Comprehensive Pollinator Planning and Outreach for UM Central Campus: Raising Awareness, Enhancing Habitat, and Celebrating Achievements

FACILITIES & OPERATIONS
OFFICE OF CAMPUS SUSTAINABILITY
UNIVERSITY OF MICHIGAN

XERCES SOCIETY
for Invertebrate Conservation

By

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University of Michigan Grounds Services

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EXECUTIVE SUMMARY

Need for a Comprehensive Pollinator Plan for the University of Michigan Campus

Pollinator populations are threatened due to habitat loss and fragmentation, harmful land management practices, and a lack of awareness of the benefit and diversity of native pollinator habitats and species, especially in an urban setting of a university campus. University green spaces have the potential to support a wide variety of pollinators in an institutional setting where outreach and educational opportunities abound. However, university green spaces come with unique challenges to supporting pollinator habitat as well, including harsh site conditions, high aesthetic expectations, high standards of human safety, and ease of maintenance. Supporting pollinators on campuses therefore requires a commitment to more sustainable landscaping practices and a shift in cultural norms that is supported by the surrounding community. Though UM Grounds Services and the Office of Campus Sustainability are already committed to and implementing sustainable practices on campus, such as limited chemical use and the restoration of habitat, they needed a comprehensive effort related to pollinator habitat and education, both to provide habitat for declining pollinator populations and for community engagement. We addressed these needs through a multi-faceted approach to 1) assess and enhance pollinator habitat on campus, 2) identify and build outreach and education opportunities related to pollinators, and 3) establish a support network to continue these efforts as part of a national Bee Campus certification program.

Pollinator Habitat Assessment and Enhancement

Based on a review of the relevant literature, we answered key questions to inform pollinator habitat enhancement and management in a campus setting. These questions include: Who are the primary pollinators on campus? Which plants and arrangements are most attractive and supportive to pollinators? What do pollinators need beyond floral resources? How can the surrounding landscape inform where to prioritize new habitat creation? How can other threats to pollinators be minimized through management choices?

We used the results of the literature review to inform the design and creation of an accessible mobile app tool for ongoing assessment of habitat quality on campus using ArcGIS Survey 123. Initial data collection with this tool revealed key patterns of the composition and spatial arrangement of pollinators and floral resources on central campus. Together with the two other analytical approaches that we propose (fluorescent dye experiments and habitat suitability analysis) this information can over time continue to inform adaptive management of pollinator habitat on campus.

To address an already known need and expand an educational opportunity, we designed and installed a native pollinator garden at UM Museum of Natural History that features over 440 plants, obtained in collaboration with local native plant nurseries and land managers at County Farm Park. To inform new pollinator habitat enhancements beyond this effort, we also developed specific design typologies and maintenance recommendations that can be used within a pollinator-friendly campus landscape.

Pollinator Education & Outreach

In combination with assessing and enhancing pollinator habitat on campus we identified and expanded opportunities to raise awareness around pollinators on campus. We provided a review of many campus and area organizations, landscape managers, researchers, and faculty already engaged in pollinator work, both so they can be celebrated and serve as potential partners in pollinator efforts on campus. We also filled gaps in available pollinator education and outreach materials through the data collection tool and BSB garden enhancement, both of which provide opportunities for using campus as a living laboratory to study and understand pollinators, as well as by creating several multimedia education tools and developing ideas for future pollinator events. To capture current and future on-campus efforts and opportunities in one place, we developed a UM Pollination Website as a resource hub and ongoing communication platform.

Support Network

To ensure durability of this projects' efforts and deliverables, we received approval for Bee Campus certification through the Xerces Society national program, and established a Bee Campus committee, which includes faculty, staff, and student champions. Through the final report of this project, we provide practical guidance on how this committee can continue and expand upon existing pollinator-related efforts on campus. We especially recommend the following next steps as priorities:

1. Integrate the project's local and landscape-level recommendations, informed by the literature, practice, and local data collection into future landscape management plans.
2. Continue pollinator habitat assessment on campus using the Survey 123 tool especially in other zones beyond Central Campus, and in a way that integrates its

use with the educational or outreach objectives of existing courses or interest groups.

3. Establish funds into the fiscal year budgets of UM Grounds and the Office of Campus Sustainability needed to maintain the ArcGIS Survey 123 habitat assessment tool, the renewal fees for Bee Campus USA certification, and a strong online presence via the UM Pollination Website.
4. Maintain the enhanced pollinator garden installation at the BSB and install educational signage that highlights the types of plants found in the garden and the value that they add.

ACKNOWLEDGEMENTS

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A huge thank you to Kira Berman for championing the existing and new pollinator gardens at the Museum of Natural History. We are so grateful for your willingness to share these important landscapes with the next generation. We also want to thank Shawn Severance and Mary Duff-Silverman for your years of stewardship caring for these and other pollinator-friendly landscapes.

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CHAPTER 1 – **INTRODUCTION**

Since the publication of Buchmann & Nabhan's 1996 landmark book *The Forgotten Pollinators* - and the many reports of colony collapse disorder in honeybees beginning in the 2000s - pollinator declines have gained attention through the larger lens of climate change and biodiversity loss (Knight et al. 2018). Many people across the globe now have some understanding that pollinators are important, and the current body of scientific literature identifies numerous anthropogenic influences - pollution, habitat loss, pesticide application, and more - that are negatively affecting many pollinators. As pollinators are essential for successful fruiting and reproduction of many plant species, including agricultural crops, declines in pollination services can have direct impacts on human health and food security. Managing pollinator habitat within agricultural landscapes has been shown to enhance other ecosystem services, including increased water and soil quality and enhanced overall biodiversity (Wratten et al. 2012). Insect pollinators themselves are an important food source for organisms in higher trophic levels like birds, which are highly valued by society as an engaging connection to nature.

The field of pollination ecology has shifted considerably in the past few decades from a focus on pair-wise plant-pollinator interactions to more holistic investigations of plant-pollinator networks within whole pollinator communities and across connected *landscapes* (Knight et al. 2018). Instrumental to these holistic investigations is a growing understanding of the global anthropogenic drivers that influence pollinators. Shifting research foci and growing understanding of the drivers of pollinator declines, coupled with a growing public awareness of and appreciation for pollinators, come together in programs that further increase awareness and seek to enhance networks. The Xerces Society for Invertebrate Conservation is a non-profit environmental organization that focuses on the conservation of invertebrate species and their habitats, especially pollinators. This organization works directly with diverse partners that include scientists, students, government organizations, educators, landowners, farmers, and communities to develop science-based plans for conserving species and habitats. Recent initiatives like the Bee City and Bee Campus USA certification programs through the Xerces Society are using this information to engage citizens and communities more closely with the issues that pollinators face. These initiatives aim to help cities and campuses tackle the issues head on via habitat creation and enhancement, reduction of pesticides and herbicides, and community engagement with pollinator issues and events.

Perhaps counterintuitively, urban areas have become hopeful spots for pollinator conservation because of the potential for habitat enhancement and connection into the type of networks that many pollinators prefer (Aronson et al. 2017). There is ample pollination research potential in these urban and developed areas. Such research has the potential to not only raise awareness of the importance and plight of pollinators, but also empower people to have positive impacts on pollinator species right where they live. Many urban and semi-urban university campuses are ideal areas for pollinator habitat enhancement both because of the potential for habitat connectivity, as well as the opportunity to engage with a broad community regarding pollinator conservation. However, tapping into this conservation and outreach potential requires significant capacity to assess and enhance pollinator habitat and engage the relevant people and organizations.

Clients & Research Site

For over a decade, the University of Michigan has been a driving leader in environmental sustainability. In September of 2011, the university adopted six long-term sustainability goals that would enhance their overall commitment to practice sustainability. Through a Campus Sustainability Integrated Assessment process (CSIA), these goals were identified and officially established by the university. The CSIA was an intensive two-year long project that was led by the Graham Sustainability Institute and the Office of Campus Sustainability. This project involved students, faculty, and staff on faculty-led committees. Participants of this program were representative of 101 organizational units and 27 academic programs. The purpose behind the assessment was to be able to identify ambitious and attainable long-term sustainability goals. The six long-term sustainability goals that were developed through the CSIA initiative to guide the University of Michigan's efforts to live, work, and learn sustainably are as follows:

1. Reduce greenhouse gas emissions by 25%
2. Reduce vehicle carbon output per passenger trip by 30%
3. Reduce the amount of water sent to landfills by 40%
4. Purchase 20% of U of M food from local and sustainable sources
5. Protect Huron River water quality by minimizing runoff from impervious surfaces and reducing chemical applications to campus landscapes by 40%
6. Invest in sustainability culture programs to educate our community, track behavior, and report on the progress over time

The University of Michigan's Office of Campus Sustainability (OCS) is dedicated to actively contributing towards the implementation of the university's six sustainability goals. The Office of Campus Sustainability was established in 2009 and is a department of Facilities and Operations, which is the organization responsible for stewardship of the university's natural and physical properties and landscapes. OCS is designed to:

1. Inspire students, faculty, and staff to become involved in helping to solve the environmental sustainability issues facing the world we live in
2. Coordinate, facilitate and advance sustainability efforts in all areas of the university campus, including operations, academics, research, clinical, and athletics
3. Connect academic and operations activities to foster collaborative sustainability learning

The mission of OCS has four key strategies. These strategies are:

1. Work with U-M leadership to set goals and standards for sustainable operations on our campus. Work with the units across campus to ensure those goals and standards are met. Track and report progress on university-wide goals to leadership.
2. Identify, support, and coordinate opportunities to reduce energy consumption and increase sustainable operations on campus that may go beyond what is required to meet campus goals.
3. Work collaboratively with the Graham Sustainability Institute on cross-functional sustainability efforts that span academic, research and operational functions of the university.
4. Provide information exchange and be responsible for communicating to internal and external constituents about efforts underway and challenges associated with sustainability work on campus.

The Office of Campus Sustainability is also a part of the program Planet Blue. Planet Blue is a cross-university initiative to lead and organize sustainability initiatives as well as actively promote sustainability awareness across campus. Multiple units and individual partners collaborate to lead, organize, and manage the U-M Sustainability Initiative and its related programs and activities. This initiative is governed by U-M President Mark Schlissel and the executive officers who work to set the university's direction and goals to ensure that sustainability considerations are integrated into institutional-level decision-making. Planet Blue receives staffing support through a collaborative partnership with the Graham Sustainability Institute, the Office of Campus Sustainability, and the Office of Global Communications.

The University of Michigan employs three primary mechanisms in order to track and measure progress towards the sustainability goals through the Planet Blue initiative. The first mechanism is through operational metrics. The Office of Campus Sustainability monitors and records progress toward operational campus sustainability goals and maintains a database including 170 distinct operational metrics spanning areas such as energy, emissions, water use, land use, waste, and procurement. This tool provides important information to help the university understand recent historical trends as it contains data dating back to 2006. The second mechanism of measurement is through cultural metrics. The Graham Sustainability Institute, in partnership with the Institute for Social Research, leads the Sustainability Cultural Indicators Program (SCIP), which is a survey tool used to assess sustainability knowledge, dispositions, and behaviors among campus community members. The findings from SCIP are shared with units throughout the university annually to inform improvements for “walking the talk” of sustainability. The third mechanism used to measure progress is through AASHE STARS participation. The Association for the Advancement of Sustainability in Higher Education (AASHE) Sustainability Tracking, Assessment, and Rating System (STARS) provides transparent and easily understandable reporting of sustainability performance. Reporting of sustainability performance takes place in three broad areas: Administration, Planning, & Engagement; Education & Research; and Campus Operations.

Working together with the Office of Campus Sustainability, the University of Michigan’s Grounds Services plays a crucial role in directly managing landscapes on campus, and therefore the potential to affect pollinator habitat. Grounds Services is a branch of the Custodial & Grounds Services Department, which, like the OCS, belongs to the larger organization of the university’s Facilities and Operations (Figure 1). Custodial and Grounds Services serve the U-M community as they are dedicated to the preservation of the natural land on the academic and hospital campuses within Ann Arbor by conserving, enhancing, and maintaining over 26 million square feet of property. They provide custodial services, pest management, grounds maintenance, and landscape design services in the support of a safe, functional, and attractive campus environment. Grounds Services are responsible for the outdoor properties and landscapes of the U-M’s Ann Arbor Campus. They consist of specialized crews who provide horticulture and grounds keeping maintenance for the entire university. These professional crews that make up the Grounds Services department specialize in one of seven areas: forestry, hardscape & mowing, horticulture & gardens, irrigation, winter maintenance & snow removal, turf maintenance, and landscape design & installation.

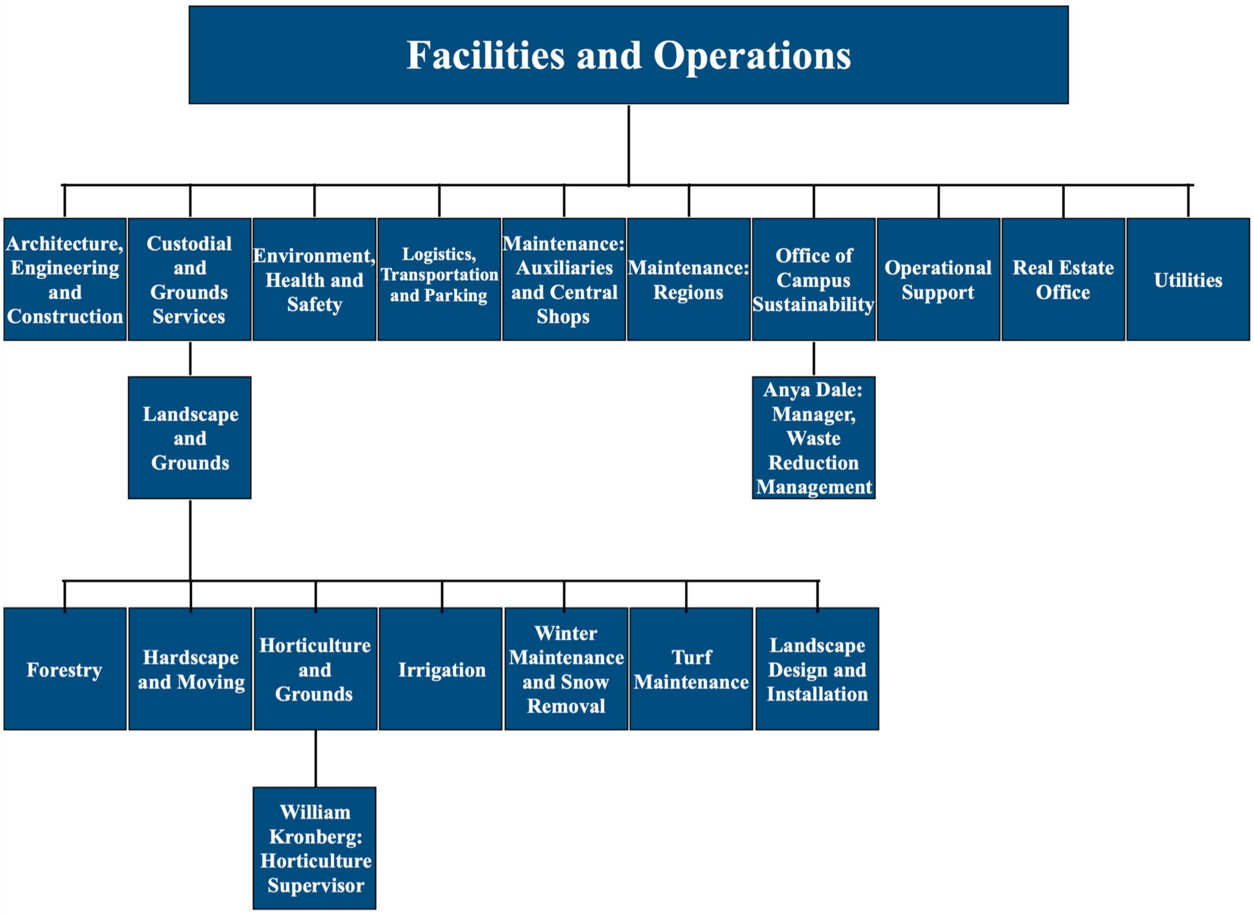

Figure 1.1 Chart of relationships between the University of Michigan clients specifically in the Office of Campus of Sustainability and Grounds Services

The University of Michigan's Grounds Services have been and continuously are engaging in creating sustainable grounds on campus through various practices. Sustainable practices include expanding natural areas and landscape, managing invasive species through the use of goats as natural lawnmowers, working with fire through prescribed burns to enrich soil, remove dead vegetation, and prevent non-native plants from taking over, maintaining healthy gardens and forestry, composting, and stormwater management. Grounds Services strives to maintain the campus landscape using the latest technologies and strategies to reduce chemical use and our carbon footprint. Efforts to reduce landscape chemical applications by 40% in 2025 have so far achieved a 37% reduction due to the work of Grounds Services that is guided by U-M's Sustainable Land Management Guidelines. These guidelines include:

1. Organic and low-impact herbicides and fertilizers where possible. 80% of campus lawns are managed using organic fertilizer.
2. Improving soil quality to reduce the need for fertilizer and supplemental irrigation
3. Expanding natural areas and planting native trees and shrubs
4. Prescribed burns and the use of goats to control invasive plants

While central campus was the main focus of our project field work, the larger University of Michigan Campus managed by Grounds Services has numerous and ecologically diverse areas that could be ideal landscapes for pollinator habitat enhancement and conservation (specific types of land cover within each map that follows are shown in Figure 2). The Central Campus Zone (Figure 3) largely consists of turf areas, but also includes numerous planting and perennial beds. The East Campus Zone (Figure 4) is predominantly covered by meadows and woods, planting beds, turf areas, with smaller areas of ground cover of gravel/much. The Medical Campus Zone landscape (Figure 5) is mostly covered by turf areas along with meadows and woods and has little land cover including planting and perennial beds. The North Campus Zone (Figure 6) is heavily dominated by planting beds, with some meadows, turf areas, and perennial beds. Finally, the landscape of the South Campus Zone (Figure 7) contains a mixture of planting beds, turf areas, meadows and woods, and slight ground cover by gravel/mulch.

