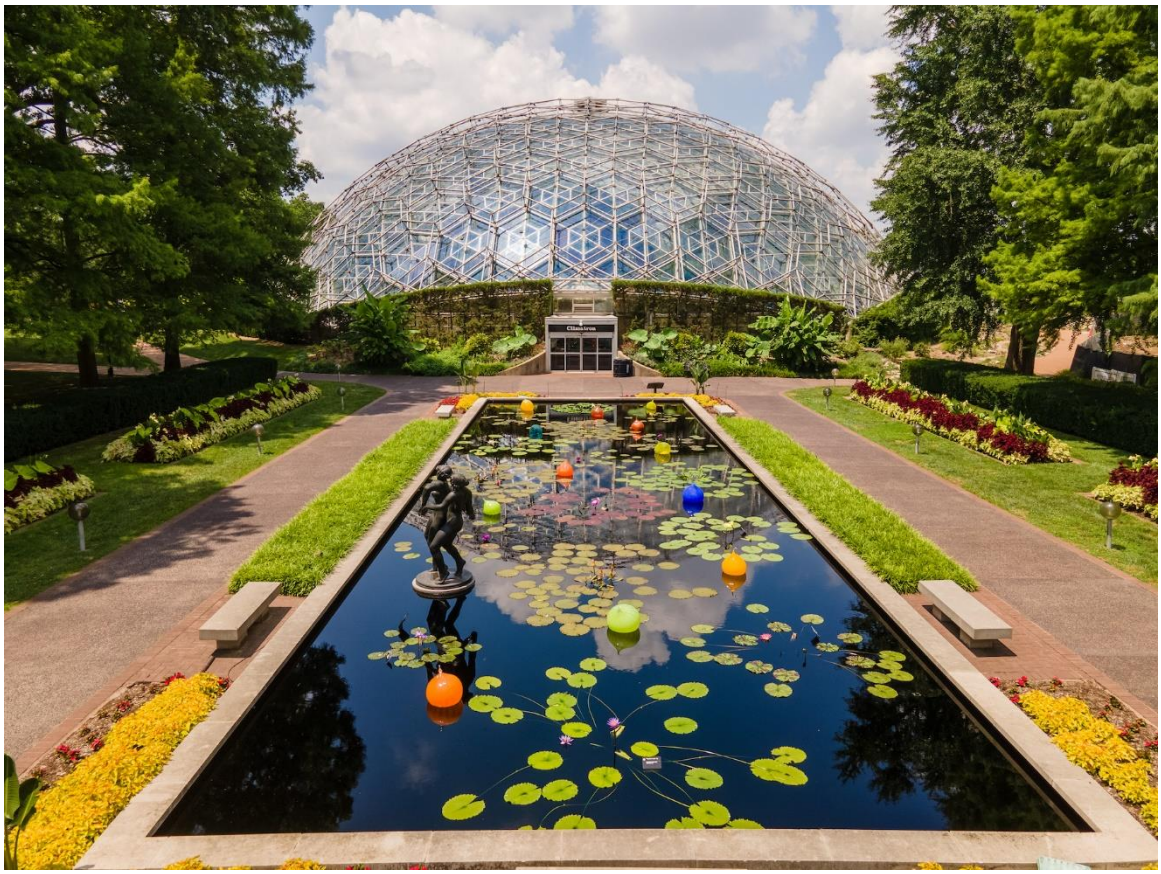

Figure 1. Missouri Botanical Garden.

BiodiverseCity St. Louis [1] is a community initiative to promote, protect, and plan for biodiversity throughout the greater St. Louis Region. Launched in 2012 at the Missouri Botanical Garden, these efforts support a nature-driven network of biodiversity-focused organizations and individuals and facilitate narrative- and data-driven communication about this work in and from our region. Activity in this public-facing initiative strives to transform landscapes and lives in three ways:

- Enabling a greater diversity of life to survive and thrive across the metro area.
- Promoting a culture of active, healthy, nature-rich living.
- Increasing capacity to practice the sustainable stewardship of local lands and waters, across the public and private sectors.

Work by our bi-state network of collaborating partners improves quality of life through education, advocacy, and action that prioritizes nature in our urban, suburban, and rural communities.

2. Initial Challenge

In November 2012, Garden President Dr. Peter Wyse Jackson convened a group of sustainability leaders from area corporations with staff of the Garden's Institutional Advancement, Education, Science and Conservation, Horticulture, and Sustainability divisions. Participants represented Garden relationships that were actively advancing

sustainability as a regional strategic priority. Wyse Jackson challenged this group to expand ongoing work to address biodiversity concerns. His call to action arose from his work on determining the Global Strategy for Plant Conservation [2] within Botanic Gardens Conservation International (BGCI), his leadership in linking the BGCI strategy to the UN Sustainable Development Goals (SDG) [3], and his lifelong, personal passion for exploring and documenting urban biodiversity.

This challenge was, however, an unfunded mandate. How would this group take on issues in biodiversity—shorthand for the health of all Earth's living systems and communities—within the limits of resources at that time? The first need addressed was how to apply institutional experiences and perspectives that had earned Missouri Botanical Garden's global reputation for collaborative plant conservation through the Garden's outstanding and diverse localized work in public education and sustainability. The formation of a network, with the Garden as its hub, leveraged early leaders' extensive connections and partnerships to elevate the regional awareness of biodiversity issues, actions, and opportunities and collaboratively grow the capacity for action and beneficial outcomes. A dozen years on, as Garden staff actively align our work on urban biodiversity with the UN SDGs and the Global Strategy for Plant Conservation, BiodiverseCity St. Louis (BDV-STL) continues to evolve and serve.

