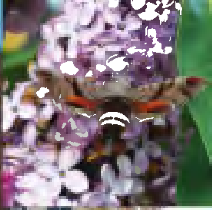
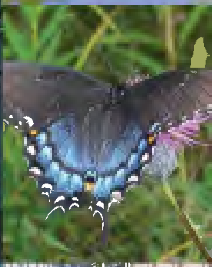
APPENDIX 5F: 2018 Urban Biodiversity Plan -

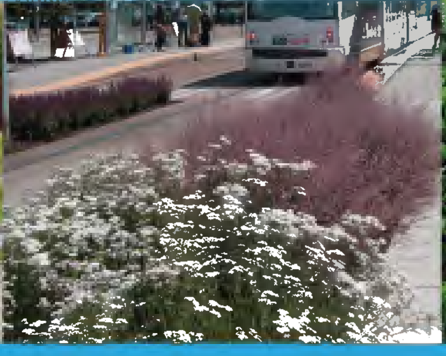




Final Draft

Using Green Infrastructure

to Enhance Urban Biodiversity in the MMSD Planning Area



PREPARED BY THE MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

November 2, 2018

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Using Green Infrastructure to Enhance Urban Biodiversity in the MMSD Planning Area
Final Draft

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Executive Summary

The Milwaukee Metropolitan Sewerage District (MMSD), with the support of local stakeholders, wrote this plan to help protect and restore native biodiversity within MMSD's planning area through the application of green infrastructure (GI). The term GI as used in this document refers to localized management approaches and technologies that infiltrate, evapotranspire, capture, and reuse stormwater to maintain or restore natural hydrology. While GI can also refer to landscape scale components, such as forests, floodplains, and wetlands, that help maintain the natural water cycle, the focus of this report is on the potential biodiversity contributions of parcel- and street-level stormwater interventions. The implementation of such localized GI provides a wide range of triple-bottom-line (TBL) framework benefits as documented in several other studies (e.g., MMSD 2012, Wallace 2012, USEPA 2013, MMSD 2013):

- Environmental benefits include reduced urban heat island effects, improved air quality, and replenished groundwater supplies.
- Economic benefits include increased property values, increased tax base, and job creation.
- Social benefits include reduced crime and an enhanced sense of well-being.

GI strategies can also provide direct and indirect benefits to regional biodiversity among other important ecosystem goods and services, although these benefits have not been as extensively researched. This plan identifies goals and strategies for enhancing urban biodiversity in the MMSD planning area by making recommendations for incorporating biodiversity into GI and other projects, identifying high priority conservation and rehabilitation areas, and suggesting future areas for research, monitoring, and education/outreach. Promoting urban biodiversity is directly linked to MMSD's core mission to cost-effectively protect the region's water resources and is also consistent with MMSD's goal of using effective planning to allow the planning area and broader region to thrive economically and environmentally. MMSD recognizes that its activities to provide water reclamation and flood management services directly impact urban biodiversity. Therefore, it is important that urban biodiversity be considered and layered into MMSD's projects to ensure a true TBL approach to management.

The MMSD planning area is particularly important from a biodiversity standpoint in that it is located in the ecological transition between the Hardwood Forest and Oak Savanna ecoregions to the west, the Laurentian Mixed Forest ecoregion to the north and the Eastern Broadleaf Forest ecoregion to the south (Wisconsin Department of Natural Resources (WDNR) 2011). Thus, it contains a diverse mixture of plant and animal species representative of the forest community types. Fragmentation and loss of these communities has led to the local extinction of many animal species found here in abundance by European settlers (Casper 2008, Casper 2012), and local ecologists predict ongoing losses in the absence of dedicated efforts by local residents to sustain and restore natural communities.

The MMSD planning area contains a diverse mixture of plant and animal species, including the Eastern Tiger Swallowtail butterfly. *Photo: Lesley Brotkowski*

"Biodiversity" in the context used here refers to diversity of life on all organizational scales: genes, species, populations and ecosystems, not just the absolute number of species. Globally, humans depend on biodiversity. Unfortunately, as human populations grow and habitats planned exclusively for humans expand, local and regional biodiversity is eroded, along with an ecosystem's ability to complete important processes (Goddard 2010). People themselves experience negative health effects when they lack exposure to green spaces (Tzoulas et al. 2007, Mitchell and Popham 2008). As a result, the quality of life and long-term economic vitality in urban areas are diminished (Millennium Ecosystem Assessment 2005).

Bioretention areas not only attenuate stormwater that would otherwise drain directly to streams, but also provide habitat for birds, bees, and, native vegetation; improve water and air quality; reduce street noise; and may improve the health of local residents. *Photo credit: MMSD*

Temperature and precipitation changes associated with climate change are also expected to impact biodiversity in the MMSD planning area. Non-native species from the south will shift north, threatening rare local ecological communities. Heavy seasonal rainfall will increase runoff and nutrient/sediment loading into streams, lakes, and wetlands. This will result in more blue-green algal blooms and a decrease in wetland biodiversity. Rising stream temperatures will also impact fish and other aquatic species that require cold water. If implemented now, GI improvements to shade streams and manage stormwater will help to mitigate the potential negative effects of increased temperatures and extreme precipitation events.

Recommendations for Incorporating Biodiversity into GI and Other Projects

The GI strategies promoted by MMSD were evaluated for their ability to enhance biodiversity. The benefits of urban agriculture (e.g., community gardening in vacant lots and parks) were also evaluated. Direct benefits include the addition of new habitat (e.g., putting a green roof on an existing building), improvements to habitat quality (e.g., planting native species, removing concrete stream channels and dams), and pollination enhancement (e.g., planting wildflowers that are preferred by bees). There are also indirect benefits. For example, GI can improve aquatic biodiversity by returning instream flows to more natural conditions.

The broader benefits of GI (beyond stormwater management) were also evaluated using the TBL framework. This evaluation builds upon earlier work done by MMSD and collaborators, including the reports "Fresh Coast Green Solutions - Weaving Milwaukee's Green and Grey Infrastructure into a Sustainable Future" (MMSD 2012) and "Milwaukee Metropolitan Sewerage District Regional Green Infrastructure Plan" (MMSD 2013). From those reports, peer-reviewed literature, and best professional judgment, the potential benefits of various GI strategies (apart from their direct stormwater effects) were reviewed to determine their relative value to benefit biodiversity and other TBL factors (Table ES-1).

Table ES-1. Relative ratings for each of the GI strategies of overall benefits (biodiversity + TBL; the more benefits, the better) and biodiversity alone.

Green infrastructure strategies	Overall rating (biodiversity + TBL)	Biodiversity rating
Native Landscaping (tallgrass prairie plants)	High	High
Bioretention/Bioswales	High	High
Rain Gardens	High	High
Wetlands	High	High
Greenways	High	High
Urban Agriculture[1]	High	High
Stormwater Trees	High	High
Green Roofs	High	Medium
Green Alleys, Streets, and Parking Lots	Medium	Medium
Soil Amendments	Medium	Medium
Porous Pavement	Medium	Low
Rainwater Catchment	Low/Medium	Low

[1]Urban agriculture is not one of MMSD's GI strategies but this plan assessed this activity for its potential biodiversity benefits.

The effectiveness of these strategies to improve biodiversity depends on additional factors as well. Considerations include the design and management of nearby built areas (Hostetler et al. 2011) and the principles of ecological theory (e.g., minimum area required for specific species, minimum number of habitat patches required, colonization distances and heights) (Threlfall et al. 2015, 2017). This plan recommends the following based on that theory and the limited available studies:

1) As shown in Table ES-1, the following GI strategies should be prioritized over others when designing new projects that are intended to enhance urban biodiversity: native landscaping with tallgrass prairie plants, bioretention/bioswales, rain gardens, wetlands, greenways, urban agriculture, and stormwater trees. In general, these strategies provide direct benefits for biodiversity by creating new habitat, improving existing habitat, and enhancing pollination. Other GI strategies, such as rain barrels and permeable pavement, provide an indirect benefit to biodiversity by helping to restore instream flows to more natural conditions but do not provide the same level of direct habitat benefits.
2) GI designers should maximize the structure and complexity of plants and physical habitat when designing new GI projects. Projects should incorporate more complex habitats (in species and structure) with diverse native species, including mosses and shrubs. Projects also should include flowering plants that bloom at various times during the year to provide more niches and resources and, thus, a greater capacity to support more species.
3) MMSD, partner agencies (e.g., SEWRPC, Ozaukee County), and regional experts should work together to identify a list of priority or desired species for protection, ideally cross-referenced to those able and most likely to benefit from increased habitat associated with GI practices. These agencies should then identify minimal habitat size (area) requirements for these species based on expert knowledge recognizing that there is a minimum habitat patch area required to support distinct species. Larger areas will support more species, but some GI projects may be too small to support some taxa. Recognize that there is a limit to what GI practices can provide, habitat-wise. These minimum habitat areas should then be included as guidance in updates to regional GI planning and design guidelines (e.g., MMSD's *Regional GI Plan* and *Green Infrastructure Standard Specifications and Plan Templates*).
4) GI planners and designers should also update regional GI planning and design guidelines to prioritize projects that are within colonization distance of existing natural areas or green space. Those GI strategies providing habitat or food resources for regional taxa (e.g., native landscaping, bioretention, rain gardens, stormwater trees, and green roofs) will most likely support more species and have the greatest effect on biodiversity if they are positioned near areas that host source or sustaining populations (e.g., riparian stream corridors, parkland, forest/prairie, Greenseams®). Isolated GI installations should be expected to support less diverse communities and contribute only a limited amount to regional biodiversity.

5) Once priority species, habitat sizes, and colonization distances have been identified, regional planners should identify priority locations where GI is likely to best promote urban biodiversity and improve the habitat for the priority species. For example, GI might be able to help expand and connect some of the existing environmental corridors and natural areas displayed in Figure 4. Planners should also consider the location of existing community garden plots, larger urban vegetable farms, and perennial food forest parks when deciding where to locate GI to help optimize urban biodiversity in the region. Regional planners should create a new map of the priority GI locations to enhance urban biodiversity that can be combined with other maps showing priority GI areas for other purposes (e.g., to implement total maximum daily loads, to reduce combined sewer overflow, or to treat sources of sewer inflow/infiltration).
6) MMSD and partner agencies should look for opportunities to incorporate GI into the other ongoing activities to improve biodiversity within the region. For example, MMSD should continue to be actively involved with the efforts to restore the Milwaukee Estuary Area of Concern (AOC) and should identify potential opportunities to integrate GI into restoration projects as they are designed. Federal funding is available for such projects through the Great Lakes Restoration Initiative. MMSD should also look for ways to strengthen its relationship with SEWRPC and find more ways to collaborate on projects, use their data, etc.
7) MMSD and partner agencies should continue to invest in Greenseams® and leverage that program's ability to enhance biodiversity through the preservation and revitalization of primary habitat corridors. MMSD has preserved over 3,700 acres of land through Greenseams® and its goal is to acquire another 10,000 acres by 2035 to provide more flood management and wildlife habitat protection throughout the region.

Given the commitment represented by this effort to support regional biodiversity through the implementation of GI, monitoring will be necessary to evaluate the effectiveness of the program for these ends. Monitoring is an important part of any program, and even more so with an innovative approach like using GI to promote urban biodiversity. Identifying applicable and practical monitoring activities would help further the science as well as evaluate effectiveness.

Some GI practices have the potential to create habitat for terrestrial organisms, directly increasing regional diversity. *Photo credit: MMSD*

GI projects should be monitored to make sure they are reducing the stressors they are designed to reduce (e.g., reduction of runoff and pollutant loads). If their primary goal is not being met, then their contribution to diversity improvement in receiving waters should not be expected. The first tier of monitoring, therefore, should be focused on GI performance in reducing the stressors they are designed to reduce. This includes evaluating whether they are designed, installed, and maintained properly, as well as monitoring the performance of representative practices in reducing runoff and pollutants.

In addition to installing GI to increase diversity in receiving waters, some GI has the potential to create habitat for terrestrial organisms. Although these GI strategies may not be intended for that purpose, if designed properly they may provide that co-benefit. Therefore, in addition to monitoring for stressor reduction, these practices should also be monitoring for the species they are able to support before and after construction. Because there is woefully little information on the empirical, as opposed to the theoretical, benefit of GI for species diversity, monitoring information will contribute to the developing science and potentially merit publication.

MMSD's primary driver for installing GI is to reduce runoff volumes, but a strong secondary benefit of GI is to reduce stressors to an extent that regional water quality and diversity improves. Monitoring regional biodiversity is beyond the scope of MMSD, but fortunately there are many statewide and local programs (many mentioned in this plan) already conducting regional monitoring of both aquatic and terrestrial systems to produce data that can be used to assess regional improvement. MMSD should engage with these programs to inform them of ongoing GI projects as they are implemented so the cumulative density of practices on the watershed scale can be related to regional measures of diversity. Again, given the lack of substantial literature on this topic, the resulting data would be very useful for informing future activities and adaptive management.

Public education and involvement will also be critical to raising awareness about urban biodiversity in Southeast Wisconsin and the MMSD planning area. The goals of public education and involvement activities are to 1) raise awareness about urban biodiversity and its importance to the region, 2) educate the public on existing programs and the activities they can implement to improve and protect urban biodiversity, and 3) motivate public involvement and action to implement these activities. These goals can be met by leveraging several existing programs in the planning area, such as MMSD's existing GI outreach and education efforts, the Neighborhood Environmental Education Project (NEEP), and the BioBlitzes run by the Milwaukee Public Museum in collaboration with groups including the Schlitz Audubon Nature Center and Milwaukee County Parks (Grant Park). New ideas recommended in this plan also include conducting a public awareness survey to gauge existing public awareness of urban biodiversity threats, benefits, current perceptions and behaviors, and creating an incentive program like the National Wildlife Federation's Wildlife Habitat Certification program.

1 Introduction

The Milwaukee Metropolitan Sewerage District (MMSD), with the support of local stakeholders, wrote this plan to help protect and restore native biodiversity within MMSD's planning area (Figure 1) through the application of green infrastructure (GI). The term GI as used in this document refers to localized management approaches and technologies that infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrology. GI can also refer to landscape scale components such as forests, floodplains, and wetlands that help maintain the natural water cycle. While those latter components are vitally important at the watershed level, the focus of this report is on the potential biodiversity contributions of parcel and street-level stormwater interventions. The implementation of GI provides a wide range of acknowledged triple bottom line (TBL) benefits, as documented in a variety of reports (MMSD 2012, MMSD 2013). GI strategies can also provide important ecosystem goods and services, including direct and indirect benefits to regional biodiversity. This plan identifies goals and strategies for enhancing urban biodiversity in the MMSD planning area by doing the following:

- Makes recommendations for incorporating biodiversity into GI and other projects.
- Identifies high priority conservation and rehabilitation areas.
- Suggests future areas for research, monitoring, and education/outreach.

1.1 Why is MMSD using Green Infrastructure to Promote Biodiversity in its Planning Area?

Promoting urban biodiversity is directly linked to MMSD's core mission to cost effectively protect the region's water resources and is also consistent with MMSD's goal of using effective planning to allow the planning area and broader region to thrive economically and environmentally. MMSD recognizes that its activities to provide water reclamation and flood management services directly impact urban biodiversity. Therefore, it is important that urban biodiversity be considered and layered into MMSD's projects to ensure a true triple bottom line approach to management.

Fresh Coast Guardians are everyday people who love Lake Michigan and want to protect it.

Fresh Coast Resource Center provides services that will help achieve MMSD's 2035 Vision goal of creating enough GI in the region to capture 740 million gallons of water every time it rains by 2035. This goal is also referred to as FreshCoast740 goal.

Greenseams® is an innovative flood management program that makes voluntary purchases of undeveloped, privately-owned properties in areas expected to have major growth in the next 20 years and open space along streams, shorelines, and wetlands.

MMSD has helped lay the foundation for improved urban biodiversity through its existing programs such as Greenseams®, Fresh Coast Guardians, Fresh Coast Resource Center, its ongoing efforts to remove dams and replace concrete-lined river channels, and through the significant improvement in water quality that has occurred because of upgrading the wastewater reclamation facilities and building the deep tunnel. By preparing this urban biodiversity plan, MMSD is building on this solid foundation by addressing ways in which programs, such as Fresh Coast Resource Center and Greenseams® can further enhance urban biodiversity, while still meeting their primary goals for improved stormwater management, water quality, and flood management.