Figure 1.2 Color-coded legend describing specific ground cover within each campus zone. Planting, Perennial, and Annual Beds as well as Meadow-Woods are potential pollinator habitats.

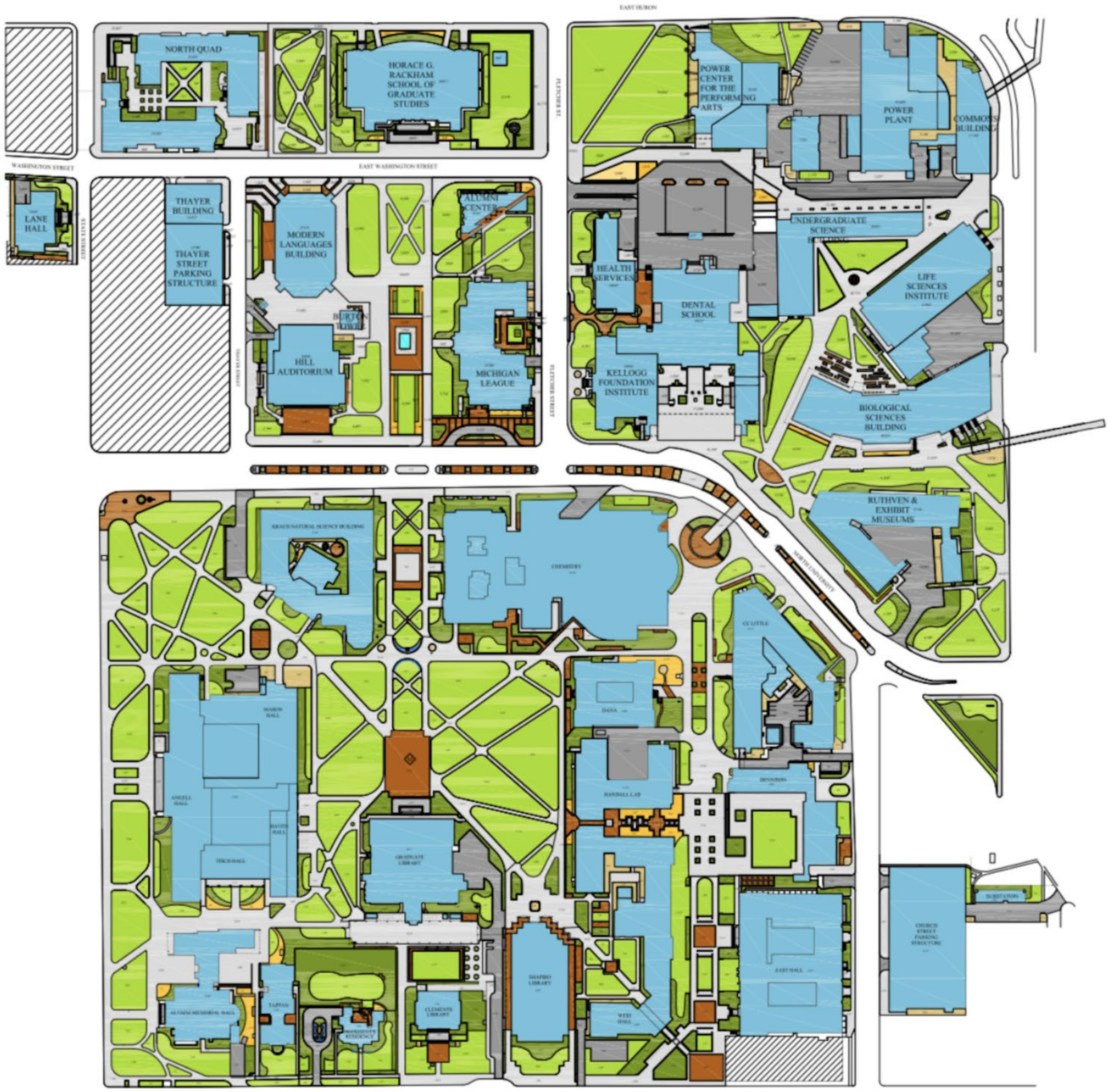

Figure 1.3 Map of Central Zone of University of Michigan, Ann Arbor Campus

Figure 1.4 Map of East Zone of University of Michigan, Ann Arbor campus

Figure 1.5 Map of Medical Zone of University of Michigan, Ann Arbor campus

Figure 1.6 Map of North Zone of University of Michigan, Ann Arbor campus

Figure 1.7 Map of South Zone of University of Michigan, Ann Arbor campus

Project Goals & Approach

The goal of this project was to tap into the fantastic potential for campus greenspaces to support pollinators and to build on the existing sustainability efforts of both OCS and UM Grounds Services. We developed a comprehensive UM campus plan for pollinator habitat and education by taking three interrelated approaches, which are outlined in Figure 1.8:

1. Assess and enhance pollinator habitat on campus in the near term, but also provide guidance on continued informed creation and management of habitat,

2. Celebrate achievements and build awareness by identifying and expanding outreach and education opportunities related to pollinators, and

3. Establish a support network of champions to continue these efforts as part of a national Bee Campus USA certification program.

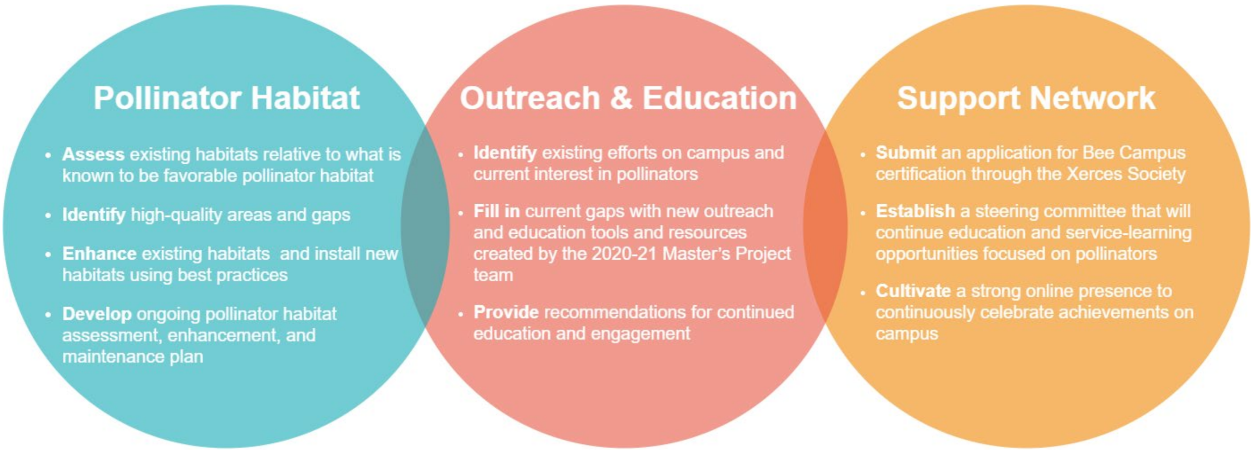

Figure 1.8 The three goals of our project

Project Significance

Impact or value-added for clients

The Office of Campus Sustainability and Grounds Services are already committed to and implementing sustainable practices on campus such as limited chemical use and the restoration of habitat for improved water quality. What they are lacking is the capacity for a comprehensive and focused effort related to pollinator habitat and education. Compiling and implementing all the aspects required for Bee Campus USA certification, including establishing a GIS map of existing pollinator habitat on campus, is time-consuming and requires coordination across multiple stakeholders. By providing the capacity to complete this service and the related information and events, this project will have a long-term impact on campus habitat quality, education, and engagement. For example, community engagement in sustainability, a major goal of OCS, will be enhanced through the creation of a 'living laboratory' campus classroom and pollinator campus engagement events. This work also provides the opportunity for continued master's projects with UM Grounds on other focal goals or topics. In addition, the high visibility and engaging nature of planting design and pollinators increases awareness for the clients themselves and demonstrate their commitment to sustainability on campus.

Impact on the broader theory and practice of conservation and restoration

The emerging fields of urban pollinator and plant conservation seek to understand the complex unknowns and site-specific interactions in urban ecosystems. As natural areas shrink or degrade, urban pollinator habitat often becomes a critically important refugia for pollinators and other wildlife (Hall et al., 2017), but which specific landscape or local characteristics determine habitat quality remains a difficult question to answer. This project builds and applies foundational knowledge of current pollinator and habitat conditions as a baseline to estimate the future effects of project-proposed changes in land management and design. Part of the project focusses on analyzing the campus landscape as an urban habitat network, combining concepts from landscape ecology with pollination biology and environmental informatics. Information gained from current conditions and the impacts of proposed improvements will help advance effective practices to enhance urban pollinator habitat and plant conservation.

"Unless we modify the places we live, work, and play to meet not only our own needs by the needs of other species as well, nearly all species of wildlife native to the United States will disappear forever. This is not speculation."

— Dr. Doug Tallamy, *Bringing Nature Home*

This project also applies to the human dimension of conservation and restoration. Adopting some pollinator-friendly landscape practices may require a cultural shift in how campus landscapes are maintained and visually curated. This landscaping culture is not limited to the University of Michigan campus, but also includes broader campus landscape management, public lands management, urban streetscaping, and private backyard landscaping as well. Making pollinator-friendly practices the norm in urban areas like a public university campus can promote a widespread shift in urban aesthetic expectations and maintenance regimes, which are often the greatest hindrance to urban habitat conservation efforts (Gobster et al., 2007; Tallamy, 2007).

Societal impacts

Current dramatic pollinator declines can lead to losses of essential ecosystem services, such as pollination for agriculture, and efforts to enhance pollinator populations can have positive effects on a variety of additional ecosystem services. As pollinators are essential for successful fruiting and reproduction of many plant species, including agricultural crops, declines in pollination services can have direct impacts on human health and food security. In addition, managing pollinator habitat within agricultural landscapes has been shown to enhance other ecosystem services, including increased water and soil quality and enhanced overall biodiversity (Wratten et al. 2012). Insect pollinators themselves are an important food source for higher trophic levels, like birds, which are highly valued by society as an engaging connection to nature.

Pollinator-friendly garden design can also provide important mental health benefits to people as well. Aesthetically pleasing, immersive, urban gardens are much needed for human wellbeing and ecological function. Currently, many campus landscapes are dominated by turf, hardscape, or overly formal landscaping. The mental health benefits of viewing and interacting with plants, even for a short period, can have significant impacts on student, faculty, and staff wellbeing (Hansen et al., 2017; Hunter et al., 2019). By bringing eye-catching botanic displays within reach of people, enhanced garden spaces can provide a sensory experience that could brighten someone's day, break dangerous mental cycles, or provide an interesting story to share later with a friend.

Chapter Overview

We designed and carried out a series of research, assessment and analysis around our three project areas, and provide recommendations to inform future pollinator conservation and associated education and outreach activities on campus. Specifically, Chapter 2 to 5 discuss key questions and detailed strategies for enhancing pollinator habitats on campus. In Chapter 2, we first lay out important pollinator habitat management questions to guide our research, then explore the answers through a literature review at both species and landscape level. Chapter 3 reveals the details of the creation of our own campus pollinator habitat assessment tool in the open-sourced, mobile app ArcGIS Survey 123 and the pilot process to assess the quantity and quality of pollinator habitat in existing green spaces on campus. In Chapter 4, we summarize and analyze the data collected through pilot assessment, then propose an analytical framework of three tools (Campus Pollinator Habitat Assessment; Fluorescent Dye Study; Habitat Suitability Analysis) to continue to gather long-term data on pollinator habitat, populations, and movement across campus that will inform future landscape decisions.

Chapter 5 integrates and applies what we learned from the literature review on effective pollinator habitat (Chapter 2) and what we learned about specific pollinator habitat conditions on UM campus (Chapter 4) through our campus pollinator habitat assessment tool (Chapter 3) to provide specific habitat creation and maintenance recommendations. We provide samples of easy-to-replicate garden designs for use in four common landscape scenarios on campus and a general pollinator habitat maintenance plan. We describe how we actually planned and implemented a pollinator-friendly garden on central campus in the fall of 2020 as an example of how to apply a sample garden design and care for a campus pollinator landscape.

Finally, in Chapter 6, we address both building outreach and education and a support network to maintain the efforts of pollinator conservation on campus over time.

Specifically, we provide an overview of existing efforts and interest in pollinators on campus, highlight some unique deliverables produced by the project team that fill in gaps in these existing efforts, and describe future opportunities that can sustain stewardship efforts in the long-term.

We took multiple approaches based on scientific research and ground-truthed data and application throughout this comprehensive pollinator planning for the University of Michigan. The combination of these approaches provides a systematic methodology that can be replicated to inform pollinator conservations in other campuses and similar urban settings.

CHAPTER 2 – WHAT DOES HIGH QUALITY, WELL-CONNECTED POLLINATOR HABITAT IN A TEMPERATE SUBURBAN SETTING LOOK LIKE?

Introduction

Successful efforts to reduce pollinator decline through improved access to quality habitat requires a strong sense of what quality, well-connected pollinator habitat looks like in an urban or semi-urban setting like a university campus. Here we review both pollinator research at the species and at the landscape level to address the following pollinator habitat management questions:

1. Who are the primary pollinators that should be the focus of improved habitat quality efforts on campuses?

2. Which plants and what arrangements of plants are most attractive and supportive to pollinators?

3. What do pollinators need beyond floral resources? What are other important habitat variables?

4. How can the surrounding landscape inform where to prioritize new habitat creation? Does habitat size matter?

To assess potential answers to these questions and provide recommendations for habitat improvement efforts in a campus setting, we searched available literature using a variety of key terms, including native and wild bee, conservation and health, pollinator biodiversity, urban green space, native plants, pollinator garden, bee hotel, urban corridor, urban garden, backyard garden, citizen science, urban nature, and habitat and landscape assessments. We focused especially on sources with information relevant to temperate urban and suburban systems as those most resemble the campus habitat focus of this project.