3. Early Action

Garden staff immediately committed to hosting a website and coordinating regular network communications. Existing online structures continue to be housed at *BiodiverseCitySTL.org*. A bi-monthly eNewsletter features the following: a Species Spotlight; a Network News section that links to local, national, and global articles of interest; event listings submitted by action project partners; and short reviews of book and article Great Reads. Currently, the newsletter reaches about 1500 subscribers; a 35–40% open rate has remained consistent over the years. From these fundamentals, technological connectivity has multiplied.

Representatives of 60 area organizations participated in 2013 in the initiative's first stakeholder meetings, facilitated to solicit strategy inputs. BDV-STL partners are environmental, educational, and social service non-profits; municipalities; state and county agencies; businesses; colleges and universities; faith-based groups; arts and cultural institutions; and many individuals. Early outreach materials displayed a vivid collage of partner logos. The Saint Louis Zoo was an original, key partner and continues significant collaborations with the Garden in the work of BDV-STL.

Electronic surveys have been used to establish, and periodically update, a network database including contacts, purpose, projects, partners, funding sources, and other key information; an update will occur again in 2024. The Garden shares information and contacts within the network, to facilitate communication while also respecting contact privacy.

A primary focus for Garden staff in the initiative's first year was researching the structure of biodiversity work in other regions. Extensive conversations and some site visits took place with representatives of the Chicago Wilderness Alliance and contacts in Pittsburgh, PA, that tapped into the Garden's strong sustainability relationship with Phipps Conservatory. Explorations informed the decision to broadly establish the geographic boundary of BDV-STL as the region's Area of Statistical Significance, which includes six Missouri and eight Illinois Counties and the City of St. Louis. A graphic representation of this region's riverine features, with geopolitical boundaries removed, gave BDV-STL a compelling visual identity.

Another early connection was with Dr. Timothy Beatley, whose book *Biophilic Cities* (2011, Island Press) documented global examples of prioritizing biodiversity in urban planning, stream daylighting, public transportation, industrial area reclamation, and more. His visit to speak in the City of St. Louis, at the invitation of the City's Office of Sustainability, established a relationship that, in 2017, secured Biophilic City designation for St. Louis [4]. Urban Vitality and Ecology [5], the City of St. Louis engagement and research collaboration

with BDV-STL that evolved from that era's City sustainability planning into forms that persist today, is documented in *Public Gardens and Livable Cities, Partnerships Connecting People, Plants and Place* (2020, Rakow, Gough and Lee, Cornell University Press) [6].

Public education has always been a BDV-STL top priority, including the Wild Ideas Worth Sharing Speaker Series. Presenters of local-to-global note have included architects, landscape architects, botanists, zoologists, ecologists, soil scientists, NGO leaders, seed-savers, authors, educators, and artists. The Garden hosted these presentations, often at no charge, two to four times per year from 2013–2019, promoting attendance through BDV-STL eNews, partner communications, and Garden membership communications. By the time the pandemic halted events, Wild Ideas Worth Sharing had established biodiversity as a topic of genuine regional public interest.

4. Working Groups, Leadership Dynamics

From the outset, work within BDV-STL was organized in topical working groups to facilitate contributors' focus from their area of expertise and circle of connections. Groups were led by Garden staff and/or initiative partners, addressing Strategic Planning and Leadership, Research and Data Gathering, Economics and Policy, Public Awareness and Education, and Biodiversity Restoration and Action Projects. Senior Garden and Saint Louis Zoo staff coordinated these efforts overall. Meeting frequency ranged from monthly to quarterly. Reports were compiled and circulated, providing valuable material for the Garden and its partners' funding proposals.

BDV-STL contributed significantly to the collaborative implementation of OneSTL [7], our regional sustainability plan. OneSTL was developed through a major HUD grant awarded in 2010 to the East–West Gateway Council of Governments, our regional planning organization; extensive stakeholder engagement contributed to the plan. However, funding supported planning only, not processes for implementation. In 2017, a OneSTL Summit convened dozens of local experts and advocates to identify SMART targets in six areas of topical focus: Transportation, Energy and Atmosphere, Water and Green Infrastructure, Food Access, Waste Reduction, and Biodiversity.

The OneSTL biodiversity target was the following:

> *By 2025, 100% of counties in the St. Louis metro area are using a biodiversity vision, atlas, and action plan to guide planning decisions.*

BDV-STL leaders then sought to secure funding for and to define processes to achieve this target, as a scope of work intended to stitch together and document partners' project-based efforts, ongoing and accomplished, over previous years.

Garden staff worked with professional and student partners from the Saint Louis Zoo and Lindenwood University to develop an ArcGIS Hub as a central home for regional biodiversity data. This embodiment of the target "atlas" is called *BiomeSTL* [8], short for Biodiversity of Metropolitan St. Louis, and includes six sections configured to house the following:

- Mapped species data gathered from regional usage of the mobile app *iNaturalist*;
- Case studies of land transformation;
- Story maps illustrating regional biodiversity corridors and connections, emphasizing properties certified by programs addressing residential, corporate, or public lands;
- Biodiversity policy models and examples of adoption;
- Summaries of and links to explore biodiversity-focused research projects, formal and citizen science;
- Summaries of and links to engage in BDV-STL partners' regional ecological stewardship opportunities.

With initial content established and update processes in development, BiomeSTL is scheduled for public access in 2024.