This plan is intended to complement a variety of other ongoing initiatives that are also addressing biodiversity issues within the region. For example, Ozaukee County is leading several initiatives to match biodiversity and critical habitat needs to conservation opportunities, there is an ongoing project to address biodiversity issues as part of the Milwaukee River AOC program, Milwaukee County Parks conducts on-going natural areas assessments and restoration activities, and the Milwaukee Public Museum has been leading BioBlitzes for several years and has collections from the Milwaukee area that span more than 100 years.

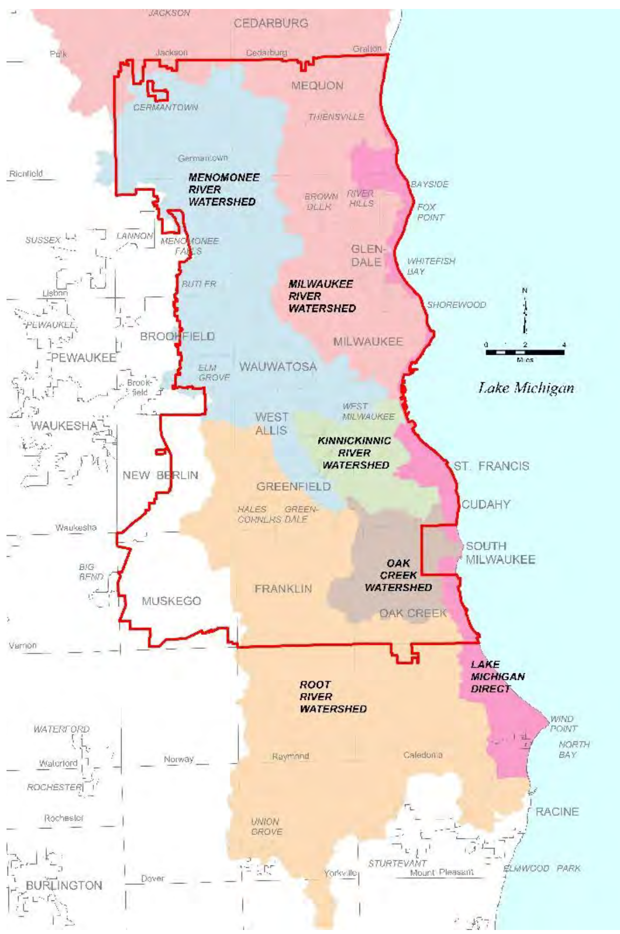


Figure 1. MMSD Planning Area

1.2 What is the Urban Biodiversity Plan?

This plan describes the historical, current, and desired future conditions for fish and wildlife habitat across the urban landscape, relying primarily on existing studies and documents; threats to regional biodiversity are also identified. The plan then discusses strategies and recommendations for implementing GI across the planning area to support the protection and restoration of biodiversity, including a review of the biodiversity benefits of specific GI practices.

The document finishes with recommendations for monitoring, education, and public involvement.

Triple Bottom Line and Ecosystem Goods and Services

The phrases (or names) "triple bottom line" and "ecosystem goods and services" have similar but not the same meanings.

Triple bottom line refers to a holistic approach to measuring benefits in terms of environmental, economic, and social outcomes.

Ecosystem goods and services refers to the many benefits provided by ecosystems, typically split into different categories such as: provisioning services (fresh water and food, timber, or fiber); regulating services (water and air purification, flood management, climate control); support services (soil formation, habitat, pollination, and nutrient cycling); and cultural services (recreation, aesthetic enjoyment, spiritual use, scientific inquiry, education) (MEA 2005).

"Biodiversity" in the context used here refers to diversity of life on all organizational scales: genes, species, populations, and ecosystems, not just the absolute number of species. Globally, humans depend on biodiversity. The diverse living species around us and the functions they perform provide clean water and air, food, clothing, shelter, medicines, and aesthetic enjoyment; they also embody our feelings of shared culture, history, and community (Chicago Region Biodiversity Council 1999). Together, these functions of our planet's ecosystems are called "ecosystem services." They include direct benefits such as food, fiber, and building materials and indirect benefits, including conversion of sunlight to energy, nutrient cycling and retention, soil formation, moderation of climate, flood management, control of insect pests, water and air quality protection, and pollination of crops (Daily 1997, Chicago Region Biodiversity Council 1999). They also include spiritual fulfillment and educational and recreational opportunities (Millennium Ecosystem Assessment 2005).

Unfortunately, as human populations grow and habitats planned exclusively for humans expand, local and regional biodiversity is eroded, along with an ecosystem's ability to complete the above processes (Goddard 2010). Habitat loss and fragmentation impair many species' ability to live in urbanized landscapes. Increased impervious surface areas decrease the services provided by soil ecosystems to filter pollutants and attenuate stormwater. People themselves experience negative health effects when they lack exposure to green spaces (Tzoulas et al. 2007, Mitchell and Popham 2008). As a result, the quality of life and long-term economic vitality in urban areas are diminished (Millennium Ecosystem Assessment 2005).

Milwaukee street trees add color to urban streets, improve air quality, reduce noise and heat, and provide habitat for birds. *Photo credit: MMSD*

As urbanization increases worldwide, preservation of biodiversity within urban landscapes becomes increasingly important (Goddard et al. 2010). Although it might be politically and economically less complicated to attempt conservation of regional biodiversity in areas undisturbed by residential, industrial, or agricultural uses, there are compelling reasons to conserve biodiversity in urban areas (Dearborn and Kark 2010). For example, many cities were established in locations rich with native species, including floodplains, riparian areas, and/or ecological transition zones. Therefore, protection of certain species must focus in those urban areas where such species are endemic or that represent important segments of regionally restricted habitat ranges (Kuhn et al. 2004). Another reason to preserve biodiversity in urban areas is for the positive physical and psychological effects on human well-being from direct exposure to green spaces (Mitchell and Popham 2008, Dearborn and Kark 2010). Although any green space conveys benefits, spaces with higher diversity are often more effective (Carrus et al. 2015). As people living in species-poor cities are increasingly disconnected from the natural world, they may be less interest in its preservation, even as it sustains them from a distance (Goddard et al. 2010). Therefore, human exposure to biodiversity may be crucial to developing an interest in its preservation. To that end, specific conservation of urban biodiversity is important (Miller 2005).

The MMSD planning area is particularly important from a biodiversity standpoint in that it is in the ecological transition between the Hardwood Forest and Oak Savanna ecoregions to the west, the Laurentian Mixed Forest ecoregion to the north and the Eastern Broadleaf Forest ecoregion to the south (Wisconsin Department of Natural Resources (WDNR) 2011). Thus, it contains a diverse mixture of plant and animal species representative of three forest community types. In addition to the three broad forest types, Milwaukee County Parks natural areas also contain a wide diversity of unique ecosystems, including areas of upland and bottomland forests, fens, oak savannas, remnant prairies, open marshes, lagoons, and grasslands (Milwaukee County Parks 2016).

Cedarburg bog is one of the largest remaining wetlands in Southeast WI. *Photo credit: Ron Londré*

These habitats, however, are only a small remnant of those that were present in 1836, when original surveys were completed (Leitner et al. 2008). In terms of plant communities, 97 percent of upland forests had been lost by 2000, 99 percent of prairies, and the Menomonee River wetlands had become an “industrial valley” (Leitner et al. 2008). Fragmentation and loss of these communities has led to the local extinction of many animal species found here in abundance by European settlers (Casper 2008, Casper 2012). A county-wide survey completed in 2008 revealed severe declines in species richness for many plant and animal groups: 37 percent of plants, 39 percent of breeding birds, 71 percent of salamanders, 42 percent of snakes, 27 percent of frogs and toads, and 20 percent of turtles. Certain plant families lost more species: 84 percent of the orchids and all of the heath (formerly 10 species) (Leitner et al. 2008). Local ecologists predict ongoing losses in the absence of dedicated efforts by residents to sustain and restore natural communities.

1.3 Threats to Urban Biodiversity

The next few decades will bring new challenges to the Milwaukee region associated with increasing urbanization and climate change. Each of these are briefly addressed in the following sections.

1.3.1 Increasing Urbanization

Growing urbanization directly affects biodiversity and may be viewed as a threat. The rate at which land is becoming urbanized is growing faster than the rate that natural areas are being preserved (McKinney 2002). In the United States, urbanization and the introduction and spread of invasive species have been shown to be the largest factors in native species endangerment (Czech, Krausman, and Devers 2000). Human population growth leads to increased build-out of infrastructure, creating a demand for open space conversion to roads, buildings, utility corridors, and stormwater facilities. It frequently results in reduced available habitat through conversion or fragmentation and leads to the inadvertent introduction of non-native species.

Habitat can become fragmented due to the presence of dams, roads, bridges, and other infrastructure (Southeastern Wisconsin Regional Planning Commission (SEWRPC) 1997b). Even though preservation areas are set aside, the remaining natural habitat is often too small to support a biologically-diverse ecosystem (Tomimatsu and Ohara 2003; Fahrig 2001). Patches of habitat can become isolated. As the distance between areas of natural habitat increases and the quality of the connecting corridors decreases, biodiversity can become reduced (Cane et al. 2006; Donovan et al. 1995).

Opportunistic species that thrive in urban habitats can take hold in compromised patches and corridors. The result is the displacement of native species by invasive, non-native species (Olden, Poff, and Mckinney 2005). Non-native species often thrive in many different urban environments, with the same species found in many different cities (Olden, Poff, and Mckinney 2005). As a result, instead of a natural habitat that can accommodate a diverse range of locally specific flora and fauna, isolated patches become increasingly characterized by few widespread non-native and nuisance species.

Increased impervious surface areas decrease the services provided by soil ecosystems to filter pollutants and attenuate stormwater. *Photo credit:* MMSD

Continued development of open space is foreseeable, with SEWRPC projecting commercial, industrial, and government land uses to increase by more than 50 percent in the MMSD planning area between 2010 and ultimate buildout conditions (SEWRPC 2016). However, the extent of the resultant habitat loss, fragmentation, and replacement of native species by invasive species does not need to be inevitable. By implementing GI and other habitat restoration/protection projects and practices into city planning, municipalities can work to reduce the impacts of a growing population and expanding urban footprint (Hostetler, Allen, and Meurk 2011).

Development Patterns as a Threat to Urban Biodiversity

Urban sprawl is the spreading of urban developments (such as houses and shopping centers) on undeveloped land near a city. This conversion of rural lands to urban areas typically has an irreversible impact on ecosystems that reduces biodiversity due to climate alteration, modified hydrologic and biogeochemical cycles, and fragmenting of habitats.

1.3.2 Milwaukee Development Patterns

Since 1850, urbanization of Southeast Wisconsin has been steady. Scattered, area-wide suburban development took place, especially after 1950. Between 1850 and 1950, the average rate of growth was about 1.4 square miles per year, whereas between 1950 and 1996, the average rate of growth was 9.2 square miles a year (SEWRPC 1997a). Figure 2 illustrates this trend through the 1990s (SEWRPC 2006).

As a consequence of European settlement, human pressures and urban development, the prairies and oak savannahs that once dominated Southeast Wisconsin have nearly disappeared (SEWRPC 1997b). Likewise, the Lower Milwaukee River and Estuary habitat and water quality have been impacted by alterations including damming, channelization, streambank modification, and industrial discharge (WDNR 2005). Many manufactured organic compounds are found at various levels in sediments, especially in urban areas, which have led to measurable effects on biological receptors, such as aquatic macroinvertebrates.

In *The Vanishing Present*, Larry Leitner, John Idzikowski, and Gary Casper tackled the topic of urbanization and ecological change due to dense human settlement in Wisconsin. They set forth that natural habitats had been eroded along with the former diversity of species they supported. Each author has been a leader in identifying and characterizing plants and animals (particularly vascular plants, birds, reptiles, and amphibians) over many years in Southeast Wisconsin. They have documented species diversity losses due to ecological changes in urbanizing areas.

Prairie cordgrass (*Spartina pectinata*) is a native Wisconsin wetland plant. *Photo credit: Ron Londré*

Trends in land use changes from rural to urban and the loss of habitat-supporting corridors have led to a steady decrease in species diversity and richness. Scientists, regulators, and involved citizen organizations in the Milwaukee region recognize these problems and have been working since before 2000 to characterize the issues and to find tools and policies that will help stop or reverse the decline in native species biodiversity.

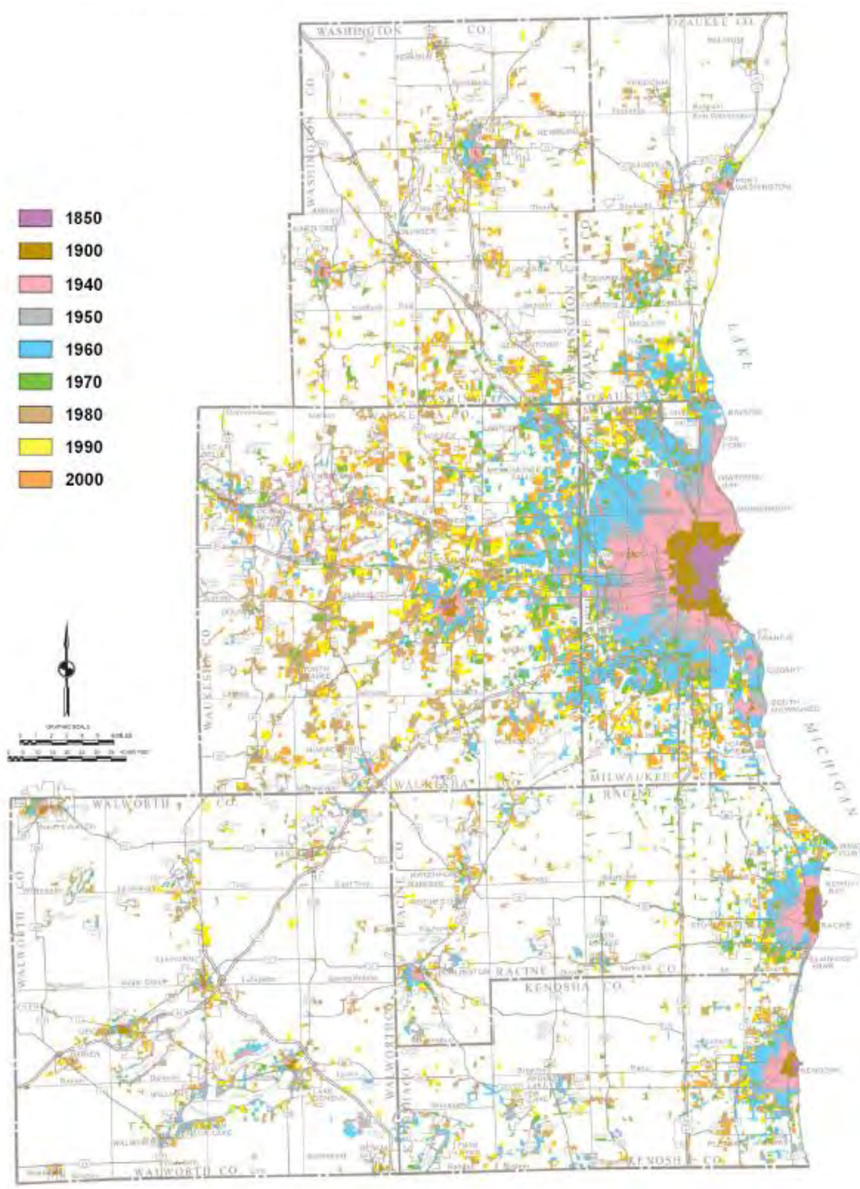


Figure 2. Historical urban growth in the region, 1850-2000 (SEWRPC 2006)

1.3.3 Climate Change

A joint task force in Wisconsin compiled and issued a comprehensive report on Wisconsin's expected changing climate (Wisconsin Initiative on Climate Change Impacts 2011). The Wisconsin Initiative on Climate Change Impacts, the Nelson Institute for Environmental Studies at University of Wisconsin-Madison, and the Wisconsin

Department of Natural Resources (WDNR) used “down-scaled” global climate models that indicated a warming trend and predicted climatic changes in Wisconsin.

By 2050, the authors predict an average annual temperature increase of 6 to 7 degrees Fahrenheit (°F) in the state over 2006 temperatures. Increases in precipitation, and especially an increase in the number of large storm events, are also predicted. The proportion of winter precipitation events is expected to be more rain or freezing rain, rather than snow.