Insect pollinators face threats in many forms: pesticides, pathogens and pests, parasitization, and habitat fragmentation. Based on the synthesis of numerous plant-pollinator interaction studies, Nicolson and Wright (2017) identify habitat/forage loss as the single greatest threat to pollinator biodiversity. Aronson et al. (2017) note that many common urban green space management practices threaten biodiversity in cities.

These include the continued maintenance of turf grass lawns, which lead to a lack of foraging resources, the application of pesticides and herbicides, and tree and shrub pruning/leaf removal (especially as "fall/spring clean ups," which can greatly diminish nesting habitat for pollinators). Knowing which pollinators are at risk from such threats is a key starting point for urban pollinator habitat enhancement and creation.

1. Pollinators – Who are the primary pollinators that should be the focus of improved habitat quality efforts on campuses?

When the general public thinks of pollinators or of the "Save the Bees" campaign they are often thinking of the European honey bee (*Apis mellifera*), which is actually an introduced bee species that competes with native bees for limited floral resources (Paini, 2004). Honey bees have garnered so much conservation attention that they are redirecting efforts that could focus on native pollinator species. This is likely due to the presumed economic contributions that honey bees provide not just in the form of honey production, but perhaps more significantly in the commercial crop pollination services that they provide (e.g. California almonds). In fact, wild bees are actually key for staple crop pollination, such as apples and blueberries (Adamson et al., 2012). Senapathi et al. (2015) stress that there are critical differences between managing habitat for pollinator services (e.g., commercial honey bees pollinating the California almond crop) and preserving overall pollinator biodiversity (e.g. native bees and other native insect pollinator groups). Such intense focus on honey bees spreads misinformation regarding pollinator biodiversity and its conservation, so it should be established that the term "pollinator" encompasses *many* species with different needs.

Pollinating insects include many species of bees, wasps, butterflies, moths, flies, and beetles. Each group of pollinators has different habitat and floral resource needs, although there are existing overlaps of such needs. This overlap provides opportunities to create beneficial habitat for many pollinator groups at once (Holm, 2014). For example, 30% of native bees are cavity-nesting species, using dead wood and plant stems as shelter for developing larvae. These cavity-nesting bees include mason, leafcutter, and carpenter bees, which all belong to different genera, demonstrating such overlap (Xerces Society). Similarly, certain plants discussed in the next section attract pollinators from completely different insect orders, e.g., butterflies and moths (Lepidoptera), bees (Hymenoptera), beetles (Coleoptera), and flies (Diptera). Thus, there are many more species to consider *besides* honeybees and many strategies for attracting these species. One key limitation to making habitat improvement recommendations for groups other than bees, however, is that much of the literature focuses on bees instead of other pollinating insects, especially flies.

Bates et al. (2011) note that despite increasing global urbanization *and* continuing pollinator declines, relatively little research has been conducted that investigates the effects of urbanization on pollinator assemblages. They found that urban areas *can* support diverse pollinator assemblages that include native bees, wasps, butterflies, moths, flies, and beetles, but such assemblages are strongly affected by local habitat quality (i.e., which plants are present) in those urban areas (Bates et al., 2011). Senapathi et al. (2017) note that the effects of urbanization on non-bee pollinator assemblages is quite under-researched, and most species-specific research focuses on native bees: e.g., that of Hinners et al. (2012), which found that suburban and urban sites containing smaller habitat patches showed increases in small bee, social bee, and solitary cavity-nesting bee species. These urban habitat patches also favor species in the family Halictidae (sweat bees) over Apidae (honey, bumble, carpenter, and cuckoo bees). These sorts of results can better direct plant selection and habitat construction in urban areas based on the floral preferences of the more favored species; for example, sweat bees prefer flowers from the plant families Asteraceae (asters and daisies) and Lamiaceae (mints) (Holm, 2014). Baldock et al. (2015) found that urban areas can actually support a higher species richness of bees than natural areas, while Senapathi et al. (2016) found that urban areas tend to support generalist, short-tongued bee species and not specialist bee species. A review of how urbanization is affecting pollinator biodiversity by Wenzel et al. (2020) concludes that:

- Pollinator responses to urbanization are quite varied and are trait- and scale-dependent
- Increased pollinator species richness is associated with urban areas with green spaces, while decreased richness is associated with zones of more extreme urbanization
- When compared to natural areas, urbanization reduced overall pollinator diversity; but when compared to conventional agricultural landscapes, urbanization increases pollinator diversity

These results demonstrate that, while it is difficult to know precisely which pollinator species to focus on when constructing or enhancing urban pollinator habitat, such habitats *can* support diverse assemblages of pollinators; therefore, plants and structures that are favored by generalist species (Table 2.1) are important to implement into urban pollinator habitats to attract the widest assemblages of species.

*Table 2.1 A list of generalist pollinator families and genera that could be supported even in urbanized landscapes *Adapted from Holm 2014*

Bees	Many (but not all): bumble bees (*Bombus sp.*), sweat bees (*Halictus sp.* and *Lasioglossum sp.*), leaf-cutter bees (*Megachile sp.*), carpenter bees (*Xylocopa sp.*)
Wasps	Paper wasps (*Polistes sp.*), yellowjacket (*Vespula*), bald-faced hornet (*Dolichovespula*)
Butterflies and Moths	Hummingbird moths (*Hemaris sp.*), sulphurs (*Colias sp.*), swallowtails (*Papilio sp.*), fritillaries (*Speyeria sp.*)
Flies	Families: bee flies (Bombyliidae), Syrphid (hover) flies (Syrphidae), Tachinid flies (Tachinidae), thick-headed flies (Conopidae)
Beetles	Families: soldier beetles (Cantharidae), long-horned beetles (Cerambycidae), leaf beetles (Chrysomelidae), snout beetles (Curculionidae)

2. Plants – Which plants and what arrangements of plants are most attractive and supportive to pollinators?

Floral abundance and diversity

Urban areas have the potential to support a wide variety of pollinators (Hall et al., 2017), however, not all urban green spaces support all pollinators equally. Urban greenspace is often described across a gradient from highly managed to semi-natural. Spaces across this gradient can be characterized by differences in landscape management intensity, vegetation composition, vertical structure, and patch size, which can all have effects on pollinator populations. Some pollinator species appear to be more sensitive to this urban gradient than others. Butterfly populations, for example, have been found to be significantly more abundant and more species rich in more naturalized urban areas (Chong et al., 2014; Dylewski et al., 2019). While studies vary on the effect of urbanization on wild bees, species richness and abundance are frequently positively associated with plant species diversity and/or natural plant cover (Dylewski et al., 2019; Tonietto et al., 2011), which most often characterize semi-natural urban areas. However, in a study of residential gardens and semi-natural areas where plant species diversity and natural plant cover are high, but the landscape context changes across an urban gradient, bee species richness, abundance, and functional diversity increased with urbanization. Additionally, in a Chicago study that included green roofs, the green roof with the highest bee species richness and abundance was planted with native plants and featured the highest plant diversity (Tonietto et al., 2011). This example suggests that greenspace in a vertically isolated and highly urbanized context (e.g., a green roof several stories high) can still provide suitable habitat for pollinators with the right plant choices. These studies suggest that it is not necessarily the degree of "urban-ness", but instead the specific characteristics of each urban greenspace that ultimately influence pollinator abundance and diversity.

Within urban areas, research has illuminated specific site-scale characteristics that affect pollinator populations. Broadly speaking, the presence of floral foraging resources is consistently found to influence the presence of pollinators in urban areas (Hall et al., 2017). More specifically, urban areas with higher floral diversity (Chong et al., 2014; Dylewski et al., 2019; Tonietto et al., 2011) and floral abundance (Pardee & Philpott, 2014; Salisbury et al., 2015; V. Wojcik, 2011) tend to have higher pollinator abundance and/or diversity. As we will detail in the following sections, the flower type is important and local-scale planting decisions such as nativity, floral shape diversity, and arrangement in time and space greatly influence the diversity and abundance of pollinators (Holm, 2017).

In terms of urban landscape-level characteristics that influence pollinators, one major pitfall of traditional urban landscaping is the application of the same, tried-and-true plant species (e.g., hostas, day lilies, etc.). These hardy, readily-available plant species keep maintenance care low and simple, however, the repeated use of these limited plant species across a landscape or region can result in homogenization of floral resources, leading to low pollinator diversity across a region (Chong et al., 2014). Therefore, by incorporating floral diversity across a landscape (akin to diversity found in natural areas), urban areas can provide a variety of pollinator resources that support a higher regional diversity of pollinators. Managers that make landscaping decisions across a large area (e.g., a university campus) are thus critically important to influencing landscape level pollinator diversity.

> *Urban areas with higher floral diversity and floral abundance tend to have higher pollinator abundance and/or diversity.*

Native vs. non-native plants

In recent years, gardeners and researchers alike have been debating the role of native and non-native, ornamental plants in supporting local biodiversity. The benefit **–** and proposed superiority **–** of native plants stems from their shared origins within the local food webs. Local native plants and insects have been waging an evolutionary arms race for millennia: plants develop defenses against insect herbivory while insects develop adaptations that often result in specialist dependencies where one species of insect only consumes one species of plant. An example of this is monarch butterfly caterpillars (*Danaus plexippus*) specializing in feeding on milkweed (*Asclepias*) species. While many insects are specialists on one plant species or genus, there are also a wide variety of insect generalists that can consume a broader array of plants. From aphids to zebra swallowtail caterpillars, these insects form the base of the food web, providing rich, abundant food resources for amphibians, reptiles, mammals, birds, and so on. Therefore, since non-native, ornamental plants have not evolved to support the local ecosystem, they are hypothesized to support less biodiversity and ecological function, however, many ornamentals do provide nectar, pollen, nesting substrate, and resources for other wildlife. Although the evolutionary arms race more directly applies to herbivorous insects (including lepidoptera larvae), the widespread use of non-native plants across urban and non-urban landscapes is likely contributing to global insect declines (Tallamy et al., 2020). Finally, the biodiversity argument reminds us that our gardens can be multifunctional and in the midst of a sixth global extinction, it is critical that we take advantage of every opportunity to maximize the potential of each greenspace.

Setting aside the importance of native plants as the foundation of local food webs, some non-native ornamental plants offer other benefits, including pollinator resources, thus they may play a valuable role as part of a mixed planting of both native and non-native species. First, landscape aesthetics are a powerful cultural driver of a greenspace's success and long-term sustainability (Garbuzov & Ratnieks, 2014). Non-native, ornamental plants have been human selected for their beauty, scent, reliability, or cultural relevance among other socially determined reasons. It follows that these plants are familiar, broadly socially accepted, and legible to the general public. These spaces inherently feel orderly and cared for, which exemplifies Joan Nassauer's "Cues to Care" (Nassauer, 1995) – the social importance of cues to care cannot be underestimated, but can be signaled in other, intentional ways in plantings that are less ubiquitous or orderly. Regardless, the social legibility of culturally beloved, ornamental plants such as peonies, roses, or boxwoods can be leveraged to make less-familiar, more "wild" native plantings more socially acceptable and therefore more likely to be cared for and persist over the long-term, which is what pollinators depend on. Additionally, not all gardeners want to plant an all-native garden but want to help pollinators. By not vilifying ornamentals and instead encouraging a mix of ornamental and native plants, we may offer a steppingstone and olive branch for anyone who wants to garden for pollinators.

Many non-native, ornamental plants signal important social cues, including legibility and familiarity, that influence the acceptance, care, and longevity of gardens.

Beyond their potential aesthetic value, some non-native ornamental plants do provide resources for pollinators that may complement a native planting. Many popular, easy-to-grow annuals can attract pollinators (Erickson et al., 2020) and as mentioned above, the social value of plants is very important in supporting the longevity of planted spaces. While many non-native ornamental plants attract pollinators, there is growing evidence that they attract a subset of pollinators, and frequently these pollinators are more generalist in their foraging preferences (Erickson et al., 2020; Salisbury et al., 2015). This support for generalists is valuable, especially in urban environments which may be resource-poor, but it is important to acknowledge this limitation and provide a variety of foraging resources for both specialist and generalist species. Many non-native plants are selected for longer blooming periods and blooming periods for the "shoulder" seasons of early spring and late fall, all of which can extend foraging resource availability temporally for pollinators (Staab et al., 2020) which may be especially important with climate change.

Although pollinators are often attracted to various non-native ornamental plants in urban landscapes (Erickson et al., 2020; Pardee & Philpott, 2014), research increasingly demonstrates that overall pollinator abundance and diversity are greatest in landscapes with native plants (Dylewski et al., 2019; Fukase, 2016; Tonietto et al., 2011). Pardee and Philpott (2014), for example, studied backyard gardens in northwestern Ohio and found that both bee richness and abundance were positively correlated with gardens that contained more native plants and thus had more floral abundance, taller vegetation, more cover, and more potential nesting sites. Similarly, Rollings and Goulson (2019) found a significantly higher diversity of pollinators attracted to native plants as opposed to ornamental plants in backyard gardens. Lowenstein, et al. (2018) compared urban pollinator visitation rates to ornamental, non-native, annual, and "weedy" plant resources, finding that perennial and native plants in urban habitats received more visits from pollinators than did ornamental or "weedy" plants. Additionally, there may be a native plant "threshold" of eight or more species of native plants within a landscape to increase abundance and diversity of native bees (Frankie et al., 2005; V. A. Wojcik et al., 2008). These findings suggest that incorporating native plants into the urban landscape is critically important for supporting abundant, diverse pollinator populations, but nativity is not the only factor in pollinator-friendly landscaping.

Although non-native ornamental plants can attract pollinators, pollinator abundance and diversity are greatest in landscapes with native plants. Native gardens typically feature greater floral abundance, taller vegetation, more cover, and more potential nesting sites that likely attract pollinators.

The growing number of “nativars”, or cultivated varieties of native plants, in horticulture has raised questions about how horticultural modification of plant traits affects the ecological function of native plants. To date, this research has produced variable answers. Cultivated plants are often selected for desirable growth traits (disease resistance, longer bloom time, tidy form, etc.) or aesthetic traits (double blooms, larger blooms, bloom color variety, variegated leaf/stem color, etc.). Either for growth form or aesthetics, alterations that change the physical traits of a plant may alter attractiveness or resource availability to insects and thus change their ecological function. Robust garden trials from Mt. Cuba Center in Delaware are actively testing pollinator use (ecological function) alongside horticultural performance (social function). Though only a few genera have been tested so far (*Baptisia* spp., *Coreopsis* spp., *Echinacea* spp., *Monarda* spp.) results vary widely with some cultivated varieties actually attracting more pollinators than the “straight” native plant. For example, within *Monarda* varieties, moths and butterflies were more attracted to selections that offered the largest abundance of 2-3” wide flowers, with *M. fistulosa* ‘Claire Grace’ attracting substantially more pollinator visits than the straight native, *M. fistulosa* (Coombs, 2017). Importantly, Mt. Cuba researchers note that this artificially resource-rich “buffet” of dense *Monarda* plantings may reveal pollinator preferences given unlimited options, but any of these *Monarda* varieties on their own in a landscape setting may perform equally well. Although current research is limited regarding which specific alterations may affect ecological function, Tallamy et al. (2020) found that native varieties that had leaves altered from green to red, blue, or purple were eaten significantly *less* by herbivorous insects. The same study found no effect of altered plant habit, fruit size, disease resistance, or fall color, but leaf variegation seemed to increase insect herbivory. These limited studies suggest that some “nativars” still provide resources for pollinators and herbivorous insects (Baisden et al., 2018), although more research is still needed to test cultivated varieties of more plant species and to investigate alterations to pollen and nectar quantity and quality.

Floral features

Beyond plant origin (native or non-native), it is known that floral features such as fragrance, color, shape, and nutritional quantity and quality influence pollinator attractiveness (Erickson et al., 2020; Holm, 2014). Heather Holm's *Pollinators of Native Plants* provides a comprehensive guide to floral features that attract pollinators, and we highly recommend this resource for a thorough understanding of the breadth and specificity of this topic. A summary of the general floral features that attract different pollinators can be found in Table 2.2.

Table 2.2 Flower color and trait preferences of different pollinators that can be used to inform planting designs to attract a diversity of pollinators.