From 2016 to 2019, BDV-STL leadership was provided by a trio of senior staff from Missouri Botanical Garden, Saint Louis Zoo, and tree-focused nonprofit Forest ReLEAF of

Missouri. This leadership team structure powerfully and efficiently leveraged individual and institutional perspectives and resources to support network dynamics and communication. Individual career moves changed the team late in 2019. BDV-STL's 2020 pandemic pivot engaged an expanded leadership team of staff from the Garden, the Zoo, and five other partner organizations, who moved BDV-STL through and beyond nearly two years of only virtual interactions.

OneSTL staff intended to evaluate and revise 2017 topical targets in 2020 to emphasize and facilitate topical group collaboration. The pandemic waylaid this plan and derailed or sidetracked efforts in some of the topical areas. The BDV-STL leadership team persevered in action toward the 2017 target and launched a "ReFocus" process to update the target, currently in draft form:

> *Increase biodiversity populations and projects across the St. Louis metro region by 2030, compared to baseline year 2023, as measured by populations of three indicator species and outcomes in three areas of project action.*

As the Garden embarks in 2024 on institutional strategic planning, we are committed to evolving the structure and function of BDV-STL, while continuing to support network efforts as a communications hub.

5. Native Plants Cultivate Action

In his landmark book *Bringing Nature Home* (2007, Timber Press) [9], University of Delaware ecologist Dr. Doug Tallamy cites St. Louis as a national leader in the movement to restore biodiversity by gardening with native plants. Through many partnerships, native plants are indeed rooting our regional understanding and appreciation of biodiversity issues and growing collaborative action. Garden BDV-STL staff are grounding ecological gardening in local popular culture, including characterizing three "Taproots" and multiple "Feeder Roots" of our native plant movement, celebrating BDV-STL relationships. The "Taproots" are as follows:

- Whitmire Wildflower Garden [10], a centerpiece of Shaw Nature Reserve, Missouri Botanical Garden's rural site, for over 30 years, where a five-acre central garden surrounded by thirty acres of reconstructed prairie and woodland showcases over 750 species of Missouri native plants. Horticultural settings range from full-sun prairie areas to woodland deep shade and from patio containers to boggy wetland beds. This diversity demonstrates the versatility and beauty of native plantings in an ecological showcase distinguished among public gardens by diligently growing only native species, compared to sites that include ornamental cultivars. Whitmire Wildflower Garden staff adhere to the scientific and horticultural position that "straight native" species optimize ecological benefits, compared to cultivated varieties of native plants (aka "nativars"), where aesthetically motivated variations in key characteristics such as foliage color, flower shape, and bloom time can disrupt optimum plant–insect relationships, decreasing the biodiversity benefits of native plantings.
- Grow Native! [11] our regional native plant program, launched in 2004 as a joint initiative of the Missouri Departments of Conservation and Agriculture and was adopted as a mature program in 2012 by the nonprofit Missouri Prairie Foundation. Grounded in the simple idea to foster both demand for and the supply of native plants, Grow Native! provides benefits to land, biodiversity, and people. Shaw Nature Reserve and the Garden are Grow Native! professional members and BDV-STL is an ardent promotional partner.
- Bring Conservation Home [12] is a highly successful program of St. Louis Audubon that employs trained volunteer Habitat Advisors to evaluate residential properties and provide owners with customized plans to bio-diversify with native plants, with the option to achieve certification. This work has engaged nearly 2000 properties since its launch in 2012. Garden-trained Master Gardeners are enthusiastic, knowledgeable program contributors.

"Feeder Roots" of the St. Louis region's native plant movement include the following:

- Metropolitan Sewer District Project Clear [13] provides grant support for residential rainscaping that requires projects to include 70% minimum native plant species in primarily plant-based stormwater management installations. The Garden's sustainability division, the EarthWays Center, administers this grant program, advocating directly for native plant design, installation, and maintenance.
- Enrollment in the St. Louis Community College Horticulture Program [14] mushroomed when a major focus on ecological landscaping was added to conventional horticulture training. Over 80 percent of graduates secure a job in their field prior to graduation. Garden staff, many of whom are program alumnae, regularly contribute to Career Day events and as speakers.
- Frequent public education events and native plant sales, hosted by groups such as Partners for Native Landscaping [15], an eight-organization collaborative including BDV-STL and the Garden' Shaw Nature Reserve, has been active since 2013. This group's pandemic pivot grew their audience from annual in-person workshops with about 300 attendees to reaching nearly 6000 people per year through a webinar series presented in partnership with the St. Louis County Library. In-person learning events and plant sales have resumed, including active outreach to underserved communities.
- "Better Business Through Biodiversity" is a component of the St. Louis Green Business Challenge [16], the Garden's program supporting sustainability practices across our business sector. Using a biodiversity scorecard developed by Garden staff, participants' Green Teams evaluate and improve biodiversity on corporate and municipal government lands. Since this program element was launched in 2013 to support the work of BDV-STL, an average of 60% of participating companies annually engage around biodiversity, even with no immediate return on investment involved. Activity ranges from pollinator gardening in concert with wellness initiatives to native-planted rainscaping features to corporate campuses earning and maintaining biodiversity certifications.

6. Community Action and Citizen Science

Beginning in 2016, the Garden received and grew the seed of a local artist's idea: to concentrate in a timeframe and intensively promote public action events to tackle Bush Honeysuckle (*Lonicera maackii*), one of our region's most visible and removable invasive plant threats to biodiversity. The Honeysuckle Sweep for Healthy Habitat [17] originally ran for a week in spring and fall; honeysuckle hack events are now hosted by dozens of BDV-STL partner groups through all of March and November. Garden staff curate event specifics and outcome data through BDV-STL eNews and webpages.