The report considered the potential impacts of climate change on natural resources, development, and the adaptation of natural and human systems in response to those changes. Temperature and precipitation changes are expected to impact Wisconsin’s natural environments, agricultural and developed lands in some of the following ways:

- Plant hardiness zones and associated wildlife will shift to the north.
- Non-native species from the south will shift north, expanding into Wisconsin.
- Opportunistic species, such as the European starling, could benefit, and will threaten Wisconsin’s biodiversity.
- Wisconsin’s water resources will be impacted by decreasing ice cover, increased water levels (in southern Wisconsin), and decreased water levels in northern Wisconsin.
- Lake Michigan coastal waters will experience decreased ice cover, changing water levels, and increases in wind strength, leading to shoreline erosion and recession and reduced coastal wetland biodiversity.
- Heavy seasonal rainfall will lead to increased runoff and nutrient/sediment loading into streams, lakes, and wetlands. This will result in more blue-green algal blooms and a decrease in wetland biodiversity.
- Rising stream temperatures will impact fish and other aquatic species that require cold water.
- Decreases in soil moisture will threaten Wisconsin’s amphibian populations.

The consensus is that regional biodiversity will face a serious threat with changing climate. A focus on planning and implementing GI will help with the adaptation to these changes. Implemented now, GI will help to mitigate the potential negative effects of increased temperatures and precipitation events (Gill et al 2007).

1.4 Ongoing Programs

Milwaukee and Southeast Wisconsin have a long history of engaging in public-private partnerships. Programs and partnerships are multifaceted, often including County Parks and Planning departments, regulator input (e.g., WDNR), and land and water resource management planning agencies, such as SEWRPC and MMSD. Public-private partnerships have been formed to develop programs to characterize and improve the Milwaukee River AOC, and to contribute to multiple local and regional watershed planning initiatives. For example, one organization, the River Revitalization Foundation, has been engaging urban youth, local conservation corps and AmeriCorps NCCC teams to improve habitat biodiversity on land trust properties along the Milwaukee River for over 7 years.

Blood root (*Sanguinaria canadensis*) is a Wisconsin wildflower found in undisturbed woodlands. *Photo credit: Ron Londré*

The strong partnerships are in part due to the regional wealth of academic research at the University of Wisconsin-Milwaukee (UW-Field Station) and other institutions, as well as the public environmental science and outreach centers. The Milwaukee area and nearby counties are home to the Milwaukee Public Museum, the Urban Ecology Center, the Milwaukee County Zoo, and Wehr Nature Center. All these organizations engage in robust public-private interaction and collaboration. For example, the Urban Ecology Center, perched along the floodplain of the Milwaukee River, has been at the forefront of outreach and citizen science with programs including the Neighborhood Environmental Education Project. Their programs have helped to focus awareness of the threat of habitat loss due to urban development.

There continues to be substantial progress in the Milwaukee area and surrounding counties to set aside patches, or islands, of habitat for increased inventory and potential management. The actions are consistent with MMSD's mission and include initiatives such as Greenseams®. Preservation and revitalization of open space for flood management through Greenseams directly impacts biodiversity by protecting and improving primary habitat corridors. For example, Downer Woods Natural Area, an 11-acre woodland on the UWM campus, became a part of the UWM Field Station in 1998. Prior to 1998, no management activities took place within the woodland, and it was described as bearing "little resemblance to that of the mature beech-maple forest" which would have been present pre-settlement. As is the case in most of our local woodlands, a shrub layer of non-native buckthorn and honeysuckle had taken hold. The woodland is now managed to help restore the native diversity. A trail system was developed to provide public access, and inventories of vegetation are now maintained to help document improved biodiversity.

Groups very engaged in preservation and restoration efforts include the Ozaukee Washington Land Trust in partnership with Ozaukee County and the Ulao Creek Partnership. Another active group is the Milwaukee Area Land Conservancy. The Milwaukee Area Land Conservancy was instrumental in arranging a conservation easement for the 22.5-acre Mayer Land in the City Franklin in Milwaukee County, which abuts the county-owned Franklin Savanna State Natural Area. The easement area transitions from the Savanna natural area to a white oak and hickory woodland and includes a secondary environmental corridor. Ryan Creek, tributary to the Root River, flows through the area, which also includes steep slopes and wetlands. The stated goals of this conservation easement are to maintain the existing habitat, provide a buffer to the state natural area, and protect Ryan Creek.

Linkages between the programs and collaborators are numerous. The counties situated within the MMSD planning area conduct natural areas assessments and restoration activities within their park systems, and they often involve volunteer input from local partnership and friends groups.

Since at least 2000, public-private partnerships have been active in bringing together regulators, the public, and scientists to understand the impact of urbanization on the natural environment and created momentum to foster action. The Milwaukee River Workgroup, a team that included Milwaukee conservation groups, has brought targeted attention to the riparian corridor surrounding the Milwaukee River and the need for habitat restoration, as well as for improved public access to this urban resource. This group and others have helped create an inventory of the plants and animals in the corridor using "BioBlitz" events to gather data on organisms found in a given area.

Butler's gartersnake (*Thamnophis butleri*). *Photo credit: Rori Paloski, WDNR*

Southeast Wisconsin initiatives to develop species inventories have been ongoing for many years, particularly for plants, birds, reptiles, and amphibians. One such inventory is the Wisconsin Herp Atlas (Herp Atlas), which tracks amphibian and reptile distribution. The Herp Atlas began in 1986 at the Milwaukee Public Museum with the cooperative support of the Natural Heritage Inventory Program (Bureau of Endangered Resources, WDNR; and The Nature Conservancy, Wisconsin Chapter). Developed from museum collections, field surveys, and field notes, the Herp Atlas provides information about species distributions, rare species, population trends, and habitat requirements. The information is then utilized to help document and plan conservation priorities. For example, Butler's gartersnake was listed as a protected species in 1997 and delisted in 2014 because of additional information (WDNR 2017b). Further inventories will make clear whether delisting was a sound conservation decision for the snake, which requires open or semi-open wetland and adjacent upland habitat.

2 Biodiversity Inventory

This section provides background information on biodiversity in the MMSD planning area, including a description of the landscape setting and an overview of species native to the region.

2.1 Regional and Landscape Setting – An Ecological Transition Zone

A discussion of the biodiversity of past or current native species and communities must first be prefaced by describing the region in terms of a biogeographical framework. The framework is made up of ecological regions, grouped by type, quality, and quantity of environmental resources. These regions serve as a spatial framework for research, assessment, management, and monitoring. They are also useful for developing regional or area environmental resource inventories, setting regional resource management goals, and for developing biological criteria and water quality standards.

MMSD's planning area can be broadly categorized as a Level III ecoregion, the Southeastern Wisconsin Till Plains, and is described as a mosaic of vegetation types. It is in a transition area between the hardwood forests and oak savannas of the ecoregions to the west, the Laurentian Mixed Forest to the north, and the Eastern Broadleaf Forest to the south (WDNR 2011), beyond which lies the tall-grass prairies of the Central Corn Belt Plains.

The WDNR-defined regional groupings (WDNR 2011) are referred to as "ecological landscapes" (Figure 3). The breakdown allows for groupings of similar soils, topography, ecological community types, and therefore, management opportunities. The MMSD planning area lies within the southern and central Lake Michigan Coastal areas, with the western counties situated within the Southeast Glacial Plains.

The Southeast Wisconsin landscape is described as a transition area. It contains a diverse mixture of plant and animal species that are representative of many ecosystems, including different forest community types. The Milwaukee County Parks Department describes local ecosystems as including upland and bottomland forests, fens, oak savannas, remnant wet-mesic prairie, shrub-carrs, open marshes, lagoons, and grasslands. The variety of forests, wetlands and other community types host a wealth of plant and animal species.

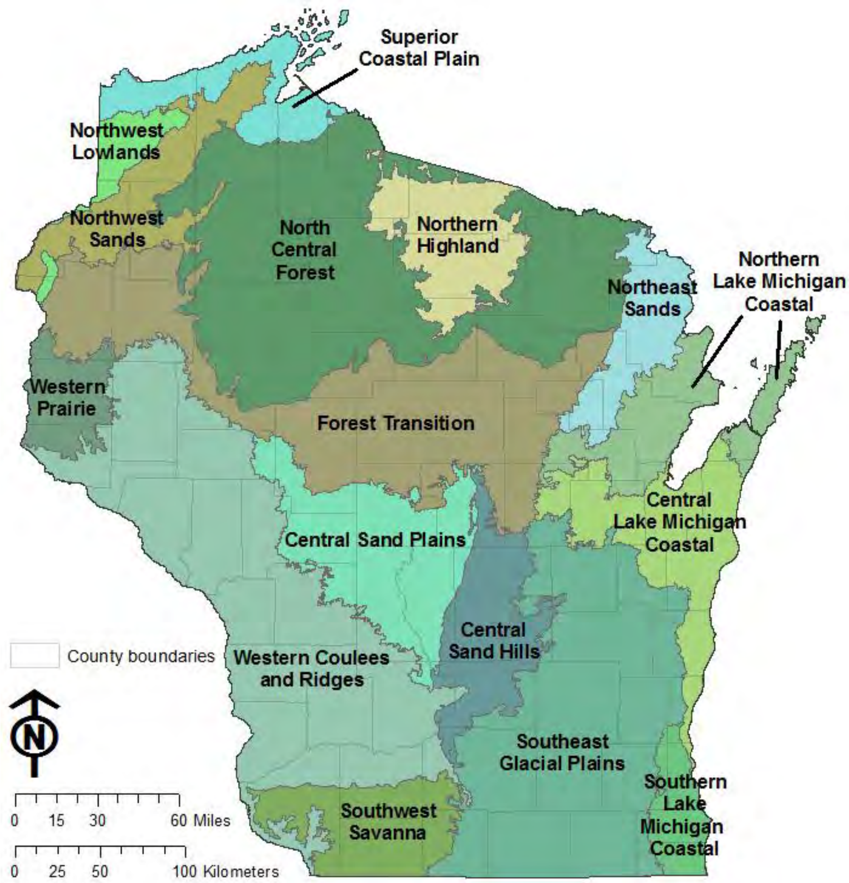


Figure 3. Ecological Landscapes of Wisconsin

2.2 Native Species and Communities, Past and Present

Because Southeast Wisconsin is situated in a climatic transition zone with many ecosystem types, the MMSD planning area demonstrates a rich diversity in its species lists. One reason for this biotic richness is that northern and southern species are at or near their range limits. As a result, many species at these range limits are rare or uncommon.

There are several initiatives in the MMSD planning area to identify which species are present, and where. This discussion begins with the long-standing regional planning effort to identify important environmental corridors and watersheds in Southeast Wisconsin.

2.2.1 Environmental Corridors

SEWRPC, working with WDNR and other stakeholders, recognizes the importance of preserving environmental corridors, in large part due to their direct benefit for maintaining and improving water quality, providing open space habitat, and providing enhanced recreational opportunities. Environmental corridors include the most important elements of the natural resource base—including wetlands, woodlands, prairies, wildlife habitat, major lakes and streams, and associated riparian areas and floodplains. The delineation of environmental corridors results in an essentially linear pattern in the landscape and they are generally located along major rivers and streams and around major lakes.

SEWRPC has defined primary environmental corridors as generally being a minimum of 400 acres in size, 2 miles long, and 200 feet wide (Figure 4). Secondary environmental corridors connect with the primary environmental corridors and are at least 100 acres in size and 1 mile in length. Areas at least five acres in size that contain important natural resources but are separated physically from primary and secondary corridors by intensive urban or agricultural uses have also been identified as “Isolated Natural Resource Areas” and should also be considered for preservation. It is now widely accepted that the preservation of corridor areas serves many beneficial purposes, including natural resource and water quality protection and aesthetic values. In this respect, a number of measures have already been put in place to preserve these environmentally significant areas. These include public ownership, state administrative rules, and local land use regulation. Combined, these measures have resulted in virtually all the primary environmental corridors in the MMSD planning area being substantially protected from incompatible urban development.

These intact areas serve as “greenways” that allow the ready dispersal of seeds and migration of species. Wider and longer corridors provide opportunities for wildlife that require larger non-fragmented tracts of forests or territories. Narrow corridors are useful for species that require edge conditions, such as birds that shelter in the woods but require an open grassland or pond to forage for food.

It should be noted that the identification of an area as an environmental corridor or isolated natural resource area does not necessarily give an indication of the quality of the natural resource involved or the biodiversity of the area. In some cases, environmental corridors and isolated natural resource areas could contain wetlands dominated by reed canary grass or a woodland consisting largely of boxelder. Such areas would have a lower level of biodiversity. However, such areas are prime candidates for resource enhancement or restoration projects.

An indication of the biodiversity of environmental corridors and isolated natural resource areas are those areas that contain SEWRPC-designated natural areas. Natural areas represent important reservoirs of biodiversity because they are identified and delineated based largely on the presence of diverse, relatively undisturbed native plant communities. In other words, designated natural areas are where much of the native biodiversity remains, and consequently, they serve as sources for the species involved to be dispersed throughout the corridors. Virtually all of the natural areas are located within environmental corridors and isolated natural resource areas.

Because proximity to water is critical to the abundance and diversity of many native species, the preservation or enhancement of riparian areas, including environmental corridors, is of great importance in preserving biodiversity (SEWRPC, 2010). The SEWRPC staff has mapped both existing and potential riparian buffers under several planning efforts within the MMSD planning area to develop an understanding of both the existing and potential resource connections. Those riparian buffers often extend beyond the limits of environmental corridors. That extension recognizes the need in some cases for additional open lands to promote biodiversity by providing adequate habitat features for a wide variety of plant and animal species. The use of native plant landscaping and GI in developed and open areas adjacent to environmental corridors would have the potential to increase and/or support the biodiversity of these riparian areas and provide a continuous "greenway" along the associated waterway.

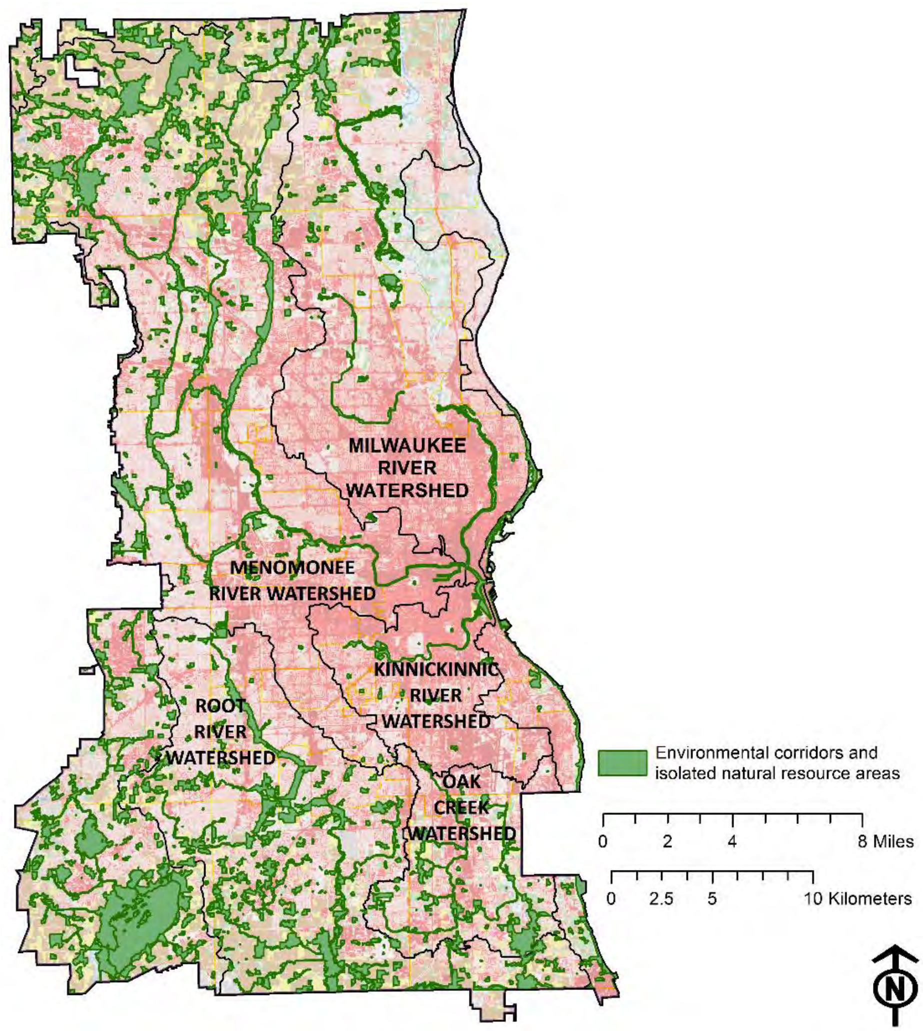
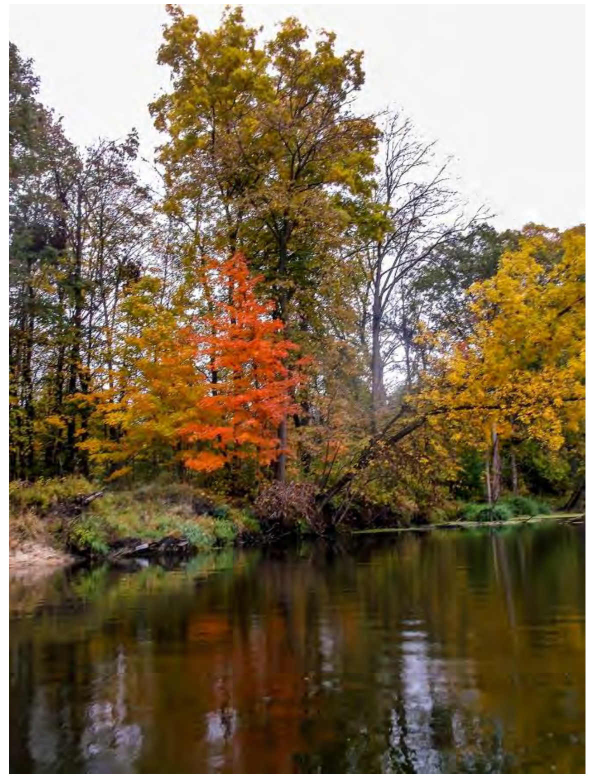


Figure 4. Spatial arrangement of primary and secondary environmental corridors and isolated natural resource areas as identified by SEWRPC in relation to MMSD planning area (SEWRPC 2017).