Pollinator	Flower Trait Association
Bees	Primary color: pink, purple, or blue Secondary: white or yellow
Wasps	Shallow corollas for nectar; white.
Beetles	Open shape; white, cream or green. Spicy or fruity fragrance.
Butterflies & day-foraging moths	Flat-topped flowers or a structure to grasp while nectaring. Prefer composite flowers.
Night-foraging moths	White or cream with a strong fragrance.
Flies	Flat or bowl shapes, umbels. White or cream color. Musty fragrance.

Pollinator response to floral color varies across plant genera (Erickson et al., 2020), but there are certain color-species associations based upon pollinator species-specific ability to perceive a certain range of colors and some species preferences. Red, for example, is perceived as black to bees (Holm, 2014) and so the color red is not attractive to bees; however, red is particularly attractive to hummingbirds, which are also essential pollinators. Bees and many other insect pollinators perceive ultraviolet light cues that often serve as nectar guides but are imperceptible to humans. White, cream, or green-colored flowers are attractive to the less popular but no less important pollinators: wasps, beetles, flies, and night-foraging moths. While these general color associations are helpful for attracting some pollinators, there are many other floral traits that may be more important.

Flower shape, structure, and size also influence the type of pollinator that can access the floral resources, nectar and pollen. First, pollinators vary in their pollen and nectar gathering strategies and have different physical structures to gather, consume, and store these resources. Some physical structures that alter a pollinator's foraging strategy include tongue length, presence of external storage structures (e.g., hairs), body size, and body weight. Long-tongued bees, butterflies, and moths can easily access tubular flowers, but short-tongued bees, beetles, and wasps can only access shallow, open nectaries (unless they “steal” resources by cutting into the flower base). For large, closed flowers such as *Baptisia* spp. or *Lobelia siphilitica*, resource access is limited to strong, large-bodied bumble bees that can push apart the heavy petals or very tiny bees that can slip in through the gaps. Flat-topped, umbel-shaped flowers including *Pycnanthemum* spp., *Eutrochium* spp., and *Zizia* spp. offer shallow nectaries that attract a greater diversity of pollinators with both short and long tongues. Floret-dense, open, composite flowers of the *Asteraceae* family including *Symphyotrichum* spp. (asters), *Echinacea* spp. (coneflowers), and *Solidago* spp. (goldenrods) also feature shallow nectaries accessible to a variety of pollinators at a high density, offering a large quantity of resources and a suitable landing pad for large-bodied butterflies. Given that flower shape, size, and structure influences resource availability to a certain subset of pollinators, it follows that by providing a diversity of floral morphologies, a diverse garden will attract a more diverse assemblage of pollinators.

> *A diverse garden that features a variety of flower shapes, sizes, and colors will attract a more diverse assemblage of pollinators.*

Putting all of these features of certain flowers known to attract pollinators together, there are many existing lists of recommended pollinator-friendly plant species for gardeners to consider. While this can be exciting for those looking to improve their pollinator habitat, such recommendation lists have limitations. Garbuzov and Ratnieks (2014) reviewed fifteen plant recommendation lists from various sources including pamphlets, websites, books, and botanical garden information stands/leaflets, and found that while these lists are useful communication tools for a general audience - and a good starting point for future research - they often contain poor recommendations, omit what would be good recommendations, lack overlap even when considering the same geographical regions, and are based on author experience rather than empirical evidence. Garbuzov and Ratnieks (2014) note that “a list is only as good as the data that went into it,” and that the lists they reviewed “almost never refer to the empirical sources on which they are based.” (p. 1019).

Arrangement of flowers in time and space

Providing not just a diversity of floral shapes, but also flowers that bloom throughout the growing season is key to supporting a diverse and abundant population of pollinators (Holm, 2014). Phenology, or timing of seasonal biological events, frequently orchestrates a tightly evolved relationship between plants and their pollinators. Different plant species bloom at different times for many reasons, including to take advantage of water availability, to have a competitive advantage over other plants, and to attract specific pollinators. Many pollinators, especially native bees, live short lives and emerge, feed, and reproduce over a period of weeks or months. Mason bees (*Osmia* spp.) for example, are active only from spring to early summer and overwintering queen bumble bees are some of the first pollinators to emerge during spring thaw. These early spring pollinators require pollen and nectar from early-blooming, often spring ephemeral flowers, such as *Geranium maculatum* (wild geranium). In fall, many pollinators are preparing to overwinter or migrate (such as the monarch butterfly) and rely on late-blooming plants including *Solidago* spp. (goldenrods) and *Symphyotrichum* spp. (American asters). By providing a diversity of blooms from spring to fall, greenspaces can support a greater diversity of pollinators throughout their life cycles.

> *Providing dense patches of a diversity of flowers across the entire growing season will support a greater diversity of pollinators throughout their life cycles.*

How flowers are arranged in space also matters for pollinators. Within the often fragmented urban landscape, what defines a functional habitat, or “patch”, for pollinators? Some research suggests that while garden size does not influence invertebrate communities (Smith et al., 2006), floral density (the number of blooms per unit area) frequently has a positive effect on pollinator abundance and diversity (Hülsmann et al., 2015). Keasar (2000) found the effect of clustering flowers, even if these clusters included resource sterile plants, increased native bee visitation rate. Spatially-speaking, a dense planting, even one that includes a mix of sterile and non-sterile flowers, is an important garden-level factor that influences pollinator communities. In a later section of this chapter, we discuss larger spatial considerations about the placement of gardens across the landscape.

3. Additional Habitat – What are other important habitat variables?

Quality pollinator habitat includes more than just floral and foraging resources. Native pollinators, especially wild bees, must have habitat for nesting and overwintering. Many native bees nest in plant material like hollow plant stems and leaf litter that is typically discarded as part of regular garden maintenance. Leaving such materials can pose an aesthetic challenge especially in urban gardens and campuses where the city or school may have yard care guidelines. However, a recent campaign to "Leave the Leaves!" is spreading thanks to the Xerces Society and the National Wildlife Federation. Both organizations have published materials explaining the ecological value to pollinators of leaf litter, plant stems, and other dead and decaying plant debris. Butterfly larva such as that of the great spangled fritillary (*Speyeria cybele*) overwinter in piles of leaves, and other species like the red-banded hairstreak (*Calycopis cecrops*) lay their eggs on fallen oak leaves, which the hatched caterpillars will eat in the spring. Bumble bees (*Bombus sp.*) are a well-known pollinator group that depend on leaf litter for protection over the winter. These are just a few of many examples, demonstrating that planting pollinator-friendly plants is only one part of creating a quality pollinator habitat.

Bees can be organized into three guilds based on their nesting habits: ground-nesting, above-ground nesting, and cleptoparasitic (O'Toole and Raw 2004). The ground-nesting guild is dominated by the families Andrenidae, Melittidae, Halictidae, and Colletidae, while the above-ground nesting guild includes mostly Megachilidae and Apidae species (Michener 2007). Nesting sites for cavity-nesting bees in the form of "bee hotels" are increasingly promoted as a way to aid pollinator conservation. Bee hotels vary in size and are typically constructed from wood, contain different sized cavities and a variety of materials to be used for nesting, like bamboo tubes and bricks with holes. Unfortunately, installing bee hotels can be counterproductive because most of North America's native bee species (and 70% of the ~20,000 bee species worldwide) nest under - not above - the ground (MacIvor & Packer 2015). A large majority of bees either nest underground or parasitize other bees' nests, which limits the value of above-ground created habitats such as bee hotels.

Bee hotels are widely touted as a positive addition to any pollinator garden: but numerous studies have documented increased parasitization of native bees nesting inside such hotels (MacIvor and Packer, 2015). Additionally, non-native and non-pollinating bee and wasp species have been demonstrated to use bee hotels more often than native, pollinating bee species, thus outcompeting native bees for nearby resources (MacIvor and Packer 2015). Geslin et al. (2020) found that 40% of all individuals recorded using the 96 bee hotels they installed were *Megachile sculpturalis*, a leafcutting bee native to Japan and China. They also found a negative correlation between the presence of *M. sculpturalis* and native bees in the hotels. MacIvor and Packer (2015) coined the term "bee-washing" (a form of green-washing) to warn promoters and users of bee hotels against spreading potentially misleading information. They note that, much like pamphlets of pollinator-friendly plants, bee hotels are useful tools for engaging the public in citizen science and pollinator conservation outreach, but that their potential pitfalls must be thoroughly flushed out with additional research before they are recommended as “pollinator friendly.”

Although bee hotels may not necessarily be the best choice for bee nesting sites, bees still do need habitat in which to nest and overwinter. Neame and Griswold (2013) cite nesting requirements as a key element to consider in research regarding urbanization impacts on pollinator biodiversity; nesting requirements are as important to consider as floral resources. Bumblebees (*Bombus sp.*) often overwinter beneath the base of clumped grasses, while many ground-nesting bees will utilize bare patches of soil for nesting. Bare patches in particular pose an aesthetic challenge in an urban setting: those who do not know the purpose of the bare soil may find it less aesthetically pleasing than a patch of foliage or flowers. Such challenges could be overcome by signage that explains the purpose of the bare patches and their value to native pollinators. Alternatively, soil squares - smaller patches of bare soil that form a 0.5 m deep hole into the ground - could be constructed to provide nesting sites for cavity-nesting bees (Fortel et al., 2016). Finally, an interesting study by Cane (2015) shows that native species of *Halictus* prefer to nest beneath decorative landscaping pebbles instead of bare soil patches. Much like providing an array of floral resources will tend to attract the most diverse pollinator assemblage, providing a variety of nesting materials and sites that can be maintained (rid of harmful parasites if necessary) is most beneficial to urban pollinators.

Providing dense patches of a diversity of flowers across the entire growing season will support a greater diversity of pollinators throughout their life cycles.

Leaf litter, plant stems, and other dead and decaying plant debris, as well as bare soil, provide valuable nesting and overwintering habitat for pollinators.

4. Landscape-level Planning and Connectivity – How can the surrounding landscape inform where to prioritize new habitat creation? Does habitat size matter?

Pollinator abundance and richness differ across urban habitat types, with areas that contain more floral resources and a higher diversity of flowering plants (e.g., community gardens, residential gardens) having significantly more abundant and diverse pollinator communities (Baldock et al., 2019). The patchwork of other urban habitat types (e.g., open parks, lawns, paved areas, buildings) surrounding these floral hotspots represent a resource poor “matrix” that is unusable to pollinators. While local, garden-scale characteristics are often stronger predictors of pollinator abundance and richness (Majewska & Altizer, 2020; Pardee & Philpott, 2014), the surrounding landscape matrix may influence the accessibility or quality of any individual garden. For isolated garden patches, finding opportunities to create “corridors” of even marginal pollinator habitat to connect patches of higher quality habitat can facilitate movement across a landscape, encouraging opportunities for short- or long-distance migration, shifting life cycle habitat requirements, and genetic exchange. In contrast, some urban cover types or features such as buildings or busy roads may present barriers to pollinator movement across an urban landscape. Additionally, proximity to more natural habitat types such as forests, wetlands, or grasslands can provide additional resources for pollinators and thus increase pollinator use of nearby garden patches in an urban context. Pollinator habitat planning at a landscape scale, such as at the institutional scale of a university campus, must consider the spatial distribution of existing pollinator habitat and the land cover in between.

Matrix quality

Overall, landscape-level variables are frequently not as strong as garden level characteristics at predicting pollinator population metrics; however, the effect of the surrounding landscape matrix type may differ by pollinator guild. In urban habitats of Chicago, Tonietto et al. (2011) found that bee species richness was positively correlated with the proportion of natural area within a 500-meter radius. Pardee and Philpott (2014) found cavity-nesting bee abundance was higher in urban gardens with more natural areas within 1 km and hypothesized that a mix of natural and man-made resources may assist with nest building. Ground-nesting bees were more abundant where wetlands were within 1 km which suggests an association with wet habitats. Increased forest cover within 500 m and 2 km was associated with increased abundance of both cavity- and ground-nesting bees, respectively (Pardee & Philpott, 2014). The authors speculate that the smaller-bodied cavity-nesting species they captured had smaller foraging distances and thus were more associated with nearby forest resources, whereas larger-bodied ground-nesting bees could travel farther and utilize more distant resources. These studies suggest that the effect of the landscape matrix is species-specific and influences life cycle needs and foraging distance.

In addition to the quantity of different land cover types within the matrix, the quality and permeability of the matrix may influence pollinator populations. As opposed to the rigid definitions of usable patches and linear corridors within an unusable matrix, matrix permeability describes a more fluid gradient of use that "spills over" into and within the matrix. A meta-analysis of wildlife habitat creation in agricultural areas suggests that increasing the permeability of a matrix by improving the quality of the matrix, may be a more effective method to increase fragment connectivity and reduce the negative effects of patch isolation (Donald & Evans, 2006). With this in mind, perhaps urban pollinator habitat improvement efforts should consider not just creating more habitat patches or corridors, but also improving the quality of the surrounding matrix.

Increasing the quality of the matrix surrounding habitat patches may be an effective strategy to increase habitat connectivity.

Patch arrangement and connectivity

How gardens are spatially arranged at a local scale can also influence pollinator diversity and activity. Pollinator foraging distances are species-specific and are influenced by body size, foraging specificity, and eusocial lifestyle (Holm, 2014). Larger, colony-nesting bees such as bumble bees are considered more generalist pollinators and have larger foraging ranges than smaller, solitary bees. Bumble bees (10-23 mm body length) can forage up to one mile from the nest, while smaller mason bees (6-11 mm body length) forage within 300 feet from the nest (Holm, 2014). Especially for smaller pollinators with a limited foraging range, the proximity of abundant floral resources is critically important for survival and successful reproduction. Even across a small area, such as a campus promenade, having frequent patches of dense foraging resources will ensure that pollinators with small foraging ranges will have accessible resources.

To support small pollinators with limited foraging ranges, a landscape should feature frequent patches of dense foraging resources.

Patch isolation is one measure that could negatively impact pollinator use of any one patch and the metapopulation of campus pollinators as a whole. Several studies have found that as a habitat patch becomes more isolated from a natural habitat, pollinator populations begin to decrease (Garibaldi et al., 2011; Kennedy et al., 2013). However in urban grassland areas of Berlin, Fischer et al. (2016) found that only one pollinator species (*Bombus terrestris*) was affected by degree of habitat isolation (negatively), but the authors note that the goodness-of-fit for this model was low and the results should be used cautiously. One possible solution is the use of small "steppingstones" of pollinator habitat to connect isolated patches across a landscape (Van Rossum & Triest, 2012). While flight distances vary by body size and local site conditions, these estimates may provide a starting point to determining how far away a functional steppingstone habitat should be (Figure 2.1). Creating steppingstones between habitat patches could essentially increase the quality of the matrix and facilitate pollinator movement across the landscape.