City Nature Challenge [18] uses the mobile app *iNaturalist* in an annual biodiversity and citizen science learning event, coordinated by a global team with worldwide city participation. The Garden partnered with City of St. Louis sustainability leaders to join this event in 2018. We configured *iNaturalist* so that all observations made within the BDV-STL region are archived for mapping and analysis; they comprise the Species Inventory section of our ArcGIS Hub, *BiomeSTL*. Drawing on *iNaturalist*'s popularity, we encourage individuals and families to explore and enjoy our region's biodiversity all year round. BDV-STL staff curate and periodically update a map of "50 Nature Places to Love", a mix of well-known and obscure publicly accessible nature-rich sites on the Missouri and Illinois sides of our region, to facilitate an appreciation of both local biodiversity and app-based personal inquiry.

The Academy of Science St. Louis [19] is an original, valued BDV-STL partner, engaging the public with scientists and the use of *iNaturalist* in Bioblitzes coordinated at Shaw Nature Reserve, Forest Park, Tower Grove Park, and other prominent locations. The Academy also co-produced BDV-STL's Wild Ideas Worth Sharing speaker series. As their outreach ramps up post-pandemic, we look forward to resuming collaboration, especially in the vibrant citizen science space.

Mosquito Alert STL (MASTL) [20] is a citizen science and public health research partnership of Garden BDV-STL staff, the City of St. Louis Health Department, St. Louis County Department of Public Health, St. Louis Academic Health, and the Saint Louis University School of Public Health and Social Justice. Based around the mobile app *Mosquito Alert*, MASTL combines public health advocacy with ecological education to augment the capacity of our public health agencies to monitor and respond to the presence of disease-vector mosquito species in our area. In addition to ongoing outreach, in 2024, the MASTL team is conducting a formal study on the efficacy of citizen science for public health awareness and action and developing an MASTL curriculum for grades 6–12.

The BDV-STL network includes and cross-promotes more local ecological action fostering nature connection, including terrestrial and aquatic clean-ups, Green Schools work, the migrating bird protection work of Lights Out Heartland, and our region's local food and food waste reduction movements.

Regional citizen science projects draw on partnerships with BDV-STL's promotional resources, including Shutterbee, Frog Watch, Turtle Watch, Stream Teams, and the Mississippi River Plastic Pollution Initiative. BDV-STL staff have engaged in a newly formed St. Louis Citizen Science Working Group, to promote crowd-sourced research as a rallying focus for nature learning, protection, and restorative efforts among BDV-STL network partners.

7. Policy and Green Jobs Advocacy

Garden staff advocate for ecological policies through BDV-STL partnerships. Through the Green Cities Challenge, a component of our St. Louis Green Business Challenge, we support the efforts of municipal Green Teams to adopt regulations encouraging native landscaping, sharing a model ordinance developed by Grow Native! and providing public talks to educate residents and decision-makers.

Garden staff participate in the Missouri Invasive Plant Council [21], from which a first piece of legislation, pending in 2024, proposes to cease the sale, propagation, and distribution of five "ornamental" plant species known to be serious threats to biodiversity. Garden staff have contributed to a multi-year Invasive Plant Assessment conducted by this council that identified and mapped the most threatening invasive plant species statewide and by ecoregion. Staff also regularly present information about invasive plants to public and professional audiences.

As a founding member of the Midwest Climate Collaborative [22], based at Washington University, the Garden advocates for and contributes to bioregional partnerships addressing climate action planning, community resiliency, equity, resource conservation, and other areas of focus linked to biodiversity.

Regional advocacy for Green Collar Jobs is advancing through sustainability, social service, and economic development partnerships supporting biodiversity through a strong focus on ecological landscaping. Garden staff teach Roots of Success [23], a Department of Labor certified environmental literacy and job training curriculum, in the Green Communities Workforce program, launched in 2023 by the Missouri Department of Conservation. Initiated in 2018, the Garden's Outdoor Youth Corps and Outdoor Leadership Corps [24] employ youth and young adults in programs promoting career paths addressing biodiversity and community needs through professional partnerships and ecological horticultural work.

8. Biodiversity Research and Conservation

All Garden community biodiversity work is informed by our institutional core of scientific rigor. Leaders of the public-facing, professional education and collaborative projects coordinated through BDV-STL learn from and appreciatively partner with current contributors to the Garden's decades of global plant science leadership.

With a mission to safeguard Earth's biodiversity, the Missouri Botanical Garden's Center for Conservation and Sustainable Development (CCSD) [25] advances conservation and biodiversity science through research in ecology, genetics, global climate change, and

ecosystem restoration. The CCSD concentrates its conservation and research activities on geographic areas where the Garden has a depth of experience and expertise, including the St. Louis region, the United States, the Tropical Andes, Mesoamerica, and the Western Indian Ocean region.

Focusing on areas where conservation needs are urgent, the CCSD undertakes research central to conserving biodiversity and informing tangible conservation actions to prevent the loss of biodiversity. For example, CCSD scientists study and conserve at-risk plant taxa in ex situ collections, conduct population genetic analyses, carry out species reintroductions, and develop state-of-the art geographic and statistical tools to identify present and future threats to biological diversity. With a particular focus on promoting the recovery of at-risk native plant species, the CCSD has recently advanced conservation recovery plans with 67 plant species listed on the United States Endangered Species Act.