2.2.2 Municipality-Based Biodiversity Assessments and Planning Tools

When stakeholders want to restore open space, for example, by providing breeding and/or stopover habitat for migratory birds and waterfowl, they need to understand its species diversity. They ideally will need to know what birds were there historically, which are currently present, and which species could be expected to thrive if habitat improvements are made.



Fox River. *Photo credit: Ron Londré*

Logically, improved habitat conditions within a park system, greenway corridor, or a natural area are expected to have ecological benefits: attracting native wildlife, increasing species mobility and reproductive exchange, and improving opportunities for foraging, nesting, and sheltering. But if a key objective for protecting habitat is to improve biodiversity, especially when public funds will be used, then targeted studies to measure success criteria are needed. Species richness indicators, especially when coupled with watershed-level geophysical conditions, are also useful in evaluating if a particular habitat should be protected. Is it high quality now? Could it be, and will it respond to restoration actions? Restoration actions may need to be implemented for many years, and at a potentially high cost.

Because of these needs, municipalities within MMSD's planning area are now developing protocols and tools to use when deciding whether to expend funds for preserving specific parcels. For example, prior to buying or committing resources to manage land, Ozaukee County Planning and Parks Department uses an Ecological Prioritization GIS Tool (described in the next section) to help determine the value of preserving or restoring the tract.

Ozaukee County has also been involved in a variety of planning initiatives to catalog and map its land and water resources for the purpose of protecting water quality and to identify avenues to preserve, protect, and improve key ecological resources. In August 2016, Ozaukee County updated the County Master Plan to incorporate prior reports and studies and to set forth a program for prioritizing county natural resources. This new plan incorporates several other plans, including a Multi-jurisdictional Comprehensive Plan, a Land and Water Resource Management Plan, a Park and Open Space Plan, and updates to the Ozaukee Washington Land Trust Priority Preservation Project Areas. The new combined plan—the Coastal Resources Ecological Prioritization Master Plan (Ozaukee County 2016)—includes a parcel-level prioritization and planning element called the Ecological Prioritization GIS Tool. The tool is used by the county when they are evaluating land for preservation, management, or restoration, and it provides insights into options for biodiversity planning.

3 Biological Indicators and Ongoing Biodiversity Efforts

Achieving desired improvements in biodiversity is aided by indicators useful for assessing status and measuring progress. Because complete species inventories are generally not feasible, bioindicators are often used to assess the ecological quality of a particular environment and detect changes over time. Bioindicators are species, biologic processes or communities that can be relatively easily measured and reflect environmental health (Holt and Miller 2010).

The application of bioindicators to measure the health of an ecosystem increased in application in the US in the 1960s; bioindicators are applied to both aquatic and terrestrial environments and reflect a variety of important ecological attributes, including diversity, richness, evenness, tolerance, and frequently feeding and reproductive traits. A brief description of some typically used biological indicators is provided in the following sections, first for aquatic and then for terrestrial and riparian ecosystems.

3.1 Target Indicators for Aquatic Communities

The relationship of water quality and aquatic biota has been well documented. Species-based inventories serve to provide a snapshot in time about the status and distribution of different taxonomic groups. Many inventories have focused on particular areas (e.g., Milwaukee River), habitat types (e.g., wetlands), and particular groups of species (e.g., warmwater fishes, macroinvertebrates).

Water quality assessments are used by WDNR to determine needed actions when evaluating existing water quality conditions or restoration requirements for impaired waters. The WDNR Bureau of Water Quality developed the Targeted Watershed Site Selection Tool (TWSST) to assist in the selection of monitoring locations in Targeted Watershed Assessments (TWAs). TWSST is a watershed-scale classification system that groups stream reaches according to a variety of stream channel and landscape-level physical characteristics (land cover, soils, slope, stream flow volume, and water temperature). The tool uses fish survey data from WDNR's Fisheries Management database. It also uses water chemistry and benthic macroinvertebrate data from the publicly-available Surface Water Integrated Monitoring System (SWIMS) database.

Some stream condition assessments conducted by WDNR focus on the composition of fish and/or macroinvertebrate assemblages, in addition to other baseline indicators of water quality. Locations for these past surveys and sampling stations are depicted in Figure 5.

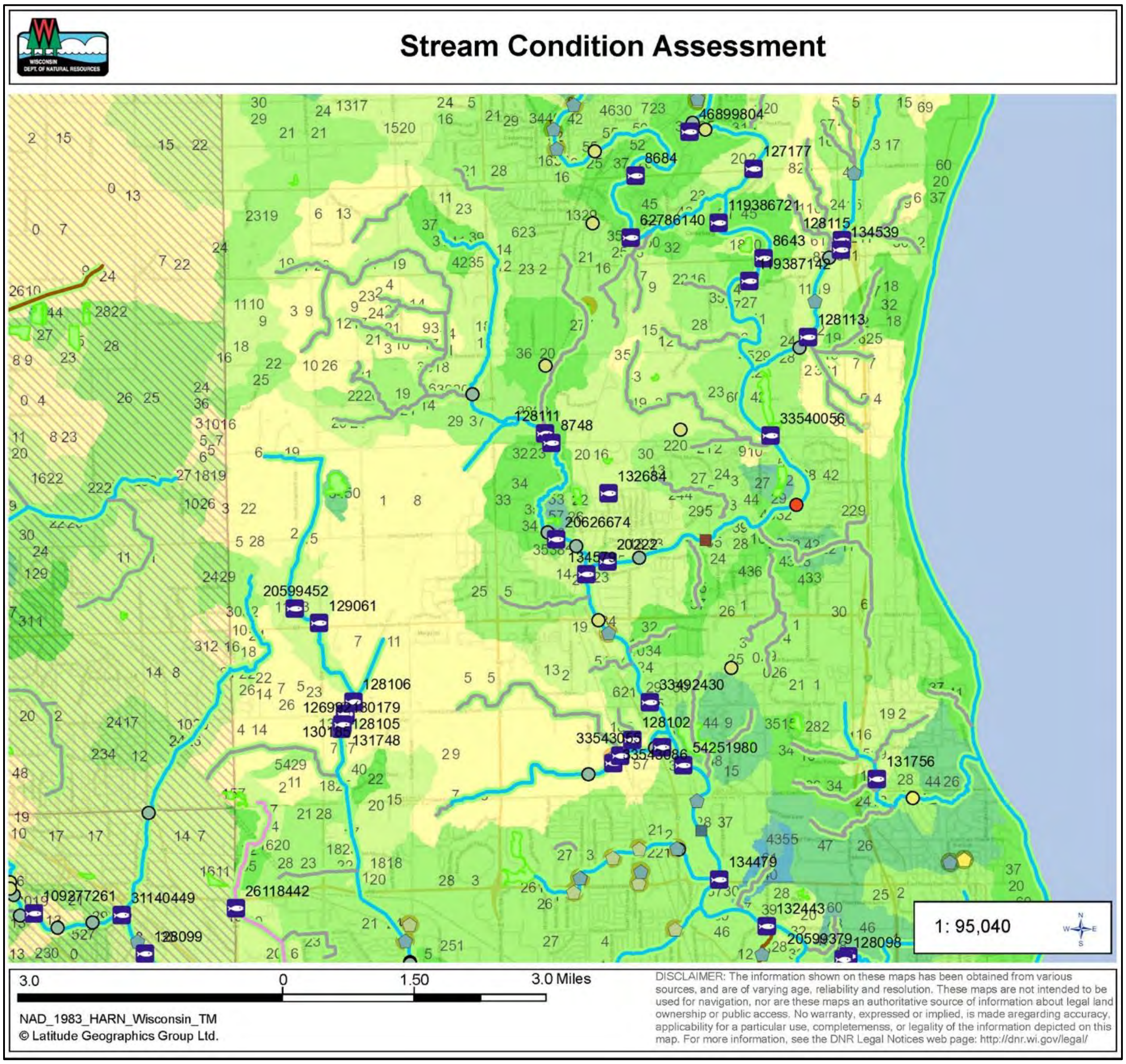


Figure 5. Location of stream condition assessments in Southeastern Wisconsin (WDNR https://dnr.wi.gov/maps/).

WDNR uses key aquatic indicators (physical, chemical, toxicity, and biological) in its baseline water quality assessments. Specific water quality parameters, compared against known thresholds, provide insight into the water quality and condition of a waterbody. They also use inventories for the type and number of fish or macroinvertebrate species, which are then compared to expected values for biological measures.

Water quality assessment data and inventories are typically compared to indices of biological integrity. Two commonly used indices for water quality and stream condition assessments are the Fish Index of Biological Integrity (FIBI) and the Macroinvertebrate Index of Biological Integrity (M-IBI). Fish IBIs developed by WDNR are used to assess the biological health and quality of fish assemblages. They incorporate metrics for the structural, compositional, and functional attributes of fish assemblages of streams and rivers (WDNR 2017a).

Macroinvertebrates are good bioindicators of conditions within a stream. An unimpaired stream or river could contain many different macroinvertebrates, each with specific tolerances and habitat preferences (Holt and Miller 2010). As a result, they serve as good bioindicators since certain taxonomic varieties respond to stressors differently. Some are very sensitive to disturbances or pollutants, while others are very tolerant.

The map in Figure 6 depicts median M-IBI values at over 2,000 Wisconsin monitoring stations sampled between 2002 and 2012. The red values are indicative of poor conditions, such as degraded biological community or excessive sedimentation.

As demonstrated in Figure 6, most of the stream reaches in Southeast Wisconsin are yellow or rated “Fair” for their M-IBI median value. Understanding the baseline aquatic health of a stream is needed before quantifiable targets for improvement can be set. Using the M-IBI, achieving improvement could be tied to a particular use of that waterbody.

Under the Clean Water Act, Wisconsin waters are assigned four “uses,” each with a set of goals: Fish and Aquatic Life, Recreation, Public Health and Welfare, and Wildlife. WDNR’s methodology for conducting assessments is outlined in its Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) guidance document. Wisconsin must document the methodology it uses to list (or delist) impaired waters. When water quality data demonstrates that the designated use has been restored, an impaired water can be delisted.

For example, attainment of the Fish and Aquatic Life use for a given stream may be achieved once acceptable parameters are measured and achieved. Wisconsin’s use designations for streams and rivers are categorized as Cold Water, Warm Water Sport Fish, Warm Water Forage Fish, Limited Forage, and Limited Aquatic Life. The assessment could include documenting the type, number, and presence of aquatic macroinvertebrate species and fish species.

A stream with poor water quality or with habitat deficiencies may be capable of supporting small populations of forage fish or tolerant macroinvertebrates. It would be classified as a Limited Forage Fish Community. The typical aquatic communities associated with these waters would be tolerant of warmer temperatures and concentrations of dissolved oxygen above 3 mg/L. In contrast, streams found in northern Wisconsin may support a cold water sport fishery and/or spawning area for cold water fish species. Aquatic life typically present in a Coldwater Community would require colder temperatures and higher concentrations of dissolved oxygen.

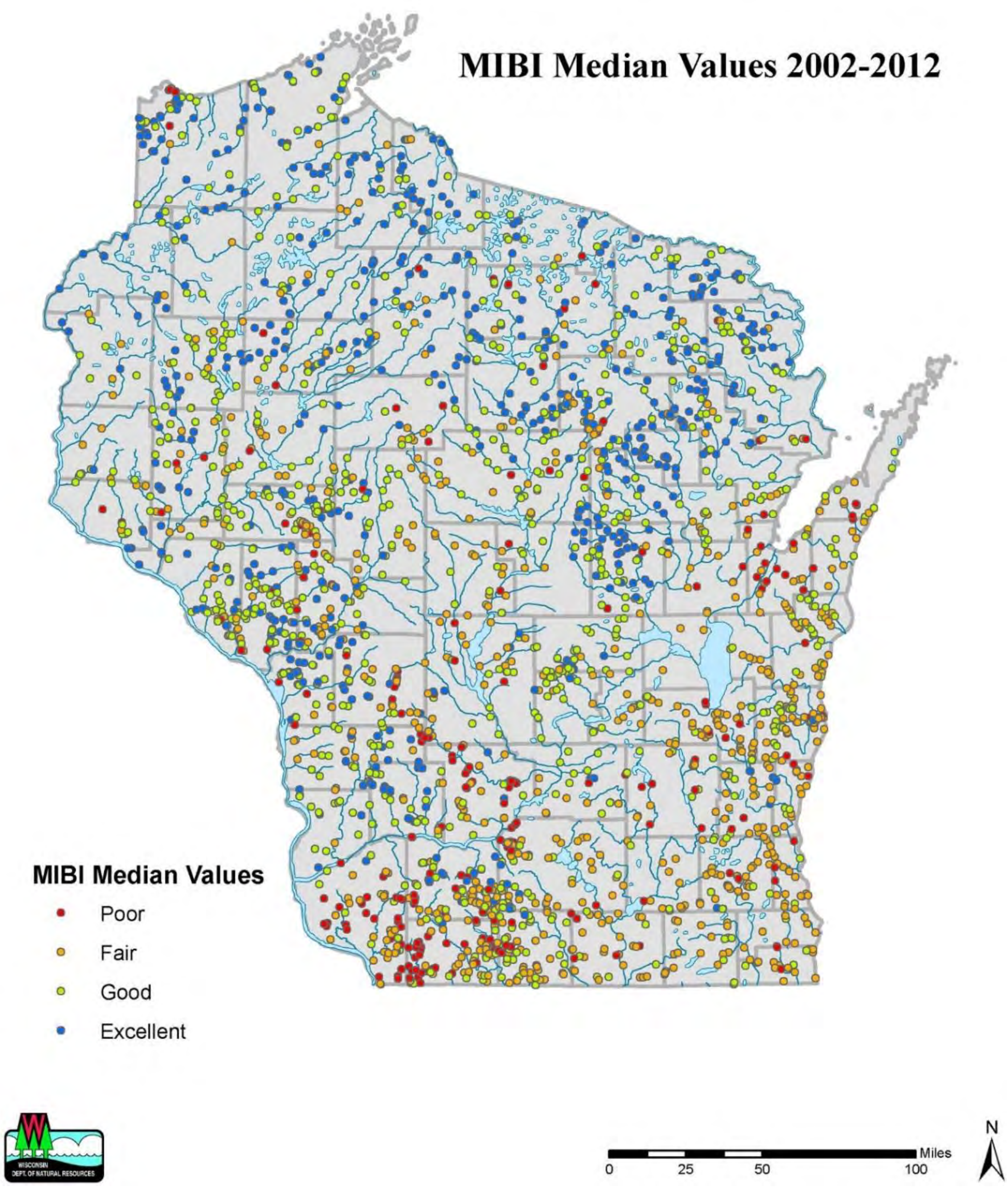


Figure 6. Macroinvertebrate IBI Values (M-IBI) 2002–2012. Location of excellent, good, fair, or poor biological data. (http://dnr.wi.gov/topic/impairedwaters/mibi_2002_2012.html).