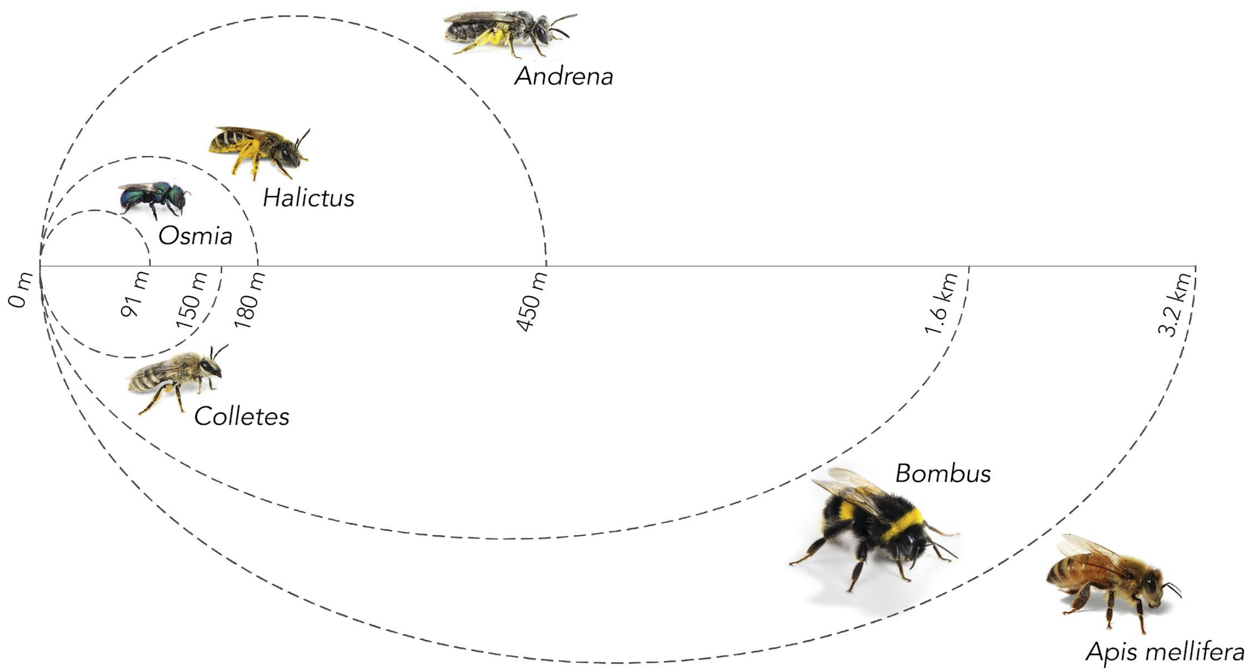

Figure 2.1 Estimated flight distances of bees (Holm, 2014) can provide insights into steppingstone spacing.

Although much of the research on pollinator corridor habitat has focused on agriculture, corridors of linear habitat may serve to connect habitat patches and facilitate pollinator movement across the urban landscape as well. In croplands, linear habitat in ditches can increase pollen dispersal between isolated habitat patches (Van Geert et al., 2010). A similar study of linear hedgerows in cropland in Southern England suggests that both hedgerow quality (absence of gaps; high species diversity; and abundant, flowering understory layer) and landscape context (hedgerows were more valuable in intensively managed landscapes) influenced the value of hedgerows to pollinators and other insects (Garratt et al., 2017). Comparisons can be made between an inhospitable matrix of monoculture crops and a matrix of resource-poor urban environments such as traditional lawns or parking lots. Linear corridors of unbroken, floral-rich habitat may facilitate movement through intensively managed landscapes devoid of pollinator resources, however, the strategy of increasing matrix permeability (see Matrix above) should also be considered.

In conclusion, much research suggests that landscape scale variables are less important than garden-scale variables in determining pollinator populations; however, pollinator foraging distances and proximity to natural habitats may be helpful factors to consider when prioritizing locations for new pollinator habitat. Where feasible, improving matrix quality and creating linear habitat corridors are two potential strategies that may improve overall urban landscape connectivity for pollinators, and these are areas needing more research. Interestingly, there is some evidence that the heterogeneous, dynamic, and cosmopolitan nature of urban landscapes has actually increased the number of species that can thrive there and perhaps is evolutionarily selecting for species that are more tolerant of these conditions (Sattler et al., 2010). The field of urban pollinator landscape ecology is still developing, but there is no question that there is high potential for urban landscapes to support functional pollinator habitat.

Pollinator foraging distances and proximity to natural habitats may be helpful factors to consider when prioritizing locations for new pollinator habitat.

Conclusions & Recommendations

Based on our literature review, we can confirm that creating and enhancing urban pollinator habitat is a promising area of biodiversity conservation with many opportunities for further research, landscape planning, and citizen science and community engagement. It is clear that urban green spaces present ample opportunity for meaningful – and quantifiable – biodiversity conservation work. There are certain gaps in the existing body of literature where we see room for exciting research, such as surveys of which non-bee native pollinators favor habitats in urban settings compared to natural or agricultural settings. We would also see the need for more work that is based specifically in a campus setting, as research and data in this area is limited compared to general urban settings such as cities and urban/suburban backyard gardens. We are hopeful that engagement with our pollinator habitat assessment tool using Survey123 (see Chapter 3) could potentially contribute to such campus-level data and future projects. Finally, with the installation of a pollinator garden on our campus (see Chapter 5) we know that enhancing existing habitat on campus – in an urban setting – is feasible.

Key findings from the literature that can be applied to create high quality pollinator habitat in a campus setting:

- ★ For urban habitats, it is not necessarily the degree of "urban-ness", but instead the specific characteristics of each urban greenspace that ultimately influence pollinator abundance and diversity.
- ★ Urban areas with higher floral diversity and floral abundance tend to have higher pollinator abundance and/or diversity.
- ★ Incorporating native plants into the urban landscape is critically important for supporting abundant, diverse pollinator populations.
- ★ By providing a diversity of floral morphologies, a garden will attract a more diverse assemblage of pollinators.
- ★ Providing a diversity of flowers across the entire growing season will support a greater diversity of pollinators throughout their life cycles.
- ★ Local, garden-scale characteristics are more important than landscape-scale characteristics for supporting pollinator diversity and abundance.
- ★ Pollinator foraging distances and proximity to natural habitats can inform prioritization of locations for new pollinator habitat.

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CHAPTER 3 – **CREATION OF POLLINATOR HABITAT ASSESSMENT TOOL FOR A CAMPUS SETTING**

Introduction

Urban and suburban areas, such as university and college campuses, have huge potential to support a diversity of pollinators if they are designed to include features that provide high-quality, well-connected pollinator habitat (reviewed in Chapter 2). To meet the goal of being a pollinator-friendly campus and support the important diversity and ecosystem service value of pollinators thus requires several steps (Figure 3.1):

1. Data collection: Assess existing habitats relative to what is known to be favorable pollinator habitat,
2. Data analysis: Identify high quality areas and gaps,
3. Action: Enhance existing habitats and install new habitats using best practices, and
4. Adaptive management: Develop an ongoing pollinator habitat assessment, enhancement, and maintenance plan.

Thus, the essential first step for informed and effective action is to assess the quantity and quality of pollinator habitat in existing green spaces on campus.

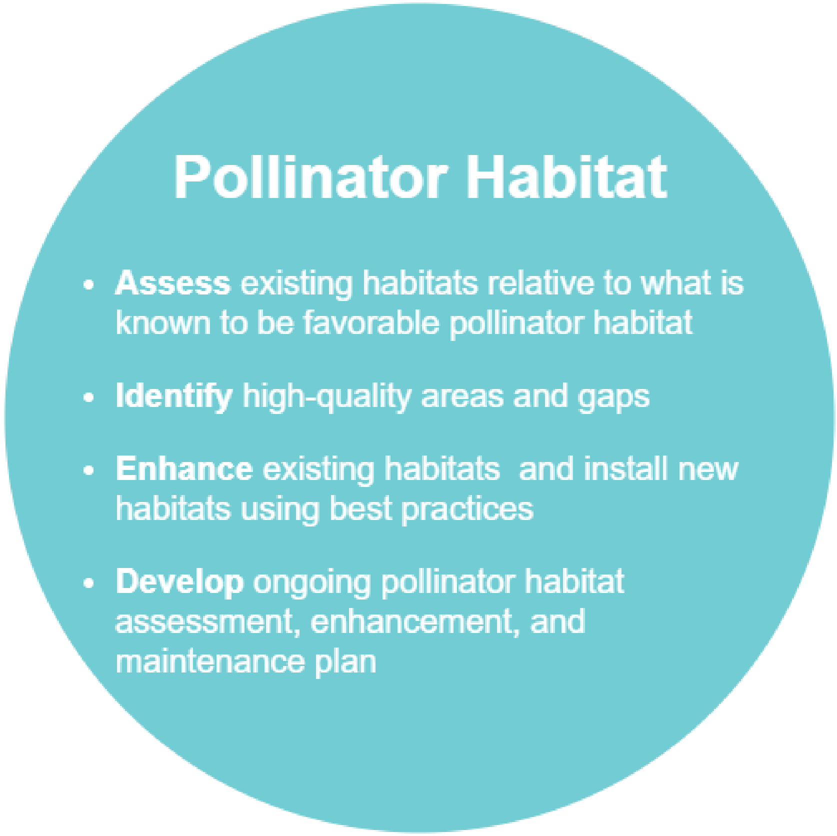


Figure 3.1 Steps toward the goal of enhancing pollinator habitat on campus

There is currently a lack of a systematic pollinator habitat assessment tool specifically designed for university campuses; this not only limits more informed actions to improve these landscapes, but also the potential to engage with stakeholders – from Grounds Services to faculty to citizen scientists – who could actively be involved in this assessment. In this chapter we will first review existing assessment tools and give the rationale for developing a new tool which better meets both assessment and engagement needs of a campus (see Figure 3.2). Then we will describe the iterative developing process and the key features of our proposed campus pollinator habitat assessment tool. At the end, we will discuss general conclusions and recommendations on how to apply this tool to a broader geographical and social scale with more audiences. Our main goal of this chapter is to help the next network "champions" learn how to use and edit the assessment tool. More broadly the approach described here can be used by other efforts that are interested in assessing pollinator habitats or creating survey tools using Survey 123.

Research and rationale for the form and content of our campus-based pollinator habitat assessment tool

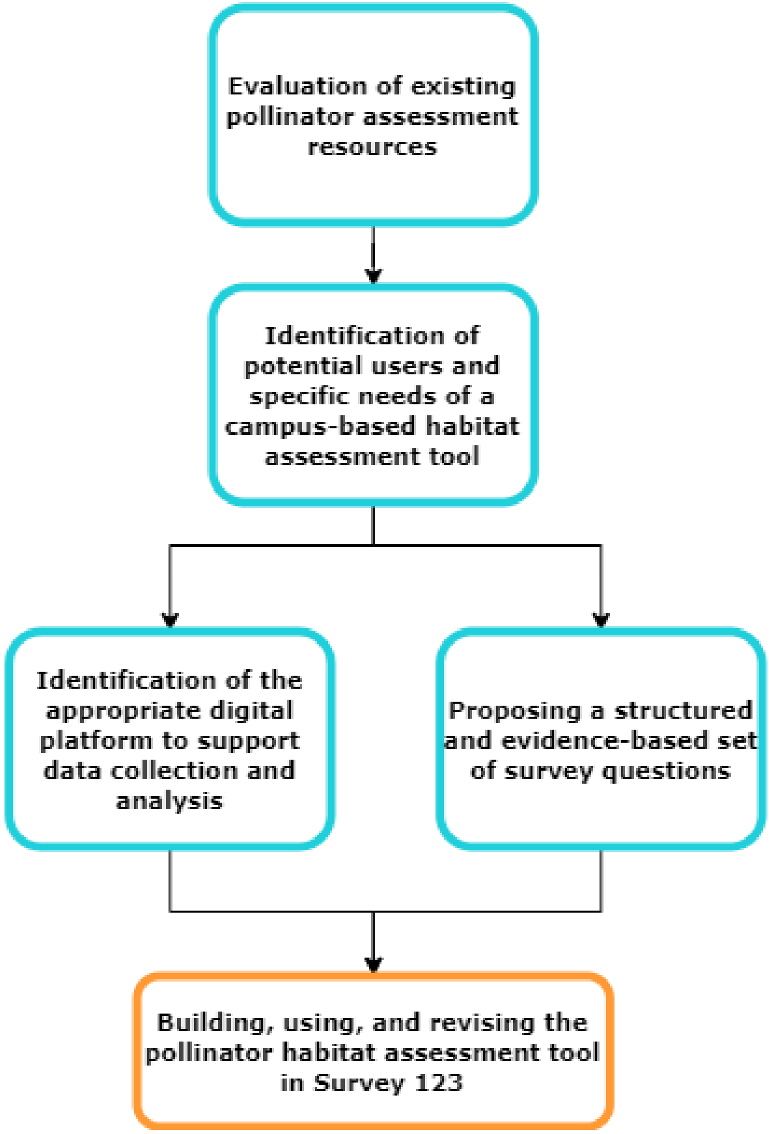


Figure 3.2 Overall process used to create a campus pollinator habitat assessment tool

Evaluation of existing pollinator assessment resources:

Our search for pollinator habitat assessment tools began with the Xerces Society, which is a science-based organization that produces a range of reliable pollinator-related resources. Since one of the project deliverables is to achieve Bee Campus USA certification through Xerces Society, we thoroughly reviewed the resources published on the Xerces Society website. However, their website provides resource mostly for backyard habitat, but does not include any systematic pollinator habitat assessment tools specifically designed for campuses or other more urban settings. A broader assessment of existing surveys was therefore needed to inform our habitat assessment.

In the previous chapter, we reviewed the scientific literature to identify key questions to inform pollinator habitat management. Here we used these key questions (Figure 3.3) to guide our search for supportive pollinator assessment resources. We compared five existing, widely used pollinator assessments for their ability to answer the key questions. Other factors like designated areas, generalizability, and multifunctionality (i.e., education) were taken into consideration as well (Full comparison table see Appendix 1). We found the *Habitat Assessment Guide for Pollinators in Yards, Gardens, And Parks*, (partially shown in Figure 3.4, complete in Appendix 2) to be most relevant for our scenario and it answers our key questions well. It assesses the presence and abundance of important floral resources (superfood plants, host plants, etc.), supports (nesting, over-wintering resources, etc.) and threats (herbicides and pesticides use, etc.) from site and surrounding contexts and provides an easy-calculated scoring system and related recommended action list. Other assessments only partially answer our questions or are designed for other types of land (agricultural, natural areas, etc.) Therefore, we decided to use this assessment guide as the foundation for creating our own campus pollinator habitat assessment.

Key questions informing pollinator habitat management

Who are the primary **pollinators** that should be the focus of improved habitat quality efforts on campuses?

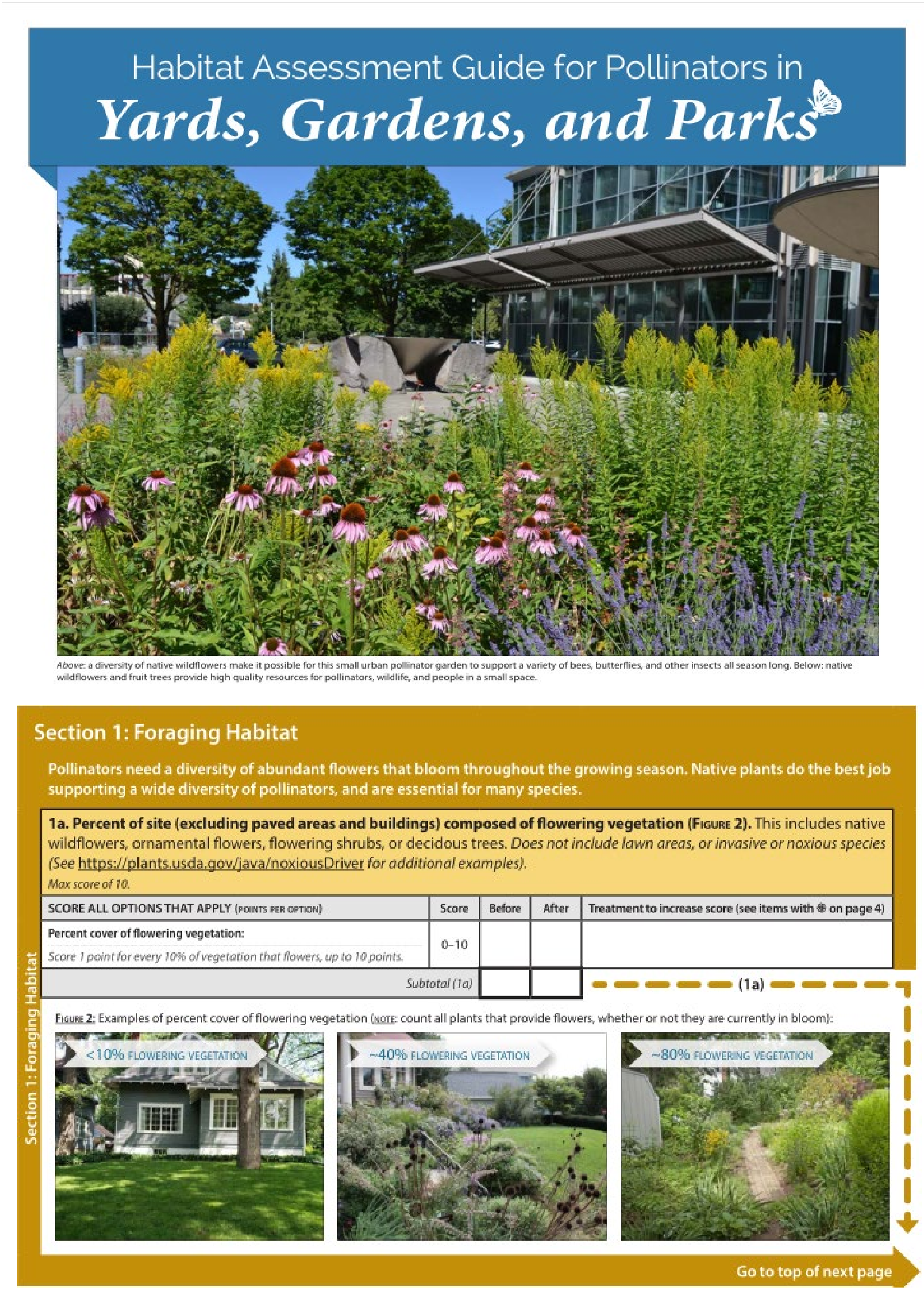
Which **plants** and what **arrangements of plants** are most attractive and supportive to pollinators?