The Garden's CCSD is committed to building capacity for science and conservation by training and exchanging knowledge with people locally, nationally, and internationally. Through courses, workshops, mentored fellowships, and internship programs, the CCSD trains students and professionals in science, conservation, and restoration with an emphasis on supporting diverse communities. In recent years, CCSD scientists mentored nearly two dozen graduate students from local and international universities and hosted several international fellows.

The CCSD builds collaborative partnerships with scientists, policymakers, practitioners, and local communities. At the Missouri Botanical Garden, the CCSD advances the restoration science of Midwestern ecosystems, including grasslands and oak forests, in partnership with the ecological restoration team at Shaw Nature Reserve. In the St. Louis region, CCSD staff participate in the Living Earth Collaborative (LEC) [26] at Washington University, which involves a partnership between the University, the Missouri Botanical Garden, and the Saint Louis Zoo. As a collaborative hub, the LEC is dedicated to advancing the knowledge of biodiversity and addressing the most pressing issues in biological conservation. Internationally, the CCSD is working on a participatory action research project in Colombia that includes local *campesino* farmers, university scientists, and the staff of a local botanical garden and a national Natural Park System, to study and conserve endangered plants in the genus *Espeletia* in the Sumapaz Páramo near Bogotá.

9. Biodiversity Science and Conservation in Madagascar

One example of the Garden research–practice synergy is its Madagascar Program [27]. The island nation of Madagascar harbors remarkable flora and fauna, products of over 100 million years of evolution in relative isolation. Madagascar is considered a biodiversity hotspot by Conservation International due to having a high degree of endemism (organisms found nowhere else on earth) and having its biodiversity being highly threatened. For this reason, Madagascar is a globally recognized priority for biodiversity conversation. With six families of flowering plants known only from the island, and more than 90% of around 14,000 vascular species of plants likewise endemic, Madagascar possesses a flora unparalleled in its diversity and uniqueness. For the past three decades, the Missouri Botanical Garden has conducted botanical explorations across the island to inventory, describe, and document the plants of Madagascar; this task is still far from complete. Madagascar's flora also is highly threatened by a variety of impacts including deforestation, shifting agriculture, and pressures from climate change such as increased wildfires and extreme droughts. While humans are part of the problem, we are also part of the solution.

The Garden's Madagascar Program operates 12 community-based conservation sites across the island. These sites were selected for their need to preserve unique and threatened habitats while also supporting local communities' livelihoods. Our program today employs over 100 Malagasy staff within Madagascar, and our activities range from the discovery of new species to assessing and mitigating habitat threats to rebuilding damaged ecosystems. Collaboration underpins these exploration, conservation, and restoration activities, as

effective biodiversity actions involve local people, colleagues across the nation, and support and scientific expertise from around the world.

In St. Louis, several Madagascar-based collaborations have also formed through Garden participation in the Living Earth Collaborative, advancing our capacity to undertake ambitious interdisciplinary projects, such as connecting biodiversity and wild foods to human diet diversity and nutritional health; combining primatology and botany to better understand the behavior of lemurs, Madagascar's unique group of primates, and the diversity of tree species that they feed upon; and working with local people to understand how culture and natural resource use can facilitate adaptation to climate change and create resilient natural environments and human communities.

10. Conservation Horticulture for Biodiversity

The Horticulture staff of Missouri Botanical Garden works to address biodiversity issues both globally and locally. On the global scale, we work with various organizations to preserve critically endangered species, such as the wild crop relatives of common fruit and nut plants in Kyrgyzstan, a hotspot of biodiversity. Many of the crops currently grown in our agricultural systems have limited genetic diversity, making them more susceptible to pest and disease issues and the effects of climate change. However, through Garden work domestically and abroad to preserve wild crop relatives and their habitats of plants such as apples, plums, cherries, and almonds, we can ensure that future varieties will have greater genetic diversity and can better withstand the challenges of a changing climate. Garden horticulturists study how best to propagate and preserve the species through seed, cuttings, air layering, and micropropagation. All the growing information we learn is recorded and shared with partner organizations to use in conservation efforts.

At the local level, our staff at the Kemper Center for Home Gardening engage with the public and provide visitors with the best gardening advice to advance more sustainable landscapes. We discourage visitors from planting invasive or problematic plants, educate them as to why they should be avoided, and suggest plants that are more suitable and beneficial to their landscape.

Grounds around the Garden's Sophia M. Sachs Butterfly House [28] are abundantly landscaped with native plants, showcasing local biodiversity to visitors coming for this conservatory's winged delights, butterflies of the world. Staff specializing in horticulture, entomology, interpretation, and events join the insects in residence to inspire and educate all ages toward a care for biodiversity.

11. Ecological Restoration

Since 1980, the Garden's Shaw Nature Reserve (SNR) [29] has been a focus for native habitat management and restoration, including prescribed burning; the selective thinning of woodlands; the judicious use of herbicides for invasive species control; plant diversity enhancement; and the reconstruction of prairies and wetlands. Across a site that has been steadily reclaimed from intensive agricultural impacts, SNR offers 17 miles of hiking trails through an array of Ozark Border landscapes, including floodplain forest, dolomite glades, tallgrass prairie, oak–hickory woodlands, savannas, and wetlands. The restoration of these habitats provides SNR visitors a vivid, varied experience of Missouri's rich biological heritage and personal connections to the value of biodiversity.