3.2 Target Indicators for Terrestrial Habitats and Riparian Buffers

Open space and corridor linkages contain terrestrial habitats that are often targeted for conservation. The higher quality patches within them, many with riparian zones along waterways, have been degraded due to urban encroachment, spread of invasive species, or fragmentation caused by land use changes. Biological indicators help identify habitat restoration and preservation opportunities, especially if the goal is to improve the opportunity for viable wildlife populations and biodiversity protection and enhancement. As in aquatic systems, terrestrial biological indicators focus on assemblage inventories, both plant and animal based. While plant surveys enjoy a longer and more pronounced application in terrestrial ecosystems, invertebrate and vertebrate approaches are not uncommon for measuring status and trends in ecological condition, including diversity.

As mentioned, vegetation surveys are a common application for measuring biological integrity in terrestrial environments. These consist of surveys of the presence, abundance, and characteristics (e.g., size) of different plant species using any of a variety of standardized sampling approaches (e.g., plot or transect based). A large fraction of the biodiversity of many sites is in the flora, so their measurement is important to overall biodiversity protection and restoration. In addition, many plant species cannot disperse across degraded or fragmented landscapes, so identifying diverse patches is important and a conservation priority. Plants also integrate impacts of past disturbance, meaning they provide more than short term snapshots of stress and degradation. Vegetation is also a valuable indicator because so many non-plant species depend on them. Insect biodiversity and abundance are dependent on several measures of plant biodiversity (e.g., Panzer and Schwartz, 1998; Ebeling et al., 2008), and communities dominated by non-native species tend to have reduced, often dramatically reduced, insect biomass and diversity (e.g. Heleno et al., 2008; Tallamy and Schropshire, 2009). Since insects serve to pass energy and nutrients from vegetation to higher trophic levels in ecosystems, and insect communities are strongly influenced by plant communities, assessment of biological diversity and ecological integrity should consider plants as bioindicators.

In addition to traditional floristic surveys of presence and abundance, weighted average plant biological indicators also exist that use trait-based information assigned to plants. For example, Floristic Quality Assessments (FQA), are used in ecological assessments and monitoring of wetlands and upland areas. An FQA is essentially a weighted richness metric based on assigned coefficients of conservatism (C) applied to each species based on their tolerance to degradation and the degree to which the species is faithful to natural remnant habitats (Freyman et al. 2015). FQAs can be used to measure ecological integrity over time, as metrics like mean coefficient of conservatism are sensitive to ecological degradation. Similarly, mean coefficient of conservatism is sensitive to habitat improvement. Coarser metrics like proportional abundances of native vs. exotic species are also useful and sensitive to change.

In addition to plant surveys, terrestrial vertebrate or invertebrate surveys are useful and have been applied with some regularity in this region. Wildlife territory needs, even for a turtle or frog, are complex, since certain species require a mosaic of habitats to complete their life cycle; therefore, their presence often integrates conditions over a variety of habitats. Dr. Gary Casper has conducted inventories and studies to quantitatively measure ecological condition using a variety of species in this region. In partnership with the Milwaukee County Parks and WDNR, he is currently conducting a comprehensive wildlife survey of the Milwaukee Estuary and its associated waterways (as well as conducting studies throughout Southeast Wisconsin). Much of that work focuses on species of local conservation interest (SLCIs), but general approaches need not be constrained to specific taxa and, in fact, may benefit from broader focus.

New England aster (*Symphyotrichum novae-angliae*) a perennial Wisconsin prairie flower. *Photo credit: Lesley Brotkowski*

Butler's gartersnake (*Thamnophis butleri*) lives in crayfish burrows (Casper 2013). *Photo credit: Owen Boyle, WDNR*

Bioindicators based on a wide range of species will generally more effectively indicate the condition of the environment because species tend to vary in their specific habitat needs and their tolerance to environmental disturbance. Therefore, to assess conditions in multiple habitats across wide ranges in disturbance, using a wide range of taxa provides greater signal across the broadest range of conditions. Such approaches need not focus on rare or common species. Common species provide generally low signal, since they are generally tolerant to a wide range of habitat, although this can make them good indicators in disturbed systems. Rare species are complicated by what is sometimes referred to as a zero inflation problem: their absence may be due to stress or simply the fact that they are rare. Not finding such species, or finding fewer, may not be indicative of the overall biotic condition of a site (Holt and Miller 2010).

Some efforts choose to focus on umbrella species. For example, one umbrella species, the wood frog, requires wetlands in proximity to woodlands. Improvements that benefit wood frogs also benefit blue-spotted salamanders and tiger salamanders. A presumption is made that recovery or improvement in an umbrella species benefits others. However, the evaluation of one or just a few species to measure landscape-level quality is short-sighted. Typically, several assessments of both the flora and fauna within an ecosystem are needed to effectively measure or characterize biological condition. Both assemblages are valuable, not only for their own sake, but because floral and faunal biodiversity are not strongly linked in this region, since most of the fauna are relative habitat generalists. Invasive species should also be measured, since invasive species are often stressors, displacing native taxa.

The use of biological indicators (terrestrial, riparian, as well as aquatic) forms the basis of much of the baseline and new data being gathered and applied in Southeast Wisconsin for biodiversity applications. Ozaukee County uses a Fish and Wildlife Decision Support Tool (previously referenced in Section 2). The tool identifies native fish and wildlife SLCIs that are used to help support identification and prioritization of areas for ecological restoration or preservation. The tool integrates past studies, inventories, and modeling. It helps to target lands with critical habitats where restoration or protection will foster the survival of native fish and wildlife.

The wood frog (*Lithobates sylvaticus* depends on ephemeral wetlands to reproduce (Casper 2013). *Photo credit: Loren Ayers, WDNR*

In Southeast Wisconsin, watershed plans, Land and Water Resource Management Plans, and Park and Open Space Management Plans (to name just a few) often set goals for the number of acres to be protected, restored, or enhanced (SEWRPC 2014, SEWRPC 2017). Using tools and indicators to measure baseline habitat quality and biological condition as lands are protected will add valuable information to the inventoried database. This body of information is also serving to provide some of the detail needed to demonstrate the value of connected habitat.

3.3 Habitat Goals and Strategies for Enhancing Urban Biodiversity

There is an abundance of existing scientific collections, studies, research, and plans available that address known and/or ongoing biodiversity baseline information in the MMSD planning area. They variously describe the historical, current, and desired future conditions for fish and wildlife habitat across the urban landscape (SEWRPC 2010). SEWRPC studies and plans are rich with information about the plant diversity within designated natural areas and environmental corridors (e.g., SEWPC 2004). WDNR and non-governmental organization (NGO) watershed plans document both historical and current conditions. They address water quality, impairments to waterways, and restoration objectives to improve habitat along riparian corridors, including many within local Milwaukee neighborhoods.

The Milwaukee County Parks, Ozaukee Washington Land Trust, Ozaukee County, and many others are moving forward with inventories that address habitat quality. The Milwaukee Estuary AOC study added significant new information in 2017, with additional information forthcoming in 2018. The comprehensive surveys being conducted now, along with past documentation, are building a story about biodiversity in Southeast Wisconsin. All these surveys and inventories will culminate with a refreshed look at the number and type of species that are found in the Milwaukee region. But it is important to note that knowledge gaps must be identified as well. Continuing the survey initiatives will be critical to fully track, update, and manage new and updated data about species' richness, presence, or absence, along with the locations of habitats that will respond quickly to management and restoration.

If one key purpose of having good inventories is to be able to identify habitats and green corridors that require protection, restoration, or improved linkages, then strategy for habitat conservation throughout the MMSD planning area is needed. This strategy is compatible with the SEWRPC Regional Water Quality Management Plan, which listed land use development objectives, such as balanced land use allocation, natural resources protection, and preservation of land for habitat. To meet the goal of fishable, swimmable waters, the Southeastern Wisconsin Watersheds Trust, Inc. (Sweetwater, or SWWT) has been an active leader in collaborating with diverse partners to restore ecosystem health within the greater Milwaukee watersheds.

American Bullfrogs (*Lithobates catesbeianus*) are native to the MMSD planning area, but may out compete other aquatic frog species and be indicative of degraded habitat (Casper 2013) *Photo credit: Drew Feldkirchner, WDNR*

Therefore, in keeping with goals set forth in multiple plans, local government leaders involved in zoning and development decision-making need to remember the value of "First, do no harm." Where needed to incorporate the concept of protecting natural resource features, comprehensive plans at the county, town, or city level may need to be refreshed to include more environmentally-protective ordinances and/or incentives. The city of Franklin, for example, requires mitigation if woodlands will be impacted, which creates a disincentive to developers to cut down an established group of trees.

Buffer requirements could be added to ordinances, and disincentives could be added or strengthened for encroachments into an environmental corridor. Development or expansion encroachments into habitats known to support populations of listed species should be discouraged beyond what is typically regulated, especially if SLCIs are known to be present. If avoidance is not possible, translocation of species that could be impacted should be allowed and supported, where feasible.

More municipalities and permitting authorities should also incentive GI with reduced permit fees or review times for projects that use GI to improve habitat. Municipalities should also continue to reduce barriers to GI, such as codes and ordinances that are not consistent with GI.

4 Using GI to Enhance Biodiversity

Previous sections summarized the importance of urban biodiversity and presented an overview of the regional landscape and desired future conditions. This section provides information on how GI can be used to enhance biodiversity.

4.1 Overview

A primary focus of this urban biodiversity plan is to identify how strategic application of GI can help support regional efforts to maintain and restore biodiversity. The primary goals associated with GI installations are to capture stormwater and allow it to soak into the ground or evaporate instead of running into watercourses with excessive pollutant loads or entering sewers and contributing to sewer overflows. These goals provide their own explicit biodiversity benefit because reducing stress from altered flows and pollutants due to excess stormwater will benefit a wide range of stream species and downstream lake species and improve diversity. In addition, these GI practices provide a biodiversity co-benefit for adjacent

GI captures stormwater and allows it to soak into the ground or evaporate instead of running into watercourses or entering sewers and contributing to sewer overflows. *Photo credit: MMSD* terrestrial and wetland ecosystems by essentially increasing habitat. To fully evaluate both the direct and indirect benefits of GI, this section is split into two parts: the first evaluates the capacity of each of the core MMSD GI strategies to provide biodiversity co-benefits and the second presents approaches for improving the potential for GI strategies to improve biodiversity based on existing research and ecological theory.

4.2 Evaluation of GI Strategies for Biodiversity Potential

The purpose of this section is to identify the direct and indirect biodiversity benefits associated with MMSD-targeted GI. This plan evaluated each of the key GI strategies for their ability to enhance biodiversity. Their broader benefits (beyond biodiversity) were also evaluated using the TBL framework (environmental, economic, and social) (Wallace 2012, USEPA 2013). This latter evaluation builds upon earlier work done by MMSD and collaborators, including the reports “Fresh Coast Green Solutions - Weaving Milwaukee's Green and Grey Infrastructure into a Sustainable Future” (MMSD 2012) and “Milwaukee Metropolitan Sewerage District Regional Green Infrastructure Plan” (MMSD 2013). This report differs in that it provides a more comprehensive evaluation of the roles that the GI strategies play in enhancing biodiversity based on the existing and available science.

Brown-eyed Susan (*Rudbeckia trilobia*) provides sustenance for Wisconsin birds and bees. *Photo credit: Ron Londré*

Brief descriptions of the GI strategies can be found in Table 1, and the benefits of each GI type for biodiversity are summarized in Table 2. In some cases, published literature could not be identified documenting the benefits of a specific GI strategy on biodiversity; in such cases, this plan used and noted best professional judgement. Direct benefits of GI for biodiversity include the addition of new habitat (e.g., putting a green roof on an existing building), improvements to habitat quality (e.g., planting native species), and pollination enhancement (e.g., planting wildflowers that are preferred by bees). There are also indirect benefits. For example, as shown in Figure 7, GI practices can improve aquatic biodiversity by returning instream flows to more natural conditions. Some GI strategies – like rain barrels, cisterns and porous pavement – only provide indirect benefits to wildlife. More detailed descriptions of the biodiversity benefits of each strategy, as well as relative rankings of each strategy (high, medium, low), can be found in Table 3. It should be noted that the effectiveness of these strategies also depends on additional factors, which are discussed in greater detail in the ensuing section. Considerations include the design and management of nearby built areas (Hostetler et al. 2011) and the principles of ecological theory (e.g., minimum area required for taxa, minimum number of habitat patches required, colonization distances and heights) (Turner 1989, McGarigal and Marks 1995, Pinho et al. 2016, Threlfall et al. 2015, 2017).

As shown in Table 2**,** this plan also evaluated the broader TBL benefits of GI strategies, and considered these benefits when making an overall rating (Table 3). The principal environmental benefits of these practices are clearly reduced runoff volume and increased infiltration, which decreases the volume of stormwater runoff entering Milwaukee's streams, combined and separate sewer systems, and ultimately Lake Michigan. The increase in infiltration also improves the rate at which groundwater aquifers are 'recharged' or replenished, thereby improving stream baseflow. This runoff control has important implications for biodiversity in Milwaukee's rivers and streams, as well as drinking water supplies. Flow and the dimensions of flow (magnitude, frequency, duration, timing, and rate of change) are master drivers of biodiversity directly and indirectly (Poff et al. 1997). Flow controls biodiversity directly because individual aquatic organisms depend on flow for feeding, reproduction, and movement at least at some point during their life. This dependency has structured the evolution of different species and the flow environments different species have adapted to and can, therefore, inhabit. Flow also affects biodiversity indirectly because it influences water quality (e.g., pollutant runoff and transport), food supply (e.g., primary producer growth and fine particle transport), physical habitat (e.g., channel form), and biological interactions (e.g., predator movement, competitive interactions) (Poff et al. 1997); all of these affect the species that can occupy streams and rivers.

In addition to stormwater volume control, another environmental benefit of GI is that many strategies treat and clean runoff, since the plants and microbes naturally filter and break down many common pollutants found in stormwater. The plants and soils of many types of GI also sequester carbon by capturing and removing carbon dioxide from the atmosphere via photosynthesis and other natural processes. Other environmental benefits of GI include mitigation of urban heat island effects (which results in reduced energy demands) and improved air quality since trees and vegetation absorb certain pollutants from the air.

Economic benefits of GI include the creation of 'green' jobs (e.g., construction and maintenance of GI), reduced treatment costs (this includes offsets to traditional sewer infrastructure use and costs), and increased property values.

From a social perspective, GI can have a positive impact on human health. For example, improved aesthetics have been shown to decrease stress and green spaces have also been linked to reductions in inner-city crime and violence (MMSD 2013, city of Newburgh 2015).

Table 1. Brief description of the strategies used in MMSD's Regional Green Infrastructure Plan (MMSD 2013, MMSD 2012).

Green infrastructure strategies	Description
Bioretention	Depressed catchment areas planted with vegetation (similar to a rain garden). Usually located along transportation corridors or parking lots. Designed to maximize the time rainwater spends in the swale.
Cisterns	Rain barrels and cisterns are similar, although cisterns tend to be relatively large and sometimes are installed underground. Both capture and store rainwater. The stored rainwater can be reused for gardening and lawn watering.
Rain barrel	
Rain garden	Hold and infiltrate stormwater runoff and are an excellent means of removing pollutants. Typically planted with wildflowers and deep-rooted native vegetation in slightly depressed areas. The plants are watered by the collected or pooled stormwater runoff.
Soil amendments	Examples include aeration and compost topdressing. Improves turf grass health and growth, and increases water holding capacity.
Stormwater trees	Hold rainwater on their leaves and branches, infiltrate it into the ground, absorb it through root systems and evapotranspire it to the atmosphere.
Porous pavement	Can be asphalt, concrete or pavers. Differs from traditional pavement in that it provides pore spaces that store and pass water. Surface runoff infiltrates through its permeable surface into a stone or filter media below and is conveyed offsite as part of a stormwater system or is collected and contained for future use.
Green roofs	Roofs are either partially or completely planted with vegetation growing in soil (or a growing medium) to hold rainwater.
Native landscaping	Native plant species that evolved in a particular area and are adapted to local climate conditions. Can tolerate drought and flooding cycles.