What do pollinators need **beyond floral resources**? What are other **important habitat variables**?

How can the **surrounding landscape** inform where to prioritize new habitat creation? Does habitat size matter?

How can other **threats** to pollinators be minimized through management choices?

Figure 3.3 Key questions informing pollinator habitat management



Habitat Assessment Guide for Pollinators in
Yards, Gardens, and Parks

Above: a diversity of native wildflowers make it possible for this small urban pollinator garden to support a variety of bees, butterflies, and other insects all season long. Below: native wildflowers and fruit trees provide high quality resources for pollinators, wildlife, and people in a small space.

Section 1: Foraging Habitat

Pollinators need a diversity of abundant flowers that bloom throughout the growing season. Native plants do the best job supporting a wide diversity of pollinators, and are essential for many species.

1a. Percent of site (excluding paved areas and buildings) composed of flowering vegetation (Figure 2). This includes native wildflowers, ornamental flowers, flowering shrubs, or decidous trees. *Does not include lawn areas, or invasive or noxious species (See* https://plants.usda.gov/java/noxiousDriver *for additional examples).*
Max score of 10.

SCORE ALL OPTIONS THAT APPLY (points per option)	Score	Before	After	Treatment to increase score (see items with ❁ on page 4)
Percent cover of flowering vegetation: *Score 1 point for every 10% of vegetation that flowers, up to 10 points.*	0–10			
Subtotal (1a)				(1a)

Figure 2: Examples of percent cover of flowering vegetation (note: count all plants that provide flowers, whether or not they are currently in bloom):

Figure 3.4 Portions of the Habitat Assessment Guide for Pollinators in Yards, Gardens, And Parks *published by The Xerces Society*
https://www.xerces.org/publications/habitat-assessment-guides/habitat-assessment-guide-for-pollinators-in-yards-gardens

Even though the existing pollinator habitat assessments capture important features of high-quality pollinator habitat, their paper form limits their usefulness compared to a digital assessment tool, which can add value, usability, and accessibility and better meet stakeholder needs. The Xerces survey works well for residents to assess an individual garden, but transforming the survey onto a spatially explicit, digital data collection platform would allow for easy assessment across a landscape and digital data comparison over time. It also encourages the greater campus community to participate in data collection by using a handy, accessible app. Data collected on where pollinator habitat is located on campus can even then be easily shared using StoryMaps or other web applications, which can then help curious nature lovers find nearby pollinator hotspots.

Identification of potential users and specific needs of a campus-based habitat assessment tool:

To identify who the specific users are and understand their specific needs, we must first clarify the possible user groups of this campus-based habitat assessment tool: 1. Data collectors - experts (or non-experts who want to learn) that can quantify existing campus conditions, 2. Data end-users - people who can view the data collected and analyze it, and 3. Actors - people who can act on the data by creating new habitats (Figure 3.5). All of these user groups are essential partners for measuring, improving, and monitoring pollinator habitat on campus.

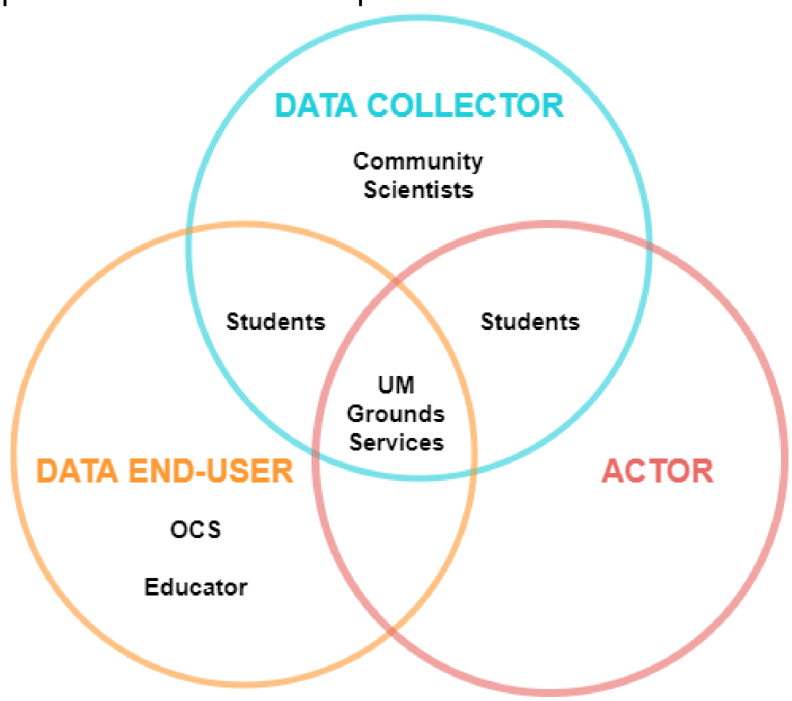


Figure 3.5 Potential users of a UM campus pollinator habitat assessment tool.

Our clients will be the primary users of our proposed campus-based habitat assessment tool. UM Grounds Services is seeking a tool to help them identify and manage existing and potential pollinator habitats on campus, which makes themselves data collectors, end-users and actors at the same time. Therefore, a handy tool that could be easily used/managed and provide recommendations on adaptive management on pollinator habitats will be ideal. The Office of Campus Sustainability (OCS), as our other client, is expecting to create a series of activities and programs about pollinator conservation to further create opportunities for community outreach and education around campus sustainability. This intention makes the OCS more likely to be an end-user who uses analyzed data to engage with more people. Thus, the data collected by our proposed tool should be easily updated and accessed for end-users like OCS.

Apart from our primary users (clients), more users are expected as the outreach and educational components of our project are carried out. For instance, the idea of creating a "hands-on living pollinator laboratory" and related curriculum is expected to engage faculty members and students in campus pollinator conservation. What's more, the approaches created and information collected in our project will be shared through cities and campuses to raise awareness of pollinator protection in a wider social and geographical range. Therefore, community scientists are expected to be the potential users as well. In particular, students and community scientists are more likely to be the data collectors with different background knowledge, thus providing necessary supportive/explanatory information in our proposed assessment tool is important.

In general, the clients and users would like to see a very handy tool meeting some specific needs listed in Figure 3.6.

Specific needs identified - HANDY

The tool needs to be **comprehensive** yet **concise** and focused on **the most important aspects of pollinator habitat**.

In addition, to be an accessible education tool the assessment should **be easy to use by surveyors of all experience levels.**

Last but not least, to ensure long-term use, both the **tool and the data collected** should be easy to **update and access.**

Figure 3.6 Clients' requirements for the campus-based pollinator habitat assessment tool

Identification of the appropriate digital platform to support data collection and analysis:

We compared several data collection, analysis, and visualization tools to find the most appropriate platform for our assessment. After comparing the benefits, drawbacks, accessibility and usage of several common platforms for data collection (Table 3.1), Survey 123 stood out for several reasons (Figure 3.7).

Reasons for Choosing Survey 123

It is an **open-source** software which does not require a subscription or registration.

It enables multiple types of **explanatory information** (text, images, audio, etc.) to be embedded in the assessment.

It can collect **multiple types of data,** including text, time, location, and photos.

The **"offline editing"** function enables field data collection that can be uploaded later when a wifi connection is available.

Automatic functions ("calculation", "relative", etc.) make future data analysis easier.

As an Esri product, both the assessment and the data collected are easily **shared across other Esri tools** (e.g. ArcGIS Online, Collector, StoryMap, etc.).

Figure 3.7 Reasons for choosing Survey 123 as the assessment tool

Table 3.1 Comparison of potential platforms that could be used to collect, analyze, and visualize pollinator assessment data.

Platform	Type	Benefits	Drawbacks	Potential User	Use
iNaturalist	Data collection	Public engagement.	Less scientific rigor, in general.	Public, students, anyone	Gathering pollinator or plant observations casually or following a protocol.
Arc Collector	Data collection	Map-centric data collection. Ability to create digital data forms that collect spatial data. Feeds directly into an online ArcGIS map. Potential for easy connection to visualization platforms like Story Map	Collector does not support using ArcGIS Online public accounts.	University members only.	Gathering habitat or pollinator survey data following a protocol.
Zooniverse	Data collection	Public engagement & Data processing	No control over how fast data is processed	Public, students, anyone	Process pollinator visitation data from still photographs or video.
Survey123	Data collection	Form-centric data collection. Ability to create digital data forms that collect spatial data. Feeds directly into an online ArcGIS map. Potential for easy connection to visualization platforms like Story Map	ArcGIS Credits (of the survey creator) would be cost for data storage, subscriptions.	Public, students, anyone. Can create annonymous account.	Gathering habitat or pollinator survey data following a protocol.
ODK Collector	Data collection	Ability to create digital data forms that collect spatial data. Open-platform software that is publicly accessible.	New platform that the team would need to learn. Additional data transfer from ODK to ArcGIS.	Public, students, anyone	Gathering habitat or pollinator survey data following a protocol.
ArcGIS	Data analysis	Most developed; Source code can be changed only by the company or person who developed it.; More advanced mapping functionalities; Different data frames can be added and linked; Better spatial topological analytical capabilities; Results are more reliable; Has some unique tools; Larger database and associated tools and supports (ArcGIS Online)	Requires license	Big firms; Educational institutions, **Windows users**	Store, analyze and visualize pollinator related data
QGIS	Data analysis	Open source software; Source code can be read, modified and improved by developer or volunteer; Consumes all types of data; Less processing time; Better rendering capabilities; Simple tool to generate the shortest and fastest route; Has various of plugins	Has less tools and cartographic capbilties, less professional supports, less secure	All users	Analyze and visualize pollinator related data
GrassGIS	Data analysis	Open source software; Focuses on data analysis and processing; Do not have to deal with the projection conversions and or inconsistencies; Better systems to organize data; The GrassGIS toolbox could be used in QGIS	Has cartographic capabilties, less professional supports, less secure	All users	Analyze and visualize pollinator related data
Kepler	Data visualization	Open source software; Allows technical and non-technical audiences to visualize trends in a city or region	Does not have its own analysis tools	All users	Visualize pollinator related data to analyze trends and make intriguing graphics
Adobe Creative Suite	Data visualization	Most developed software for graphic design	Requires subscriptions; Cannot process data	Big firms; Educational institutions	Make intriguing graphics

Developing a structured and evidence-based set of survey questions:

Based on the key questions identified in the literature and common themes across existing pollinator habitat assessments, we developed targeted questions to assess pollinator habitat in a comprehensive and efficient manner. We broke the assessment into several categories of questions: Survey Data, General Site Condition, Foraging Resources, Life Stage support, Multifunctionality and Pollinator Population. Questions under “Survey Data'' collect general information (e.g., Surveyors’ name, time, temperature, season) of the survey process. Questions under “General Site Conditions” collect general information of each planting bed and its context (especially surrounding pollinator resources). The “Foraging Resources” section asks about the existence and abundance of some essential floral resources (superfood plants, host plants, etc.) for pollinators. “Life Stage Support” questions help potential users to identify the quality of other essential support for pollinators at different life stages, such as nesting and overwintering support. Habitats on campus can also be multifunctional, or have value beyond pollinators (e.g., stormwater management, erosion control, etc.). Therefore, we included questions about “multifunctionality” to investigate the potential for green spaces on campus to serve other landscaping goals. Finally, there are questions in the “Pollinator Population” section to assess which pollinators are actually present and active on site at the time of observation (e.g., which types are seen, the rate at which they visit flowers, etc.) All survey questions are listed in Table 3.2.

Table 3.2 Questions in the Habitat Assessment

Category	Question	Descriptive text before question	Level options	Variable measured
Survey Data	Surveyor Name(s)			
	Are you completing this survey as part of a class?		Yes, No	
	Class Name/Number/Instructor Name		Partner classes with "Other"	
	Are you completing this survey on campus or remotely?		On Campus, Remote	
	Survey Date		-	Seasonality of blooms
	Season		Winter (December, January, February), Spring (March, April, May), Summer (June, July, August), Fall (September, October, November)	Seasonality of blooms
	Survey Start Time		-	Effort
	Survey End Time		-	Effort
	Temperature	Please survey when pollinators are most active: warm/hot, sunny days with little wind are ideal.	Number text entry	Indicator of poll. activity
	Weather conditions		Sun, Part sun, Cloudy	Indicator of poll. activity
General Site Conditions	Take a picture of the site, fitting all or most of the site in the frame.		-	
	What type of planting bed is this?		Perennial/annual bed, Prairie, Woodland, Clover lawn, Food garden, Green infrastructure, Other	Site scale category
	In the greater area surrounding the bed, are there any other pollinator resources?		Flowering trees, Flowering shrubs, Unmown lawn, Woodland, Other	
Foraging Resources	Considering the entire bed area, what is the percent area of flowers blooming now?	What is blooming now?	Low (0-25%), Med (25-50%), or High (50-100%)	Floral density
	What flower colors are present?		Violet, Blue, Green-White, Yellow, Orange, Red, Pink	Proxy for flower types that attract diff. polls
	What flower shapes are present?		Composite, Umbels, Tubular, Nodding, Complex	Proxy for flower types that attract diff. polls
	Superfood plant:	Pollinator "superfoods" provide exceptional forage for a diverse variety of pollinators. Are any of the following pollinator "superfoods" present and flowering? You can select more than one.	Spring (Aquilegia spp., Crocus spp., Geranium maculatum, Amsonia spp., Baptisia spp.), Summer [Giant hyssop (Agastache spp.), Sage (Salvia spp.), Russian Sage (Perovskia spp.), Calamint or Catmint (Calamintha or Nepeta spp.), Joe Pye (Eutrochium spp.), Blazingstar (Liatris spp.)], Fall (Helenium spp., Helianthus spp., Solidago spp., Aster spp.)	Native & non-native plant species
	Considering the entire bed area, what is the percent area covered by this plant?		Rare (0-25%), Common (25-50%), or Abundant (50-100%)	
	Specialist plant:	Are any of these foods for specialist bees present? You can select more than one.	Spring (Packera spp, Penstemon spp., Viola spp., Zizia spp.), Summer [Harebell (Campanula spp.), Coneflower (Echinacea spp.), Boneset (Eupatorium spp.), Sunflower (Helianthus spp.), Beebalm (Monarda spp.), Black-eyed Susan (Rudbeckia spp.), Vervains (Verbena spp.), Ironweed (Vernonia spp.)], Fall (Eurybium spp.)	Native plant species
	Considering the entire bed area, what is the percent area covered by this plant?		Rare (0-25%), Common (25-50%), or Abundant (50-100%)	