A current highlight in SNR efforts is the Wolf Run Restoration [30]. In November 2021, the SNR team began restoring an area that was farmed until the early 1900s and had become highly degraded by dense thickets of invasive species and early successional trees. Crews methodically cleared acres of privet, honeysuckle, buckthorn, lindenleaf viburnum, bittersweet, and cedars. In January 2024, a crew of staff, volunteers, and contractors seeded the first 40 acres of the 120 acre Wolf Run Grassland. A cold snap, frozen ground, and tracks in snow cover were perfect conditions to ensure the even sowing coverage of more than 230 native woodland, wet swale, and prairie species. The crew mixed 1100 pounds of hand-collected seed with 250 pounds of pure seed purchased through a cost-sharing

program. Seventy barrels of seed were sown with 11 cubic yards of seed cleaning chaff and debris collected from prairies across Missouri. Meticulous documentation complements skilled physical efforts, as teams convert this area into high-diversity grassland habitat and learn from the process. Visitors of all ages will observe the transformation, as the introduction of an abundance of native flora attracts and supports native wildlife.

The goal of ecological restoration at SNR is the creation or rehabilitation of a mosaic of habitats that can support healthy populations of the maximum possible number of plant and animal species native to the St. Louis region. In concert with this work, educational and cultural programs communicate how living and non-living disturbance processes—fire, storms, floods, migrating bison, even insect plagues and pathogens—help maintain biodiversity, and that restoration simulating natural disturbances is a vital activity.

The Garden established the Seed Bank [31] at SNR in 2013 to supplement on-site plant conversation locally and globally, with the biodiversity goal of conserving seeds of all plants that are native to Missouri and beyond. Seed banking enables the long-term storage of the genetic diversity of large numbers of plant species. It involves collecting, cleaning, drying, recording, and storing seeds at low temperatures for future conservation and restoration uses. Seed Bank volunteers dedicate copious time along with SNR staff to this demanding, rewarding work.

Collaboration enhances Shaw Nature Reserve's already respected role as a refuge for the biological heritage of east-central Missouri. By 2030, we plan to be actively managing all 2400 acres of the Reserve to preserve and enhance biological diversity.

Litzsinger Road Ecology Center (LREC) [32], managed by the Missouri Botanical Garden, is a 39 acre center for place-based ecological learning, located in the heart of metro St. Louis and open by reservation to school groups. LREC staff and volunteers restore, tend, and study the site's prairie, woodland, and stream communities and provide students with field experiences in ecosystems that dominated the region's landscape prior to current urban and suburban development. Restorations provide habitat to help conserve and restore species and ecological processes that were once common in this area. Restoration efforts, which began as the LREC was established in the late 1990s, tackled new challenges when Metropolitan Sewer District Project Clear improvements necessitated a cut through the site. Resulting reconstruction draws on the prodigious, collaborative skills of staff and volunteers to establish healthy and functional wildlife habitats for education and research.

12. Public and Professional Education

The Garden provides advanced levels of adult biodiversity education. Native Plant School [33] is a year-round series of public classes offered since 2007 at Shaw Nature Reserve, in partnership with the Missouri Department of Conservation and the St. Louis chapter of Wild Ones, a national native plant advocacy organization. Shaw Professional Series [34], coordinated by the Garden's EarthWays Center, offers CEU-based seminars and tours to individuals and companies working in landscaping, design, engineering, planning and other specializations. Services from these programs promote an awareness of biodiversity issues while spotlighting replicable solutions, advancing our regional green economy, and supporting biodiversity projects.

The annual Sustainability Institute for Educators [35], coordinated by staff from the Garden, Saint Louis Zoo, and Webster University, will focus a week of teacher professional development on biodiversity in summer 2024, growing biodiversity knowledge and perspective and providing K-12 classroom resources for formal and non-formal educators.

Our Garden Education Division [36] offers biodiversity resources for teachers, schools, and home-school learners, including a loan of "BioDiverse City" [37], an original interactive game designed for middle school students that simulates the experience of urban neighborhood development over a 10 year period. Players work as a part of neighborhood teams to enhance their communities using granted funds, focusing on sustainability and urban biodiversity. The game involves strategic planning, cooperation, and resource management. Key components include different types of properties, enhancement tokens, and a

currency system that equates money with community labor hours. Players face challenges and make decisions to improve their neighborhoods, balancing immediate needs with long-term sustainability.

The Center for Nature-Inspired Learning [38], the Garden's catalog of school programs, offers classes, field experiences, year-long programs, loaner backpacks, and more to connect young people to nature. Environmental educators know—and a burgeoning body of research documents—how personal discovery in and about nature is essential to foster the human caring and commitment that biodiversity protections require.

Eco Act [39], a Garden Education Division program for over 40 years, works with high school students to study basic ecology and peer-teach program lessons in elementary schools near their own. Students choose ecological topics for team research projects, which they present to Garden staff and their families and peers. Summer orientation and weekend activities give many Eco Act students their first experience of outdoor adventure trips and nature-based leadership and teamwork. Eco Act fosters in youth an appreciation for biodiversity that inspires, for many, environmental career paths in the sciences, teaching, and business and non-profit work.

Therapeutic Horticulture [40] is a Garden education specialty that brings creative and stimulating plant-based activities into the facilities of health care institution partners, to enhance the physical, mental, and social wellbeing of participants. As a richly textured complement to BDV-STL, Therapeutic Horticulture practices deepen individual connections to nature. Highly trained and motivated staff hold certifications from the American Horticultural Therapy Association.