Other ongoing work undertaken by MMSD, such as stream restorations involving removal of concrete channels and dam removals, also provides similar biodiversity and ecosystem service benefits. Removal of concrete channels can restore the hydrologic connection between the channel and the hyporheic zone and floodplain which may increase nutrient cycling, raise the water table for rooting plants in the riparian zone, and improve habitat quality for fish and benthic macroinvertebrates (Newcomer Johnson et al. 2014). Dam removals also improve and enlarge fish and macroinvertebrate habitat and restore nutrient cycling (Doyle et al. 2005). While fish and macroinvertebrate communities recover to pre-dam conditions within a couple years following removal of run-of-the-river dams in Wisconsin, riparian vegetation takes longer, and mussel communities may not be able to recover.

Table 2. Biodiversity and triple-bottom-line (TBL) benefits (environmental, economic and social) of the GI strategies in MMSD's Regional Green Infrastructure Plan (MMSD 2013, MMSD 2012).

Green infrastructure strategies	Biodiversity			Environmental						Economic				Social	
	More wildlife habitat (quantity)	Improved habitat quality	Pollination enhancement	Reduced stormwater runoff (volume)	Reduced pollutant loadings	Increased groundwater recharge	Reduced GHG emissions and/or stores carbon	Reduced urban heat island effects	Improved air quality	Green job opportunities	Reduced infrastructure costs	Reduced pumping and treatment costs	Increased property values	Improved quality of life and aesthetics	Improved green space
Bioretention	■	■	▲	●	●	●	●	●	●	●	●	●	●	●	●
Cisterns	△	△	△	●	●	◒	◒	○	◒	●	●	●	◒	◒	○
Rain Barrel	△	△	△	●	●	◒	◒	○	◒	●	●	●	◒	◒	○
Rain Garden	▲	▲	▲	●	●	●	●	●	●	●	●	●	●	●	●
Soil amendments	△	▲	△ (half)	■	■	■	■	■	■	■	■	■	■	■	■
Stormwater trees	■	■	△ (half)	●	●	●	●	●	●	●	●	●	●	●	●
Porous pavement	△	△	△	●	●	●	◒	○	●	●	●	●	◒	◒	○
Green roofs	■	■	■	●	●	●	●	●	●	●	●	●	●	●	●
Native landscaping	■	■	■	●	●	●	●	●	●	●	●	●	●	●	●

Symbol (circle/square/triangle) correspond with source

- ● MMSD's Fresh Coast Green Solutions report
- ■ Other literature (peer-reviewed or grey)
- ▲ Best professional judgment

Level of fill (full/half/none) corresponds with benefits

- ● Yes, positive benefits
- ◒ Maybe
- ○ No benefits

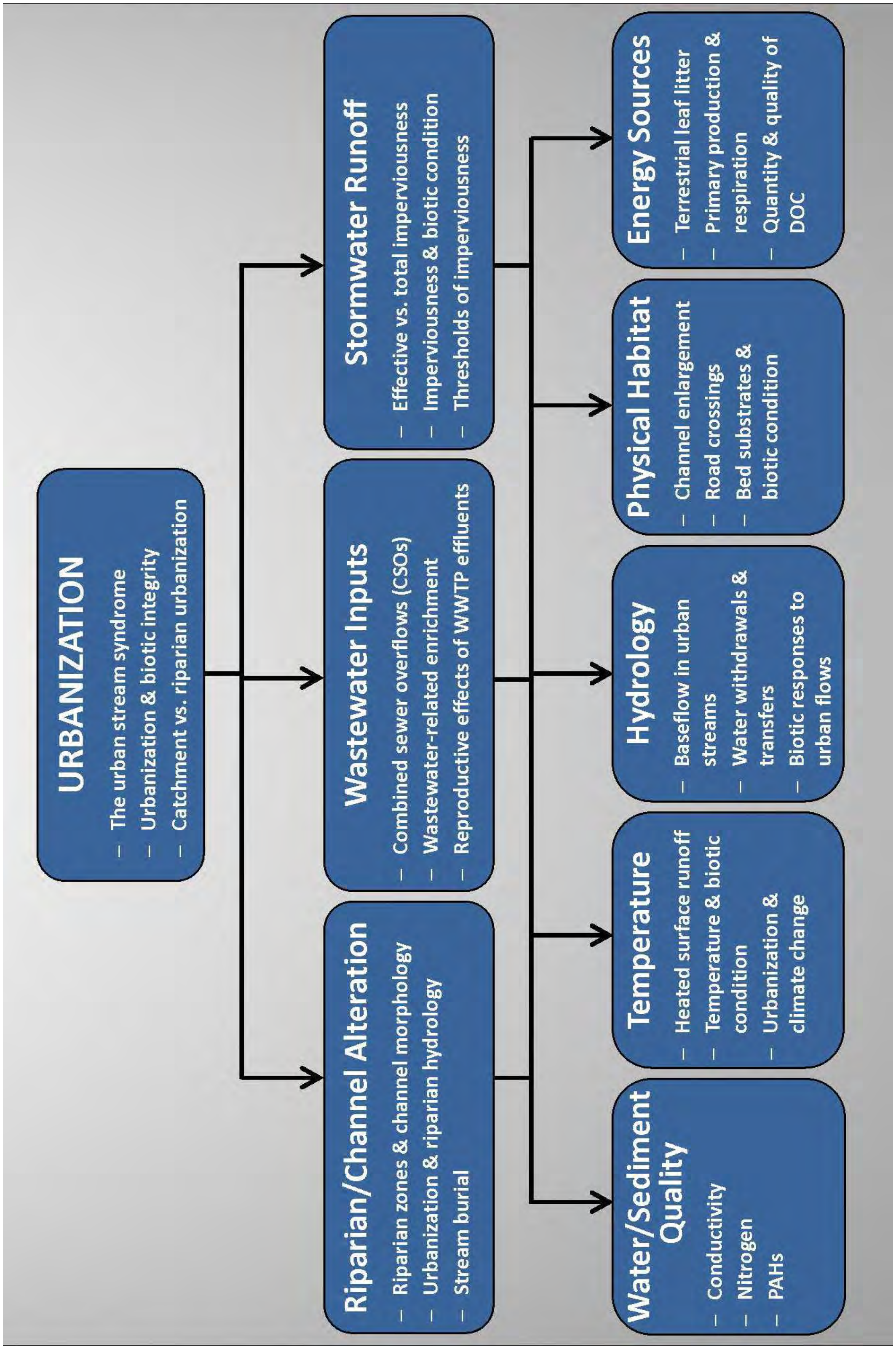


Figure 7. Illustration of the pathways through which urbanization may affect stream ecosystems.

Table 3. Relative ratings for each of the nine GI strategies of overall benefits (biodiversity + TBL; the more benefits, the better) and biodiversity alone. Each GI strategy provides indirect benefits for aquatic biodiversity through enhanced infiltration, which reduces flashiness/delays discharges and helps return instream flows to more natural conditions. For biodiversity, the effectiveness of any GI strategy depends on additional factors as well such as the design and management of nearby built areas (Hostetler et al. 2011) and consideration of the principles of ecological theory.

Green infrastructure strategies	Overall rating (biodiversity + TBL)	Biodiversity rating	Considerations	Reasoning
Bioretention	High	High	Type of vegetation	Kazemi et al. (2009a) found a greater number of invertebrate species in bioretention basins compared to garden bed and lawn-type greenspaces, likely because bioretention basins provide better quality foraging and sheltering habitat. The greater leaf/plant litter depth and larger number of plant taxa were significant contributors to biodiversity (Kazemi et al. 2009b). The bioretention basins also had lower levels of human disturbance than the lawn-type greenspaces that were subject to more human traffic and intensive maintenance regimes such as mowing.
Native landscaping (tallgrass prairie plants)	High	High	Type of vegetation	Native plant communities provide important habitat and food for native animals and insects (that have co-adapted with the plants) (Tallamy 2009, McCarthy 2014). Because the native plants are adapted to the local soils and climate, they may need less supplemental water, have fewer disease or insect problems, etc. Several studies have found that native plant species support higher biodiversity than non-natives. For example, in the mid-Atlantic region of the U.S., Burghardt et al. (2009) found that native plants supported significantly more caterpillars (both in terms of biomass and richness, likely due to the host specificity of many insects) and significantly higher bird abundance and diversity (likely because most birds feed insects to their young). In Canberra, Australia, Ikin et al. (2013) found similar results, with a higher diversity and abundance of birds in native tree species than exotic ones. A more detailed review of the impact of native versus non-native landscaping choices on biodiversity can be found in Wilde et al. (2015).

Table 3 (continued).

Green infrastructure strategies	Overall rating (biodiversity + TBL)	Biodiversity rating	Considerations	Reasoning
Rain Gardens	High	High	Type of vegetation	No empirical studies were found in the peer-reviewed literature documenting the biodiversity value of rain gardens, but results would likely be similar to those of bioretention basins that have been shown to have higher invertebrate biodiversity than garden bed and lawn-type greenspaces (Kazemi et al. 2009a). Rain gardens can provide food (fruits, seeds, and nectar) and shelter for birds and other species. Their biodiversity value can be enhanced through careful plant selection (Penn State Extension 2016).
Stormwater trees	High	High	Type of tree	Urban trees serve many different purposes for many different species. They provide habitat, refugia, food, shelter, nesting materials, breeding sites, and locations for perching and roosting (Dunster 1998). Kubista and Bruckner (2015) reported that urban trees provided 50% of the roost sites for several species of bats. Trees also serve as hosts for flora such as epiphytes (plants that grow harmlessly upon other plants), which can provide rich and diverse habitats for other organisms. Several recent studies have documented the diversity of epiphytes on host trees in urban settings (Bhatt et al. 2015, Izuddin and Webb 2015). Urban trees also benefit wildlife by reducing urban heat island effects (through shading and evapotranspiration) and providing nutrients to various levels of the food chain through leaf litter and decaying materials. Key considerations for enhancing biodiversity **Tree species**. Several studies have shown that native tree species support more insect and bird species than non-natives (Tallamy 2009, Helden et al. 2012). Tallamy published a ranking of trees and shrubs for the mid-Atlantic US according to how many caterpillar species they harbor. Oaks received the top ranking in Mid-Atlantic U.S., supporting 534 butterfly/moth species. These insects provide an important food source for birds and other species. Ikin et al. (2013) and Shackleton (2016) also found higher diversities and abundances of birds in native urban trees versus non-natives. **Tree size.** Stagoll et al. (2011) and Shackleton (2016) found a higher diversity of birds in large versus small urban trees. Both emphasized the importance of a diversity of tree sizes to support biodiversity. Stagoll et al. (2011) concluded that large trees are keystone structures in urban parks.

Table 3 (continued).

Green infrastructure strategies	Overall rating (biodiversity + TBL)	Biodiversity rating	Considerations	Reasoning
Green roofs	High	Medium	Height of roof (Madre 2013, MacIvor 2013, Williams et al 2015) Soil formation (Schrader and Boning 2006)	Numerous studies in Europe and America have documented that green roofs can enhance biodiversity in urban settings by providing feeding, breeding, resting grounds for birds (local or migratory) (Baumann 2006, Grant 2006, Eakin et al. 2015), habitat for invertebrate species like spiders, beetles, wasps, and bees (Brenneisen 2003, Kadas 2006, MacIvor and Lundholm 2011), food for pollinators (Colla et al. 2009, Tonietto et al. 2013, Benvenuti 2014), and can help facilitate dispersal of wildlife by connecting fragmented habitats (Currie and Bass 2010). The habitat created by green roofs typically does not provide the same quality of food, habitat, or shelter found in nearby natural areas, but they do provide vegetation where there would otherwise be none, thereby creating potential habitat for a variety of species. A more detailed review of the ways in which green roofs can enhance biodiversity can be found in Currie and Bass (2010). Key considerations for enhancing biodiversity (Currie and Bass 2010) **Substrate Depth.** By varying the depths of the green roof medium, it is possible to create a series of different microclimates within the same green roof zone. **Substrate Source and Composition.** Use of natural, local soils and substrates can enhance biodiversity and benefit species of special conservation concern because local species are already adapted to that particular soil environment. **Maturity and Staging.** Schrader and Boning (2006) found reductions in bulk density, increases in organic matter, and increases in species abundance and richness in extensive green roof substrates over time. **Vegetation Design.** Green roofs can support a multitude of different plant species depending on factors such as substrate depth and composition. **Structural Diversity and Microhabitats.** The addition of materials such as stones, logs and branches, and variances in plant structure and height can create niche spaces for organisms. **Proximity to other naturalized spaces or habitats.** The closer a green roof is to other green roofs, naturalized zones or green landscapes, the more likely they are to effectively facilitate natural dispersal and colonization of organisms.

Table 3 (continued).

Green infrastructure strategies	Overall rating (biodiversity + TBL)	Biodiversity rating	Considerations	Reasoning
Soil amendments	Medium	Medium		In places where native landscaping is not preferred, MMSD encourages use of soil amendments to increase water holding capacity in lawns and improve grass growth. Empirical studies in the peer-reviewed literature regarding the benefits of soil amendments on biodiversity in lawn environments are not available. However, several studies have shown organic matter amendments can enhance biodiversity in constructed or restored wetlands by stimulating microbial communities and in some cases improving ecosystem functions like nutrient cycling (Bruland and Richardson 2004, Sutton-Grier et al. 2009). These studies found that the soil amendments had limited short-term benefits for plant communities. The biodiversity benefits of soil amendments in lawns may be limited by human disturbance since these areas are subject to more human traffic and intensive maintenance regimes such as mowing.
Porous pavement	Medium	Low		No studies are available documenting the biodiversity benefits of porous pavement. However, porous pavement indirectly benefits aquatic biota by reducing stormwater runoff (Figure 7).
Rain Barrels	Low/Medium	Low		No studies are available documenting biodiversity benefits of rain barrels. However, rain barrels indirectly benefit aquatic biota by reducing stormwater runoff (Figure 7).
Cisterns	Low/Medium	Low		No studies are available documenting biodiversity benefits of cisterns. However, cisterns indirectly benefit aquatic biota by reducing stormwater runoff (Figure 7).

4.3 Improving the Potential for GI to Support and Increase Biodiversity

The previous section indicates that different types of GI provide various intrinsic benefits, both directly and indirectly, for biodiversity. The extent to which these practices can benefit biodiversity relies primarily on their intrinsic value; however, it also relies on the landscape context within which they are placed. For example, a patch of native tallgrass prairie associated with a rain garden in the middle of a large parking lot will have limited value to biodiversity if organisms are unable to disperse to and from that habitat. The same vegetation, if placed strategically proximate to existing habitat patches, corridors, or passages increases available habitat and can even serve to bridge adjacent habitat patches or connect corridors if designed and implemented correctly. The field of landscape ecology speaks directly to how the geometry of habitat influences biological diversity and ecosystem function. The purpose of this section is to draw on and encourage the use of concepts from this discipline to guide the application of individual GI strategies or groups of strategies for urban settings (or typologies) where they might provide the maximum biodiversity benefit. This, however, only refers to their diversity benefit and would need to be weighed against the other benefits they provide that were detailed above and in other documents (e.g., MMSD 2012).

Strategic Placement of GI Can Improve Biodiversity

One of the primary purposes of this plan is to heighten awareness that strategic placement of GI can help to improve biodiversity by expanding existing habitat or connecting currently disconnected habitat.

The MMSD planning area includes the confluence of the Menomonee, Kinnickinnic, and Milwaukee Rivers and contains all of the Kinnickinnic and the vast majority of the Menomonee watersheds as well as the watersheds of the Root River and Oak Creek that also drain into Lake Michigan. The MMSD planning area is 411 square miles and the agency serves over 1 million people. This region is predominantly urban, with a high degree of imperviousness. The largest focus of urbanization is located near the shore of Lake Michigan (Figure 8). Additional satellites of urbanization are present along transportation corridors.

Consistent with the heavily urbanized landscape, Milwaukee has experienced water quality problems since at least the early 1900s (City of Milwaukee 2016) including sewage overflows, algal blooms, and sediment and industrial pollution. On a larger scale, and in addition to the water quality issues associated with urbanization, Southeastern Wisconsin has suffered the loss of multiple native plant communities and animal species due to development (Waller 2008). These impacts to biodiversity are not surprising considering only 5 percent of watershed impervious surface may cause measurable adverse effects (Brabec 2002) and the region averages 28 percent imperviousness with much higher percent impervious coverage in subwatersheds within its urban core (Xian et al. 2011). Such intense urbanization and impervious cover make connecting GI strategies to natural landscape patches, corridors, and passages difficult. However, there are natural corridors in the MMSD landscape.