	6-letter species code:	(Expert) If known, list any additional species that are blooming using the six letter code (code is first 3 letters of genus & species, e.g. Monarda fistulosa is MONFIS)	-	
	Considering the entire bed area, what is the percent area covered by this plant?		Rare (0-25%), Common (25-50%), or Abundant (50-100%)	
Life Stage Support	Host plant:	Different species of butterfly and moth (Lepidoptera) caterpillars are often specialized to eat certain species of native plants. Trees and shrubs typically support more Lepidoptera species than herbaceous plants. Are any of these host plants for butterflies and moths (Lepidoptera) present? You can select more than one.	Goldenrod (Solidago spp.), Aster (Symphiotrichum spp.), Sunflower (Helianthus spp.), Joe Pye (Eupatorium spp), Sedges (Carex spp.), Lupine (Lupinus spp.), Violet (Viola spp.), Milkweed (Asclepias spp.)	Native plant species
	Considering the entire bed area, what is the percent area covered by this plant?		Rare (0-25%), Common (25-50%), or Abundant (50-100%)	
	6-letter species code:	(Expert) If known, list any additional host plants not already listed using the six letter code	-	
	Considering the entire bed area, what is the percent area covered by this plant?		Rare (0-25%), Common (25-50%), or Abundant (50-100%)	
	Are there areas on site with patchy vegetation or bare soil (no mulch)	70% of native bees build solitary nests in the soil. Well-draining soil in a sunny or south-facing area is best.	Absent (none), Sparse (1-2 small patches), Abundant (>2 small or 1 large patch)	Nesting habitat availability
	Are there clump-forming bunch grasses?	Bumble bees often build nests at the base of tall grasses.	Absent (none), Sparse (<25% of bed), Abundant (>25% of bed)	Nesting/overwintering habitat availability
	How much leaf litter is on the site?	Many pollinators overwinter in leaf litter.	Absent (none), Sparse (few piles at base of plants), Abundant (a large patch or layer of leaves)	Nesting/overwintering habitat availability
	How many dead wildflower stems are standing, including cut stems >15" tall	30% of native bee species nest in hollow stems or dead wood.	Absent (none), Sparse (<25% of bed), Abundant (>25% of bed)	Nesting/overwintering habitat availability
	Is there a bee hotel present?	Bee hotels can provide nesting sites for many native bees. However, they must be cleaned and cared for to prevent disease and parasites.	1 large or more than 1 small, 1 medium or small, None	Nesting/overwintering habitat availability
	Other habitat components present:		Shallow water source (bird bath, puddle), sunning rock, structural diversity (2 or more layers: herbaceous/shrub/tree), logs or brush pile	
Multifuncti-onality	(Expert) If known, what percent of this bed is native (or native cultivar) versus non-native vegetation?	On average, native plants provide food and shelter for a greater diversity of life, including insects, mammals, and birds. Many native plants provide other benefits as well, such as erosion control via deep root systems.	-	Native plant roots often assist in erosion control, more natives = greater biodiversity value
	Select other benefits this bed provides:		Stormwater management, biodiversity, aesthetic beauty, scent, agriculture, shade, erosion control	Multifunctionality
Pollinator Populations	Number of minutes (5-20)	Identify a random 1x1-ft square that includes currently flowering plant(s) in the bed. Observe pollinator activity in the patch for 5-20 minutes, counting the number of times a pollinator lands on a flower.	-	Visitation rate
	Number of inflorescences (flower heads)			Visitation rate
	Total number of times a pollinator landed on a flower (inflorescence) during the observation period.		-	Visitation rate
	Pollinator type	Which of the following pollinators have you observed at any time during your entire visit & roughly how many have you seen: (see "Pollinators" Sheet)	Pollinator groups (see “Pollinators” sheet)	Presence/Absence
	How many did you observe?		Number	Abundance

Building, using, and revising the pollinator habitat assessment tool in Survey 123

Using Survey 123 Connect:

After we decided upon a platform and questions, we created the assessment tool through Survey 123. In addition to the Survey 123 web application, there is a supportive desktop application called Survey 123 connect, which supports advanced functionalities (adding supportive image/audio; auto-calculate etc.) and gives the creators more customizability than the web version.

Survey 123 Connect enables users to create a new survey from scratch or by using existing templates. (Figure 3.8). “Templates” and “Samples” are survey models provided by Esri. The “Community” and “My organization” options enable users to develop surveys from existing ones that are shared through community and organization. Users could also modify the surveys that have been created before and publish an updated version by choosing “My surveys”. The “Feature service” option enables users to create surveys based on existing feature services (feature layers) from an ArcGIS Online account. Additionally, users can create a survey from the “File” option and choose an excel spreadsheet on their devices.

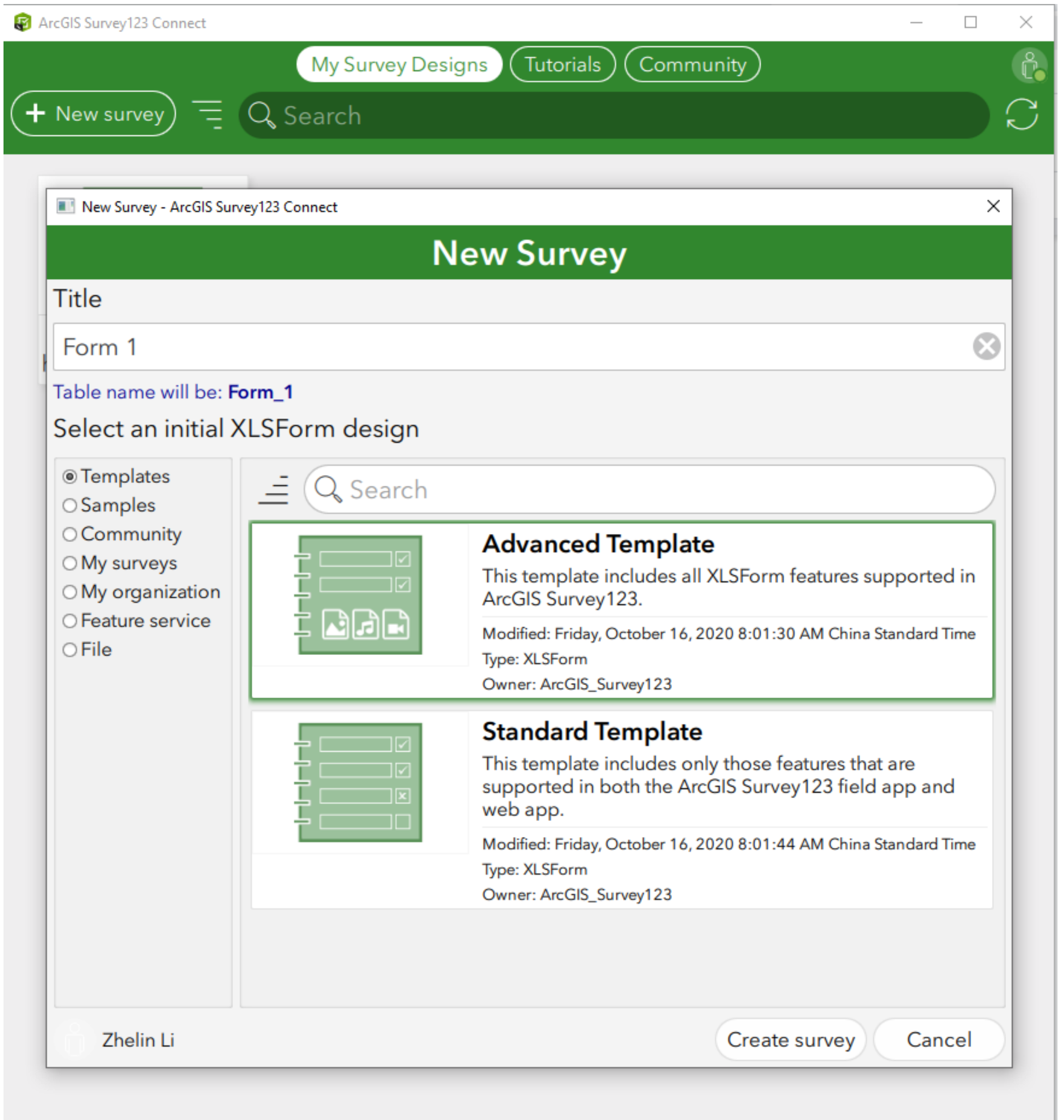


Figure 3.8 "New Survey" window in Survey 123 Connect

Since there are no available surveys that could be referenced and some advanced features (adding supportive image/audio) are desired to be embedded in the survey, we decided to use an "Advanced Template" (Figure 3.10) that has all features supported in ArcGIS Survey123.

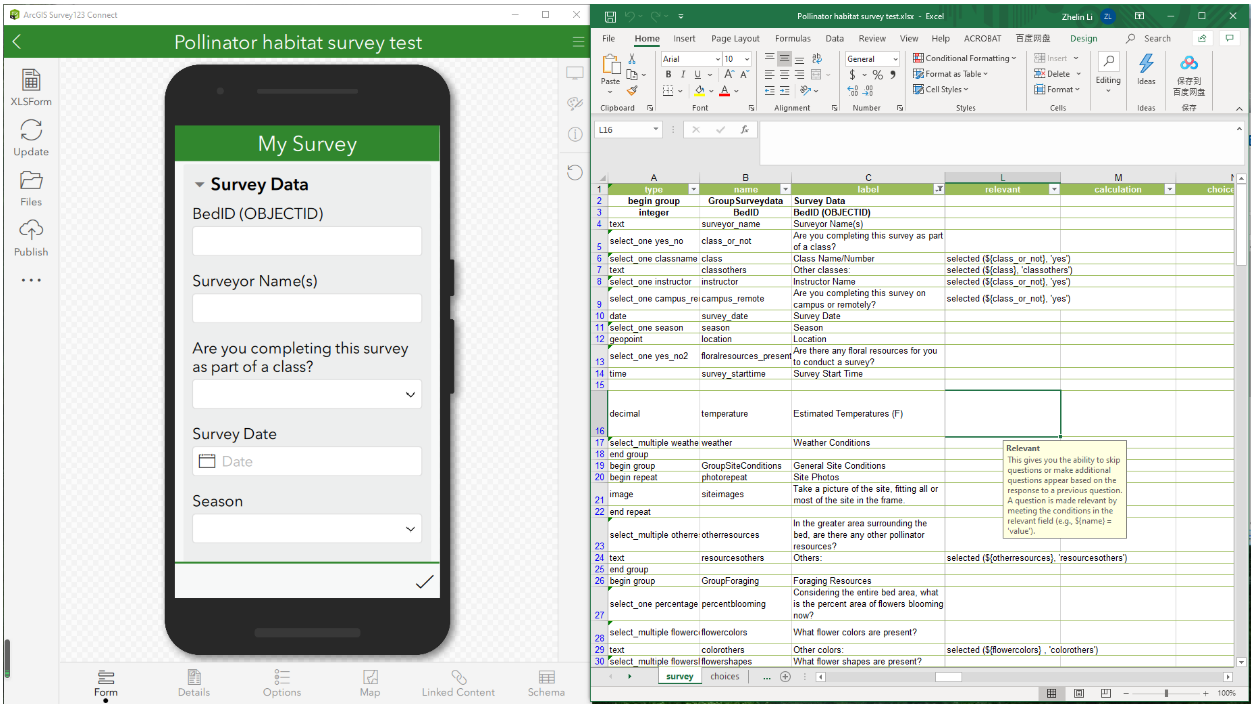


Figure 3.9 The main interface and the “Advanced Template” of Survey 123 Connect

The “Advanced Template” is a pre-set excel sheet (XLS Form) with all functionalities and associated instructions will show up if a cell under a specific column was selected (Figure 3.9) Users will generate their surveys by filling out the spreadsheet with survey questions. The instructions of each column (function) is clear and easy to understand. More resources and tutorials could be found on Esri website (Figure 3.10).

The main interface is where the survey is managed. The preview session will automatically update every time the spreadsheet is saved. The geospatial information embedded/collected in the survey could be viewed through the “Map” button. By clicking the “Linked Content”, some associated files, for example the automatic-generated web map in ArcGIS Online would be shown. On the top left corner, the “XLS Form” button is where the working spreadsheet (XLS Form) could be opened. However, the spreadsheet could be modified without opening the app. Survey 123 Connect would get the “offline” updates when the user clicked the “Update” button. And by clicking “File”, the folder (on the creator’s device) that contains all information of this current survey would be opened. Supportive information (images, audios, etc.) is also stored and managed through this button.

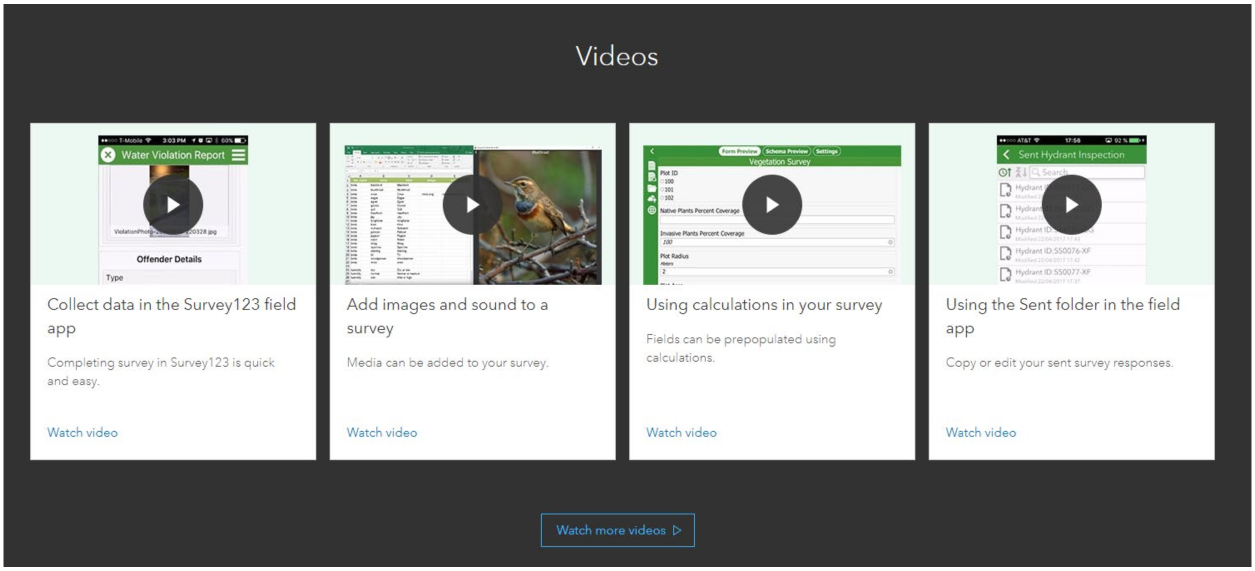


Figure 3.10 Video tutorials of Survey 123 Connect
https://www.esri.com/en-us/arcgis/products/arcgis-survey123/resources

Incorporating key features to enhance educational benefits and usability:

Educational text and images provide learning opportunities and increase accessibility to a broader audience.

In order to make the survey easier to fill out and increase the reliability of the data collected, several questions include explanatory images. Taking the superfood question as an example (Figure 3.11), botanical names, common names and the images with key characteristics of each species are included for each option. Surveyors can magnify the small images by clicking on them. Explanatory text or images can be added before or after the questions with different text styles or colors, which enables the addition of educational components. For example, we added an image of a bee hotel and shared the tips of how to use bee hotels correctly before the bee hotel question (Figure 3.12), so that the surveyors can better understand the question and learn practical tips for improving pollinator habitat.