13. Rainscaping and Green Infrastructure

The St. Louis region's green infrastructure movement has grown a practical, economically sound foundation for biodiversity action, advanced by two programs administered by the Missouri Botanical Garden that require the use of habitat-fostering native plants in rainscaping installations. Deer Creek Watershed Alliance [41], formed in 2008 to protect water quality in a watershed that includes areas of 16 suburban municipalities, has supported 542 projects through a cost-sharing program launched in 2014. MSD Project Clear, the grant-making program of the region's Metropolitan Sewer District, has supported 485 projects since initiating this program in 2012.

Embodying these water-conserving values, Garden grounds have been a highly visible public demonstration of rainscaping options since parking lots were renovated in the early 2000s. A bioswale, rain gardens, and a variety of pervious surfaces capture and hold rainwater on site, reducing runoff and soil erosion and mitigating water pollution. On the main Garden parking lot, rainscaping features covering half of the total parking area were designed to capture all stormwater from 90 percent of annual rain events, for a total of 1.14 inches or less in a 24 h period. The Garden's new Jack C. Taylor Visitor Center, which opened in 2022, includes cisterns and rainscaping plantings that reduce building and site demand for municipal water by over 80%. Over the years, such installations have included opportunities for local engineering and construction professionals to observe and learn alongside Garden staff and contractors, to grow industry capacities for infrastructure work that supports biodiversity.

14. The Challenge Persists

BDV-STL services and action have proliferated as threats to biodiversity multiply. Climate change is disconnecting plant growth cycles from deep connections to migrating insect, bird, and other animal populations with time-sensitive food sources and reproductive interdependence. Invasive plant and animal species are marching across hardiness zones. Zoonotic diseases are gaining ground as human and wildlife habitats increasingly intersect. Public education and engagement are essential for biodiversity action, yet public understanding is still slim for even the most visible biodiverse relationships.

Missouri Botanical Garden's global organizing leadership through Botanic Gardens Conservation International continues to be a primary commitment. The Garden hosted educators from 34 countries in 2015 for the BGCI Education Conference, themed "Biodiversity for a Better World". In 2023, we welcomed public garden officials serving on the BGCI Advisory Council for a workshop to define next steps in the role that botanical gardens will play in achieving the goals of the Global Strategy for Plant Conservation; colleagues traveling from 15 countries were joined by a cadre of virtual attendees.

Dr. Peter Wyse Jackson emphasized, in his 2012 challenge to Garden staff and community leaders, how healthy ecosystems and biological diversity are vital for cities to function properly. How, he asked, can we understand, cherish, appreciate, encourage, restore, conserve, and safeguard biodiversity in St. Louis?

What can spark our human attention? Simple, accessible practices like growing native plants in a pollinator garden are joyfully enlivening human places around homes, in school yards, and on corporate campuses. Technology-based nature experiences may be an oxymoron, but they work. Pandemic isolation moved us outdoors, for a long enough duration that the fondness might stick. Nature. Human Nature. We embody the connections.

The issues we face in this work include a public and professional lack of awareness—let alone appreciation—of biodiversity basics and how both economic and social concerns typically omit valuing biodiverse surroundings. Embedded in the definition of community "development" is the reduction or elimination of biodiverse spaces through human-built enterprises, though Indigenous Science practices from many cultures increasingly demonstrate how inverting these "values" can yield what sustainability defines as triple bottom line (fiscal, social, environmental) benefits. Climate change responses that can significantly boost biodiversity work are only slowly evolving beyond the concern for obvious focuses like energy use. Where people of any age or background lack a relationship to nature, nature is a void in our circles of concern.

A place like a public garden, where humans concentrate and tend nature's beauty, can network actions, ideas, and relationships to grow collaboration and cultivate understanding and appreciative care. An unfunded mandate can root in existing projects and partnerships. Cultural institutions, together, can grow a community culture that works with nature to find the solutions to human-caused problems. A culture where biodiversity thrives.

Author Contributions: Writing—original draft, J.P., M.A.A., S.D., R.H., A.J., N.K., D.M. and M.S.; Writing—review & editing, J.P., G.A. and J.S. All authors have read and agreed to the published version of the manuscript.

Funding: Funding for the work of BiodiverseCity St. Louis at Missouri Botanical Garden has been generously provided by the following sponsors: Ameren Corporation; Boeing Corporation; Caleres; Chipotle Mexican Grill; Daniel and Connie Burkhardt Household; Elizabeth and Joseph Bascom Charitable Foundation; Employees Community Fund of Boeing St. Louis; Magnificent Missouri, Inc.; The Katy Land Trust Inc.; The Trio Foundation of St. Louis; William A. Kerr Foundation.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data are available upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. BiodiverseCity St. Louis. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/sustainability/sustainability/biodiversecity-st-louis (accessed on 27 February 2024).
2. Global Strategy for Plant Conservation. Convention on Biological Diversity, 3 July 2023. Available online: https://www.cbd.int/gspc/default.shtml (accessed on 27 February 2024).
3. Department of Economic and Social Affairs—Sustainable Development. United Nations. Available online: https://sdgs.un.org/goals (accessed on 27 February 2024).
4. Connecting Cities and Nature. Biophilic Cities. Available online: https://www.biophiliccities.org/st-louis (accessed on 25 February 2024).