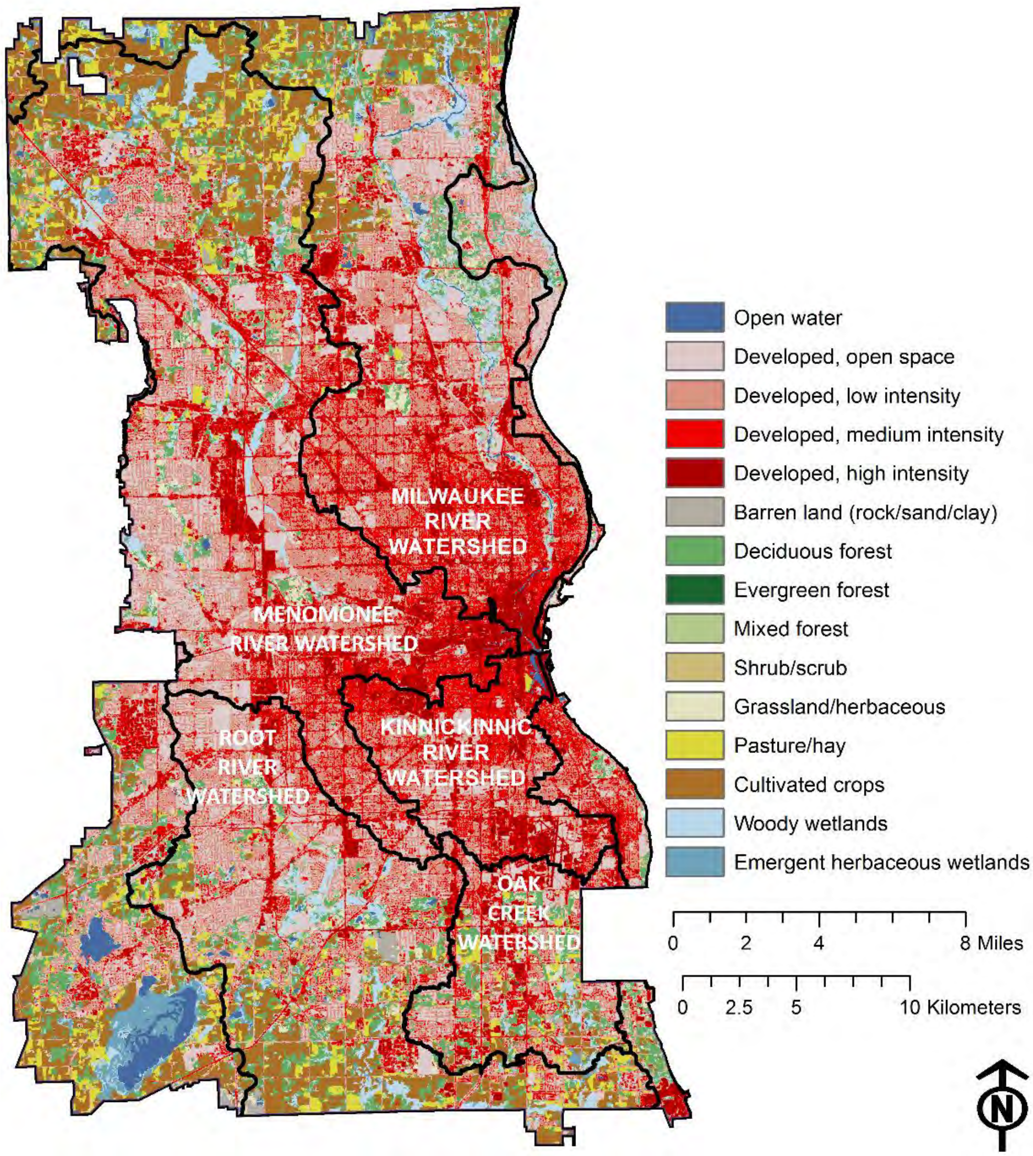


Figure 8. Spatial arrangement of urbanization in MMSD planning area as represented by National Landcover Dataset 2011 (Homer et al. 2015).

As discussed in detail in Section 2.3.1, SEWRPC has identified environmental corridors that contain the best of remaining natural resources (SEWRPC 2017). With the Milwaukee County area consisting of large impervious surfaces, those corridors do not constitute much of the central portion of the MMSD planning area. However, primary corridors stretch from the peripheral areas along the Milwaukee, Menomonee, Kinnickinnic, and Root Rivers and Oak Creek and another corridor is present along part of the Lake Michigan shoreline (Figure 4).

The corridors represent substantial patches of natural habitat, much of which is protected. These extensions of forest and open water provide food and shelter for wildlife and contain populations of native species that can colonize new habitat patches as they are created. As discussed in the preceding section, many GI projects that involve maintaining native vegetation—green roofs, rain gardens, stormwater trees, bioswales, and native landscaping—can serve as new areas of habitat for vanishing vegetation communities and animal species within an otherwise urbanized landscape. Planned habitats such as these can support plant and animal communities, thereby increasing local species diversity and abundance.

With the potential of GI to increase native biodiversity within an urban matrix, the purpose of the remainder of this section is to 1) describe the spatial arrangement and local environs of current GI projects, and 2) discuss ways to plan future projects to maximize potential biodiversity benefits.

4.3.1 Evaluation of Current GI

A first goal was to see if "typical" stormwater GI typologies could be identified. The hope was to identify a set of stereotypical settings of such practices (or typologies) that shared common characteristics with regards to the surrounding landscape matrix, including natural lands. During the preparation of this plan a list of 277 current GI projects were identified, 273 of which were in the MMSD planning area (Figure 9). Using the EnviroAtlas community scale dataset (USEPA 2016), the surrounding land cover within a 100 m buffer of the project (represented in the dataset as a point, not by its actual area) was summarized by the type of GI in ArcGIS 10.1 (ESRI 2012). The project locations represent a gradient of urbanization from 0 – 99% within the 100 m buffer. Apart from wetlands, of which there were only four, the remaining types of GI had similar land cover composition across groups. As expected, wetlands had more water and wetland adjacent to them. The distance from each project to the nearest large (900 m^2) patch of forested land (Homer et al. 2015) and the nearest stream were also measured. After narrowing the dataset to GI projects that could be considered islands of suitable habitat (green roofs, rain gardens, stormwater trees, bioswales, and native landscaping), a cluster analysis was performed to see if the project locations fell in any natural groups based on their surrounding land cover and distance to forest or streams. This did not result in any useful groups or typologies of GI projects based on the available variables. This means that specific recommendations for common GI settings are limited because no such "common" settings exist or could easily be identified.

Despite a lack of natural clusters based on all variables, the projects do reflect large gradients in extent of surrounding urbanization and distance of projects to forest and stream patches, which probably affects their likelihood of becoming colonized with native species and ability to improve regional biodiversity. Almost any GI project that replaces a paved parking area, a monoculture of grass, or disturbed barren land with either a rain garden or natural landscaping or trees is likely to increase local biodiversity, just as a green roof increases local abundance and diversity of plant and animal taxa over a conventional roof (Williams et al. 2015). While most often these may have a local, rather than regional effect, there may be more and less effective ways to prioritize project sites to increase their overall contribution to regional biodiversity across the MMSD planning area.

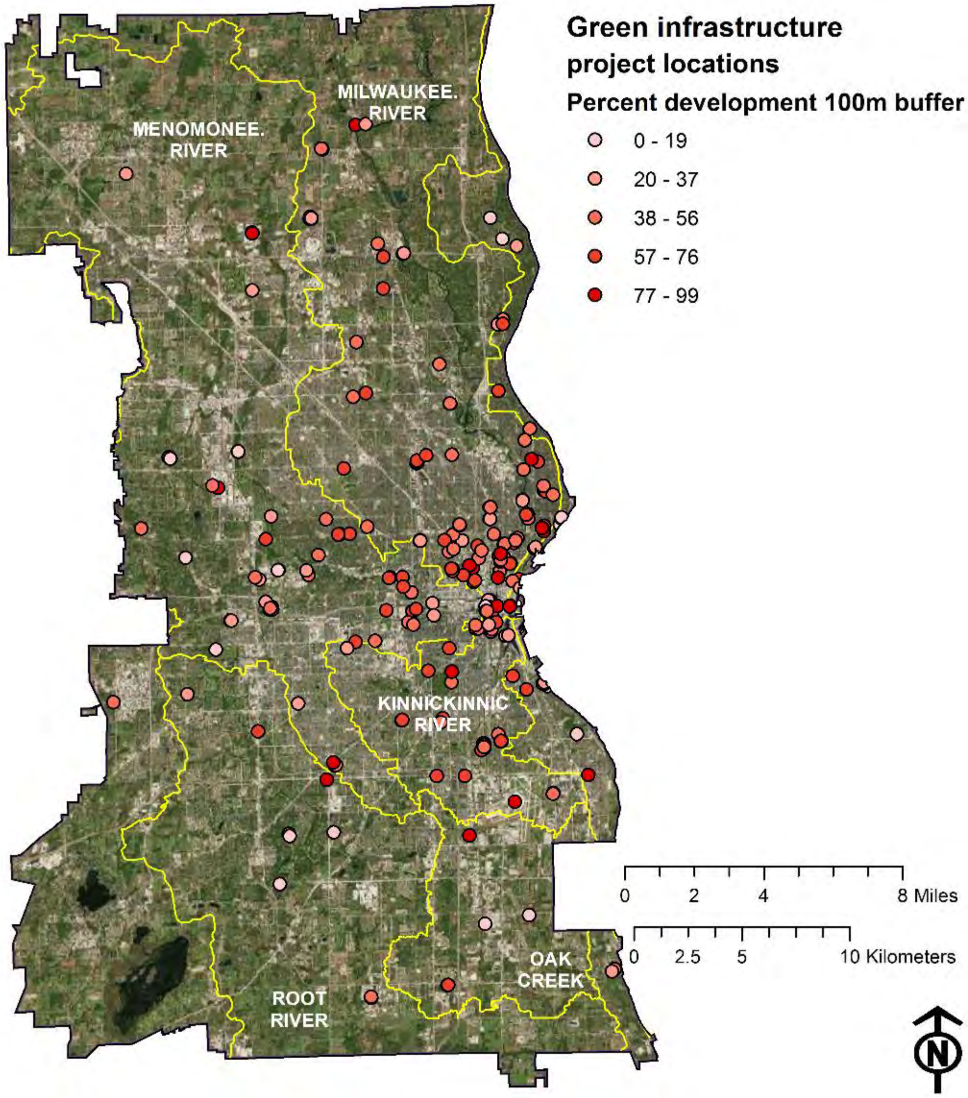


Figure 9. Percent development within 100 m surrounding buffers of current stormwater GI projects.

4.3.2 Factors Affecting the Potential Biodiversity Benefits of GI

A combination of ornamentals and native wildflowers and shrubs replace grass in city median. *Photo credit: Ron Londré*

Landscape ecology theory suggests that community composition for a given habitat patch within the otherwise unsuitable urban environment is determined by multiple non-mutually exclusive drivers including 1) local environmental factors (sun exposure, moisture, etc.) and species interactions (e.g., predation and competition for resources) and 2) mass-effect processes: emigration and immigration (Leibold 2004). Local environmental factors can be identified for regional species, and those conditions can be made available to the best possible extent for any GI installation. Providing such conditions is easier than overcoming mass effect processes. For example, evidence suggests that larger bioretention basins with more leaf litter, vegetation structure, and number of flowering plants support more insect diversity than other basins (Kazemi et al. 2009a, 2009b). Mass effect processes affect community composition to varying degrees based on species-level behavioral constraints such as distances travelled for routine movements (e.g., feeding and reproduction) and distances travelled for dispersal. Therefore, given the appropriate local environment (i.e., being suitable to support individuals of a species), projects placed closer to natural source populations or primary environmental corridors are, in theory, more likely to become colonized with regional species that use such habitats, provided they are within the routine movement or dispersal distance of the desired species (Figure 10, top). Consistent with both local environmental factors and mass effect processes, bird and lichen communities in urban forest patches in Portugal were shown to change across gradients of patch vegetation density (local effects) and amount of surrounding urban forest (mass effect processes) (Pinho et al. 2016). With regards to Milwaukee, the primary environmental corridors that reach downtown are mostly restricted to open water, so proximity of green roofs to open water habitats will not result in local species dispersal. Nevertheless, they will be colonized by flying insects with longer dispersal distances such as bees (Figure 10, bottom).

With these ideas in mind, this plan reviewed the scientific literature for attributes of GI projects that make them more or less useful for supporting regional biodiversity on an empirical rather than theoretical basis. At this time, there is a small but developing body of literature investigating green roofs and biodiversity, but there is little information regarding rain gardens, bioswales, native landscaping, and stormwater trees. Therefore, this plan prepared the following review on green roofs using the factors listed above.

Figure 10. A constructed wetland near North 107th Street and West Glenbrook Court lies adjacent to a primary environmental corridor including stream and natural wetlands (top). This arrangement will allow dispersal of native species to the constructed wetland. Aerial view of a portion of downtown Milwaukee near a primary environmental corridor (bottom). GI projects in these areas, while they may provide important stormwater, air quality, pollinator and aesthetic benefits, are unlikely to be connected in a dispersal sense to remnant areas of natural habitat.

With regards to local environmental factors, some of these will be beyond the control of project planners (e.g., climate). However, other factors, such as available sunlight (potentially a planning decision based on height of surrounding buildings and/or project aspect) and soil type are manageable and will affect what species can survive. Noise and light pollution are also threats to biodiversity that GI can help to alleviate with appropriate planning. Planners can also choose diverse, native type plantings for green roofs as opposed to sedum monocultures. Other project construction details will also affect plant diversity. For example, in northern France, substrate depth was the most important factor in increasing wild plant diversity on green roofs designed to accept colonizing species (Madre et al. 2014). In that study, there was no effect of the surrounding potential habitats at the landscape scale on green roof wild plant diversity.

The Great Golden Digger Wasp, a Wisconsin native, is not aggressive. *Photo credit: Ron Londré*

Animal diversity on green roofs can also depend on local environmental and site-scale variables. Native bee diversity on Chicago green roofs was related to the diversity of blooming plants (Tonietto et al. 2011). Similarly, green roofs with more complex vegetation supported significantly higher species richness and abundance of beetle, spider and, hymenopteran (ant, wasp, and bee) taxa in northern France (Madre et al. 2013). Roofs with mosses, herbaceous plants *and* shrubs were considered “complex” as compared to ones with just mosses and sedums; they also had deeper substrates by design to support the shrubs. Richness and abundance of true bugs (Hemiptera) in this same study were not affected by plant complexity. Green roof height probably affects biodiversity as well. Spider diversity is inversely related to green roof height (Madre 2013). Bee and wasp numbers nesting in artificial nests (MacIvor 2013) and overhead bat activity (Pearce & Walters 2012) also increase with decreasing green roof height (Williams et al. 2015).

With regards to mass effect processes and biodiversity, proximity to forest patches or forested stream corridors theoretically increases the likelihood of colonization by native species, especially for those projects with less urbanization around their periphery. Braaker et al. (2014) used arthropod community composition to evaluate the connectivity of green roof habitats in Zurich, Switzerland and determined that proximate roof and ground sites were connected by dispersal, but the level of shared species was low: 50 percent of the 72 sampled species were found only on roof or ground habitats, not both. In Chicago, the diversity of bees on green roofs was not significantly related to the amount of surrounding green space or natural area, but the statistical power was quite low for green roofs. Bee diversity did correlate strongly with the amount of green space and natural area across multiple habitat types (Tonietto et al. 2011). The lack of an obvious effect of connectivity in the bee example may be due to the relatively low diversity of bees on urban green roofs or to a larger dispersal ability of bees (Williams et al. 2015).

4.4 Urban Agriculture

Urban agriculture is an activity strongly related to GI that also has the potential to improve—and benefit from—regional biodiversity. The U.S. Department of Agriculture defines urban agriculture as "backyard, roof-top and balcony gardening, community gardening in vacant lots and parks, roadside urban fringe agriculture and livestock grazing in open space." The Milwaukee region is a national leader in urban agriculture through the efforts of Growing Power, the Urban Ecology Center, and University of Wisconsin – Extension, among others.

Urban agriculture has a potentially very significant role in not only helping with stormwater management but also ensuring healthy cities. Urban farms and gardens can improve the visual quality of neighborhoods; connect urban residents to food systems; improve access to fresh, nutritious food; help in combating childhood obesity, diabetes, and poor nutrition; provide access to rare foods that support the cultural heritage of citizens; offer opportunities for recreation and relaxation when gardening outdoors; improve the food security of households; and help gardeners and urban farmers gain new knowledge and technical skills (Freshwater Society, 2013).