5. Urban Vitality & Ecology. STLOUIS-MO.GOV. Available online: https://www.stlouis-mo.gov/government/departments/planning/sustainability/urban-vitality-ecology/index.cfm (accessed on 25 February 2024).
6. Rakow, D.A.; Gough, M.Z.; Lee, S.A. *Public Gardens and Livable Cities, Partnerships Connecting People, Plants and Place*; Cornell University Press: Ithaca, NY, USA, 2020.
7. Many Communities. One Future. OneSTL. Available online: https://www.onestl.org/media/site/documents/reports/onestl_plan/OneSTL_FinalPlan-web.pdf (accessed on 25 February 2024).
8. Biodiversity of Metropolitan St. Louis. BiomeSTL. Available online: https://biomestl-biomestl.hub.arcgis.com/ (accessed on 25 February 2024).
9. Tallamy, D.W. *Bringing Nature Home: How You Can Sustain Wildlife with Native Plants*; Timber Press: Portland, OR, USA, 2007.
10. Whitmire Wildflower Garden. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/plan-your-visit/family-of-attractions/shaw-nature-reserve/gardens-gardening-at-shaw-nature-reserve/whitmire-wildflower-garden (accessed on 27 February 2024).
11. Native Plants Work. Grow Native! Available online: https://grownative.org/ (accessed on 25 February 2024).
12. Bring Conservation Home. St. Louis Audubon Society. Available online: https://stlouisaudubon.org/bch/ (accessed on 27 February 2024).
13. Project Clear. Metropolitan Sewer District. Available online: https://msdprojectclear.org/ (accessed on 27 February 2024).
14. Horticulture Program. St. Louis Community College District. Available online: https://stlcc.edu/programs-academics/pathways/s-t-e-m/horticulture/ (accessed on 27 February 2024).
15. Partners for Native Landscaping. Available online: https://partnersfornativelandscaping.stlouisaudubon.org/home (accessed on 27 February 2024).
16. Making Sustainability Work for Your Business. St. Louis Green Business Challenge. Available online: https://stlouisgreenchallenge.com/ (accessed on 27 February 2024).
17. Honeysuckle Sweep for Healthy Habitat. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/sustainability/sustainability/biodiversecity-st-louis/honeysuckle-sweep (accessed on 27 February 2024).
18. City Nature Challenge. Available online: https://www.citynaturechallenge.org/ (accessed on 27 February 2024).
19. Academy of Science. Available online: https://academyofsciencestl.org/ (accessed on 27 February 2024).
20. Mosquito Alert STL. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/sustainability/sustainability/biodiversecity-st-louis/mosquito-alert-stl (accessed on 27 February 2024).
21. Missouri Invasive Plant Council. Available online: https://moinvasives.org/ (accessed on 27 February 2024).
22. Midwest Climate Collaborative. Washington University in St. Louis. Available online: https://midwestclimatecollaborative.wustl.edu/ (accessed on 27 February 2024).
23. Roots of Success Ten Year Report (2010–2020). Available online: https://rootsofsuccess.org (accessed on 27 February 2024).
24. Outdoor Youth Corps. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/sustainability/sustainability/sustainable-learning/outdoor-youth-corps (accessed on 27 February 2024).
25. Center for Conservation and Sustainable Development. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/plant-conservation/plant-conservation/conservation-teams/center-for-conservation-sustainable-development (accessed on 27 February 2024).
26. Living Earth Collaborative. Washington University. Available online: https://livingearthcollaborative.wustl.edu (accessed on 27 February 2024).
27. Madagascar. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/plant-science/plant-science/africa/madagascar (accessed on 27 February 2024).
28. Sophia, M. Sachs Butterfly House. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/plan-your-visit/family-of-attractions/butterfly-house (accessed on 27 February 2024).
29. Shaw Nature Reserve. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/plan-your-visit/family-of-attractions/shaw-nature-reserve (accessed on 27 February 2024).
30. Land Abandonment, Succession, and Restoration: The Wolf Run Grassland Restoration Project at the Missouri Botanical Garden's Shaw Nature Reserve. Missouri Botanical Garden. Available online: https://mbgecologicalrestoration.wordpress.com/2023/12/19/land-abandonment-succession-and-restoration-the-wolf-run-grassland-restoration-project-at-the-missouri-botanical-gardens-shaw-nature-reserve/ (accessed on 27 February 2024).
31. Seed Bank. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/media/fact-pages/seed-bank (accessed on 27 February 2024).
32. Litzsinger Road Ecology Center. Missouri Botanical Garden. Available online: https://litzsinger.org/ (accessed on 27 February 2024).
33. Native Plant School. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/plan-your-visit/family-of-attractions/shaw-nature-reserve/gardens-gardening-at-shaw-nature-reserve/native-landscaping-for-the-home-gardener/native-plant-school (accessed on 27 February 2024).
34. The Shaw Series. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/sustainability/sustainability/sustainable-learning/classes-tours/the-shaw-series (accessed on 27 February 2024).

35. Sustainability Institute for Educators. Webster University. Available online: https://www.webster.edu/education/sustainability-inst-educators.php (accessed on 27 February 2024).
36. Learn and Discover. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/learn-discover (accessed on 27 February 2024).
37. PlantLab Student Scientists. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/learn-discover/students-teachers/plantlab-student-scientists (accessed on 27 February 2024).
38. Center for Nature-Inspired Learning. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/learn-discover/center-for-nature-inspired-learning (accessed on 27 February 2024).
39. ECO-ACT. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/learn-discover/students-teachers/teen-programs/eco-act (accessed on 27 February 2024).
40. Therapeutic Horticulture. Missouri Botanical Garden. Available online: https://www.missouribotanicalgarden.org/learn-discover/therapeutic-horticulture (accessed on 27 February 2024).
41. The Deer Creek Alliance. Deer Creek Watershed Alliance—Missouri Botanical Garden. Available online: https://www.deercreekalliance.org/ (accessed on 27 February 2024).