Urban agriculture, GI, and urban biodiversity complement each other in many ways, including the following:

- Water collected from rainwater harvesting can be used to support urban agriculture activities, whether rain barrels that support small raised planter beds or large cisterns that support larger operations.
- "Depaving" a site to create a city garden will reduce stormwater runoff in the same way that GI does (e.g., imperviousness will be reduced and soil infiltration and plant evapotranspiration will increase).
- Biodiversity and agriculture are inextricably linked. Protecting and promoting biodiversity in our existing agricultural systems (including both wild and cultivated species) is key to making food systems more adaptable and resilient, and to safeguarding the ecosystem services we depend on in the face of global climate change.

This plan recommends that stakeholders include community garden plots, larger urban vegetable farms, and perennial food forest parks along with GI when considering how to best optimize urban biodiversity in the region.

4.5 Recommendations

In the absence of even modest scientific literature with regards to GI and biodiversity, theoretical ecology provides an abundant source of information for recommending strategies to improve regional biodiversity using GI and urban agriculture within the MMSD planning area. The following recommendations are offered based on that theory and the limited studies identified:

- As shown in Table ES-1 and Table 4, the following GI strategies should be prioritized over others when designing new projects that are intended to enhance urban biodiversity: native landscaping with tallgrass prairie plants, bioretention/bioswales, rain gardens, wetlands, greenways, urban agriculture, and stormwater trees. In general, these strategies provide direct benefits for biodiversity by creating new habitat, improving existing habitat, and enhancing pollination. Other GI strategies, such as rain barrels and permeable pavement, provide an indirect benefit to biodiversity by helping to restore instream flows to more natural conditions but do not provide the same level of direct habitat benefits.
- GI designers should maximize the structure and complexity of plants and physical habitat when designing new GI projects. Projects should incorporate more complex habitats (in species and structure) with diverse native species, including mosses and shrubs. Projects should also include flowering plants that bloom at various times during the year to provide more niches and resources and, thus, a greater capacity to support more species.
- MMSD, partner agencies (e.g., SEWRPC, Ozaukee County) and regional experts should work together to identify a list of priority or desired species for protection, ideally cross-referenced to those able and most likely to benefit from increased habitat associated with GI practices. These agencies should then identify minimum habitat size (area) requirements for these species based on expert knowledge recognizing that there is a minimum habitat patch area required to support distinct species. Larger areas will support more species; but some GI projects may be too small to support some taxa. These minimum habitat areas should then be included as guidance in updates to regional GI planning and design guidelines (e.g., MMSD's *Regional GI Plan* and *Green Infrastructure Standard Specifications and Plan Templates*).
- GI planners and designers should also update regional GI planning and design guidelines to prioritize projects that are within colonization distance to existing natural areas or green space. Those GI strategies providing habitat or food resources for regional taxa (i.e., native landscaping, bioretention, rain gardens, stormwater trees, and green roofs) will most likely support more species and have the greatest effect on biodiversity if they are positioned near areas that host source or sustaining populations (e.g., riparian stream corridors, parkland, forest/prairie, Greenseams®). Isolated GI installations should be expected to support less diverse communities and contribute only a limited amount to regional biodiversity.
- Once priority species, habitat sizes, and colonization distances have been identified, regional planners should identify priority locations where GI is likely to best promote urban biodiversity and improve the habitat for the priority species. For example, GI might be able to help expand and connect some of the existing environmental corridors and natural areas displayed in Figure 4. Planners should also consider the location of existing community garden plots, larger urban vegetable farms, and perennial food forest parks when considering where to locate GI to help optimize urban biodiversity in the region. Regional planners should create a new map of the priority GI locations to enhance urban biodiversity that can be combined with other maps showing priority GI areas for other purposes (e.g., to implement total

maximum daily loads, to reduce combined sewer overflow, or to treat sources of sewer inflow/infiltration).

- MMSD and partner agencies should look for opportunities to incorporate GI into the other ongoing activities to improve biodiversity within the region. For example, MMSD should continue to be actively involved with the efforts to restore the Milwaukee Estuary AOC and should identify potential opportunities to integrate GI into restoration projects as they are designed. Federal funding is available for such projects through the Great Lakes Restoration Initiative. MMSD should also look for ways to strengthen its relationship with SEWRPC and find more ways to collaborate on projects, use their data, etc.

- Finally, monitoring GI's ability to enhance urban biodiversity is sorely needed and efforts to educate the public about the benefits of urban biodiversity must continue. These issues are the topics of the next two sections of this plan.

Table 4. Recommendations for maximizing direct biodiversity benefit from different core GI practices.

Green infrastructure strategies	Recommendations for Maximizing Direct Biodiversity Benefit
Bioretention	Especially prioritize where a large area is available and maximize area; Especially prioritize where proximate/connected to other patches, especially large forested patches/corridors; Maximize plant diversity; Create diverse structure
Native landscaping	Prioritize for use everywhere, especially where large areas are available and maximize area; Maximize for connectivity to other patches, especially large forested patches/corridors; Maximize plant diversity; Create diverse structure
Rain gardens	Especially prioritize where a large area is available and maximize area; Especially prioritize where proximate/connected to other patches, especially large forested patches/corridors; Maximize plant diversity; Create diverse structure
Stormwater trees	Evaluate surrounding matrix and prioritize connectivity among trees or to large forest patches; Maximize clustering of trees to create patches
Green roofs	Maximize area, native and complexity of plantings; Increase substrate depth to increase wild plant diversity; Incorporate on lower roofs to promote more biodiversity
Soil amendments	Consider soil attributes of benefit to native fauna
Porous pavement	Limited direct biodiversity benefit
Rain barrels	Limited direct biodiversity benefit
Cisterns	Limited direct biodiversity benefit

5 Monitoring Framework

Given the commitment represented by this effort to support regional biodiversity through the implementation of GI, it is prudent to discuss monitoring and the role it might play in evaluating the effectiveness of the program for these ends. Monitoring is an important part of any program, even more so with an innovation like GI, and identifying applicable and practical monitoring activities will help further the science as well as evaluate effectiveness.

5.1 Monitor GI Strategies for Individual Effectiveness

GI is a quickly evolving practice; therefore, any effort provides an opportunity to learn and further the science. The application of GI for volume and pollutant control is relatively new in its own right, but as the review earlier indicates, the effects of these practices on biodiversity are even less well known. Application of these practices for biodiversity should, therefore, be viewed as experiments with opportunities to learn a great deal and contribute to the developing science for purposes of adaptive management. Monitoring can play a critical role in providing information to adaptively learn and improve the performance of these techniques through time and their contribution to improving regional diversity.

Site-specific practices installed to control volume and pollutants at a specific location have to be put into an appropriate monitoring context. A site-specific GI project is designed to reduce stressors from a specific landscape–either excessive flow, pollutant loads, or both. The presumption is that the reduction of these stressors will result in improvements in the quality of the receiving water, which will improve water quality and help support expected diversity. Therefore, these practices must first and foremost be monitored to make sure they are reducing the stressors they are designed to reduce. If this primary goal is not being met, then their contribution to diversity improvement in receiving waters should not be expected. Similarly, it is likely that there is some density of installations necessary to reduce stressors sufficiently to improve the receiving water. While a single practice can reduce stressors from its contributing area, it will likely have little overall effect if it is an isolated practice in an otherwise untreated watershed. Only when the combined impact of installations effectively reduces stressors should there be an expectation of improvement in receiving water diversity. This density could be estimated through modeling. The first tier of monitoring, therefore, should be focused on GI performance in reducing the stressors they are designed to reduce. This means evaluating that they are designed, installed, and maintained properly, as well as monitoring the performance of representative practices in reducing runoff and pollutants.

In addition to installing GI to increase diversity in receiving aquatic habitats, an important co-benefit promoted in this document is the potential for some GI practices to increase habitat for terrestrial organisms, thereby directly improving regional diversity. Again, these practices are not designed for that purpose, but provide that co-benefit. Therefore, in addition to monitoring for stressor reduction, these practices should be monitored for the species they are able to support. Again, there is woefully little information on the benefit of these practices for species diversity, so any monitoring will contribute to the developing science and merit publication.

5.2 Monitor Regionally for Cumulative Benefit

The ultimate outcome of GI is to reduce stressors to an extent that regional water quality and diversity improves. Monitoring regional biodiversity is beyond the scope of MMSD, but fortunately there are many statewide and local programs already conducting regional monitoring of both aquatic and terrestrial systems (many mentioned in this plan) to produce data that can be used to assess regional improvement. These programs have monitoring designs, standard operating procedures, and indicators already developed that can be used to gage the cumulative effect of GI implementation on regional biological condition. MMSD should engage with these programs to inform them of ongoing GI projects as they are implemented so the cumulative density of practices on the watershed scale can be related to regional measures of diversity. For example, MMSD should continue to be actively involved with the efforts to restore the Milwaukee Estuary AOC and should look for ways to strengthen its relationship with SEWRPC (e.g., find more ways to collaborate on projects, monitoring efforts). Again, given the lack of substantial literature on this topic, the resulting data would be very useful for informing future activities and adaptive management.

6 Education and Public Involvement

This section provides recommendations regarding public education and involvement to raise awareness about urban biodiversity in Southeast Wisconsin and the MMSD planning area. The goals of public education and involvement activities are to 1) raise awareness about urban biodiversity and its importance to the region, 2) educate the public on existing programs and the activities they can implement to improve and protect urban biodiversity, and 3) motivate public involvement and action to implement these activities.

6.1 Raising Awareness

Addressing the threats to urban biodiversity, particularly increasing urbanization, requires robust public education and outreach on the importance of urban biodiversity. While most people may not have the ability to control development decisions that lead to habitat conversion, fragmentation, and introduction of non-native species, property owners do have the ability to convert existing landscapes into wildlife habitats through sustainable gardening that promotes biodiversity, whether it is in a backyard, schoolyard, or business. The concept of gardening for wildlife, sometimes referred to as creating backyard habitats, recommends the use of native plants to provide wildlife with food and water sources, as well as cover from predators. It also emphasizes the use of sustainable practices, including integrated pest management and chemical-free fertilizing. Creating gardens for wildlife or backyard habitats aligns with many of the GI practices promoted by MMSD through the Fresh Coast Resource Center and Greenseams®.

MMSD's goal is to get more GI on the ground and on roofs that will create wildlife habitat while achieving the FreshCoast 740 goal. As mentioned in Section 4.3.1, almost any GI project that replaces a paved parking area, a monoculture of grass, or disturbed barren land with either a rain garden or natural landscaping is likely to increase local biodiversity. Therefore, MMSD's existing GI outreach and education efforts should highlight the benefits of urban biodiversity to raise awareness in tandem with highlighting the water quality improvement benefits of GI. To some extent, MMSD is already including urban biodiversity themes in GI messaging. For example, MMSD's webpage on rain gardens opens with the following message: "Invite butterflies and birds to your yard with a rain garden that helps protect rivers and lakes from water pollution." The MMSD Native Landscape Care guide also highlights the biodiversity benefits of using less chemical-intensive native plants.

While integrating these messages into GI outreach collateral is important, it is also important to determine how aware the public is about their activities and the impact they have on urban biodiversity. Understanding existing public awareness can help improve educational messaging and motivating participation in GI practice implementation. To determine this baseline public awareness, MMSD can partner with other local organizations working on urban biodiversity issues to develop and administer a public awareness survey. The survey could gauge existing public awareness of urban biodiversity threats, benefits, and current perceptions and behaviors. An understanding of the current level of public awareness will not only help to determine how to effectively tailor future educational programs and activities, the results will also identify existing barriers to implementing GI practices by different key audiences in the region and track changes in awareness and behaviors over time. This type of survey will also benefit the ongoing work of local partners. It is likely that the public has an existing awareness of urban biodiversity issues due to the ongoing work of local partners.

6.2 Educate the Public on Existing Urban Biodiversity Programs and Activities

After raising awareness, the next phase of outreach focuses on educating the public about steps that can be taken to improve urban biodiversity, including providing information on existing programs and activities.

MMSD is currently providing some of this information on the Fresh Coast Guardians website at https://www.freshcoastguardians.com/. For example, the MMSD rain garden manual for homeowners provides a step-by-step guide to install a rain garden. This manual also identifies the habitat benefits of rain gardens. Further enhancing urban biodiversity in the MMSD planning area through Fresh Coast Resource Center and Greenseams® requires enhancing existing public education and involvement efforts and materials to potentially place greater emphasis on urban biodiversity benefits and how implementation of these practices can be a valuable part of the solution.

As previously mentioned, the Urban Ecology Center has been at the forefront of outreach and citizen science with programs including the Neighborhood Environmental Education Project (NEEP). Their programs have helped to focus awareness of the threat of habitat loss due to urban development. Through NEEP, schools partner with the Urban Ecology Center for an entire year, creating a permanent outdoor classroom where teachers can reinforce science concepts taught in class with hands-on outdoor activities during multiple visits. This program would align well with MMSD's 2017 Green Infrastructure for Schools Guidebook. MMSD can consider working with the Urban Ecology Center to add GI implementation to the NEEP Program. This is a form of student/citizen science that could promote both GI implementation to achieve the FreshCoast 740 goal and improve urban biodiversity.

River Revitalization Foundation (RRF) currently offers regular opportunities to the public through their FORB (Fostering Our Riparian Biodiversity) program to engage in habitat restoration along the Milwaukee River and creates awareness about maintaining a healthy watershed. RRF has several other partnerships such as with Employ Milwaukee's Earn and Learn, UWM ISL, and Cream City Conservation to increase awareness to urban youth about biodiversity and healthy riparian greenspaces.

The Milwaukee Public Museum (MPM), in collaboration with groups including the Schlitz Audubon Nature Center and Milwaukee County Parks (Grant Park), hosts annual BioBlitzes. BioBlitzes offer interactive public education and outreach opportunities. A BioBlitz is part contest, part festival, part educational event, and part scientific endeavor where MPM brings together a group of scientists in a race against time to see how many species they can count in a 24-hour biological survey of a Wisconsin park. The first BioBlitz in Milwaukee counted 820 species in 24 hours and resulted in identifying federal and state-listed endangered species that were not previously known to occur at that location. The BioBlitz also found an invasive Asian worm, leading to immediate management steps for control.

MMSD could consider working with MPM, the Schlitz Audubon Nature Center, and other local partners to adapt the BioBlitz concept to a neighborhood and property-owner scale to focus on GI practices and backyard habitats, particularly for those with installed GI practices. This type of activity would also provide data to help MMSD communicate more quantifiable benefits of GI for urban biodiversity.

A BioBlitz is part contest, part festival, part educational event, and part scientific endeavor where participants see how many species they can count in a 24-hour biological survey. *Photo credit: Milwaukee Public Museum*

6.3 Motivate Increased Public Participation in Urban Biodiversity Programs

One area where MMSD can work with other local and regional partners is on incentive programs to increase public involvement in the programs described above. The National Wildlife Federation's Wildlife Habitat Certification program could serve as a potential model for such a program. Members of the public who participate in programs to improve urban biodiversity or implement GI practices to create backyard habitat could certify their school, home, or business as a wildlife habitat. A certification program could include signage, regional recognition through an awards program, and possibly discounts at participating gardening centers on supplies. MMSD could also motivate increased GI participation through technical assistance via the Fresh Coast Guardians Resource Center. The recommended survey for establishing a baseline level of awareness could also be used to track changes in behaviors and participation in urban biodiversity programs over time.

As mentioned in Section 3.3, good inventories should lead to the identification of habitats and green corridors that require protection, restoration, or improved linkages. If MMSD develops a strategy for habitat conservation throughout the MMSD planning area based on sound inventories, a comprehensive public education and outreach campaign to support this strategy should be developed to address the unique characteristics of the target audiences influencing decisions related to habitat protection and restoration identified in the strategy.

7 Conclusion

This plan identifies goals and strategies for enhancing urban biodiversity in the MMSD planning area by making recommendations for incorporating biodiversity into GI and other projects, identifying high priority conservation and rehabilitation areas, and suggesting future areas for research, monitoring, and education/outreach. Because so many entities have been heavily invested in land conservation to address the threats posed by increased urbanization and climate change, the MMSD planning area has the potential to achieve a thriving, diverse, resilient, and ecologically sustainable landscape. In this setting, and in the context of MMSD's 2050 Facilities Plan, it is an opportune time to consider how to best leverage and increase the value of the region's current natural, living assets.

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