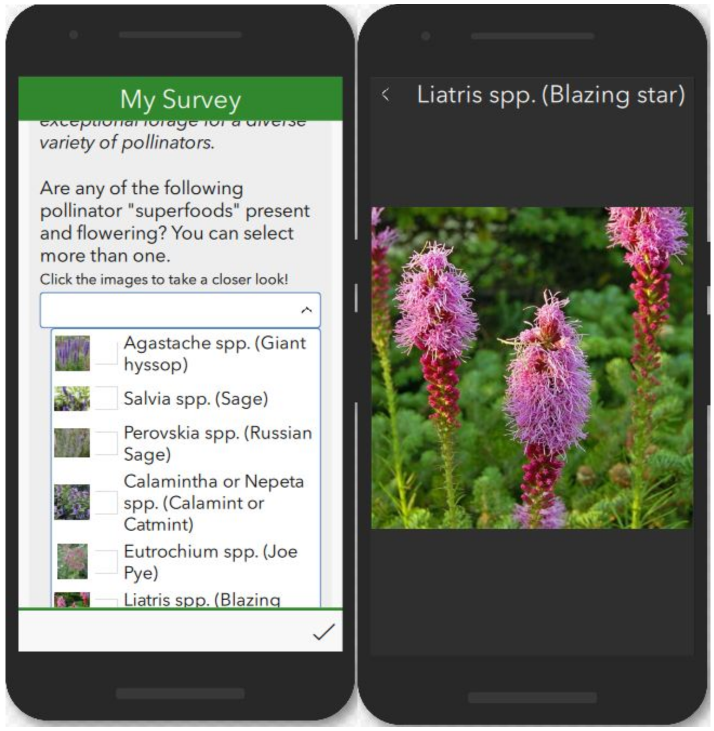


Figure 3.11 Drop-down menu options include descriptive text and images to increase accessibility, provide learning opportunities, and improve data reliability.

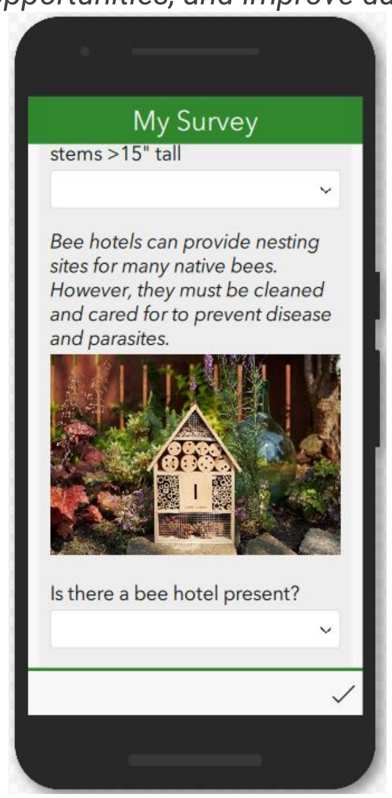


Figure 3.12 Supportive texts (in Italic) and image to increase accessibility, provide learning opportunities, and improve data reliability.

Expert and non-expert questions encourage surveyors of different experience levels to participate.

Since this assessment tool is designed for a wide range of audiences who have different backgrounds, the questions and the process of data collection were simplified. This will enhance the usability of the survey and improve the effectiveness and reliability of the assessment. Designated "expert questions", which were designed for people who have better knowledge on pollinators or plants were included to make the survey more accessible for all audiences and allow for the collection of additional information where possible. In this expert question below (Figure 3.13), the surveyors are asked to record additional host plants that are present but not listed in the previous non-expert host plants question. They are also asked to estimate the abundance of each host plant identified. The format of recording the species and their abundance is shown in the question to improve the data formatting consistency and reduce the work for data analysis.

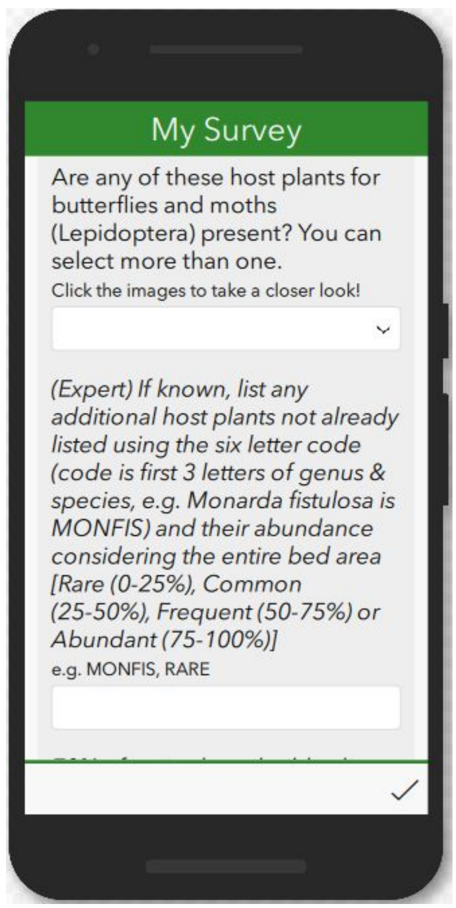


Figure 3.13 Expert question with special recording format to collect additional information and improve the data formatting consistency and reduce the work for data analysis.

Multiple user-friendly considerations reduce the work of data analysis, increase the reliability of the data and overall user experience.

Since the survey is designed to be comprehensive and cover important aspects of pollinator habitat as much as possible, the total length of this assessment tool is relatively long, which is not a desired feature of a "handy" tool. To improve the user experience, efforts were focused on these two aspects: 1) questions were put under several folded groups based on their themes (Figure 3.14) instead of one question sheet and 2) Conditional questions were set by using the typing specific expressions in the cells under the "relevant" column embedded in the advanced template. (Figure 3.15) By doing this, only necessary questions would show up based on surveyors' previous answers. On the other hand, questions that have many choices could be shown as a few questions with fewer choices. Using the pollinator superfood question as an example, it used to have a very long list of choices that contains pollinator superfoods for spring, summer, and fall. After using the "relevant" function, this question was divided into 3 sub questions based on seasons with fewer choices that only contain species blooming in each season. Thus, when the surveyor selected "spring" for the previous season question, only species blooming in spring would show up under the superfood question. Specific expression is required when applying the "relevant" function, which is clearly illustrated and shown in the associated instructions.

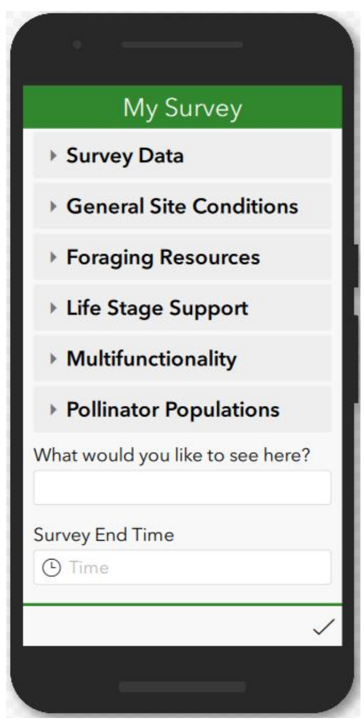


Figure 3.14 Folded groups of questions based on themes

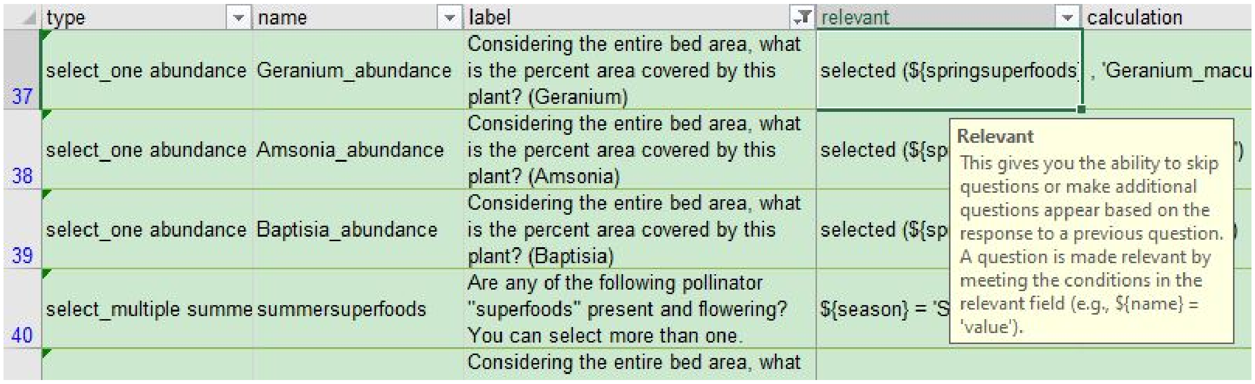


Figure 3.15 Conditional pollinator superfood questions for different seasons

Moreover, the "calculation" function was also applied to automatically calculate the duration of each survey. This way the surveyor doesn't need to keep track of how long it took to complete the survey. To do so, two-time questions (start time & end time) were set first. Then the total survey time question (Figure 3.16) was set up using the "calculation" function with specific expression. The results of the calculation could be displayed or not depending on the creator's choice. By applying the "calculation" function, raw data could be pre-treated within the assessment tool and support further data analysis.

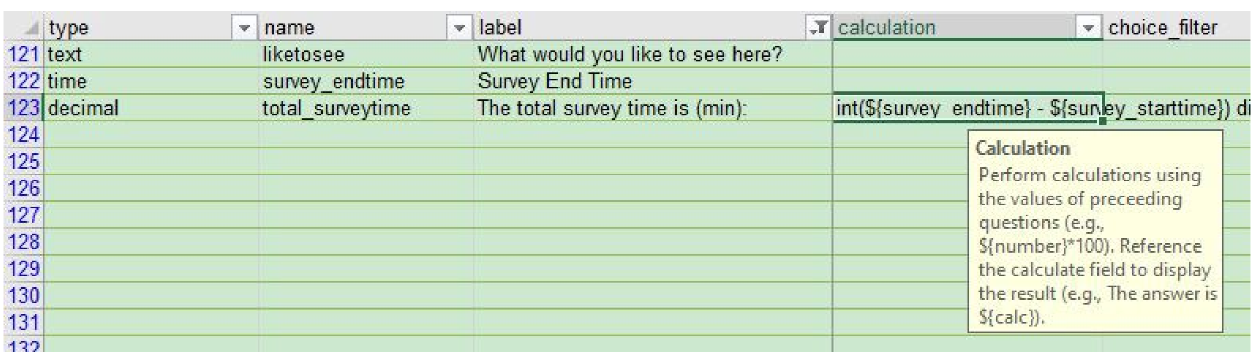


Figure 3.16 Auto-calculate the duration of each survey by using the "calculation" function

Using the Survey 123 website and ArcGIS Online for data management & visualization:

Survey 123 website

Both the survey itself and the data collected could be managed through the Survey 123 website. On the web app, quick summary information of each survey is displayed under the “Overview” tab (Figure 3.17). All the data collected is displayed under the “data'' tab (Figure 3.18) and can be exported as various formats for further analysis. Simple statistical reports (texts & graphics) of each question are automatically generated under the “analysis” tab (Figure 3.19). In the “collaborate” section (Figure 3.20), the accessibility of the survey and the data collected is managed. PLEASE NOTE that the survey opened through the URL link in browsers could be incomplete (missing supportive images within options) and therefore, accessing the survey through the Survey 123 field app is highly recommended.

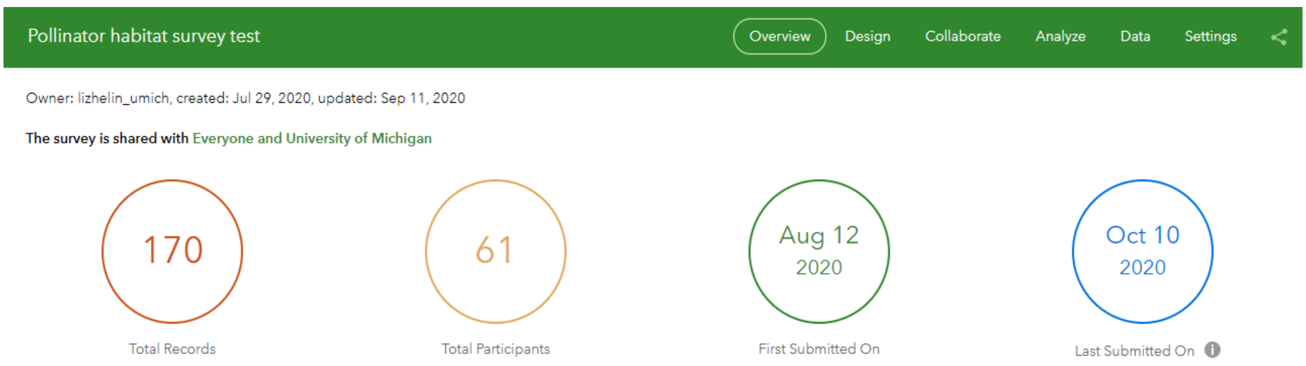


Figure 3.17 “Overview” of the survey

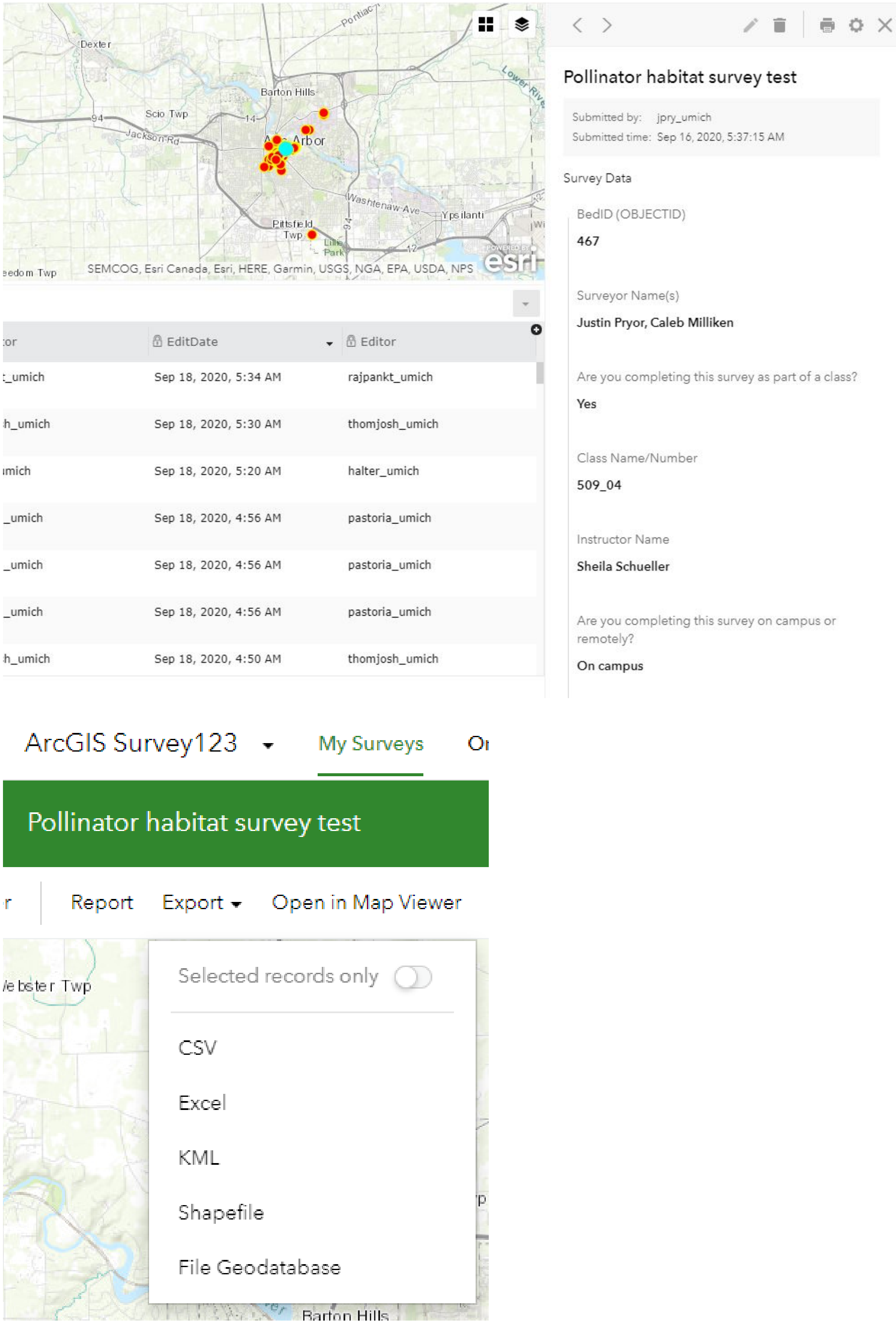


Figure 3.18 “Data” of the survey

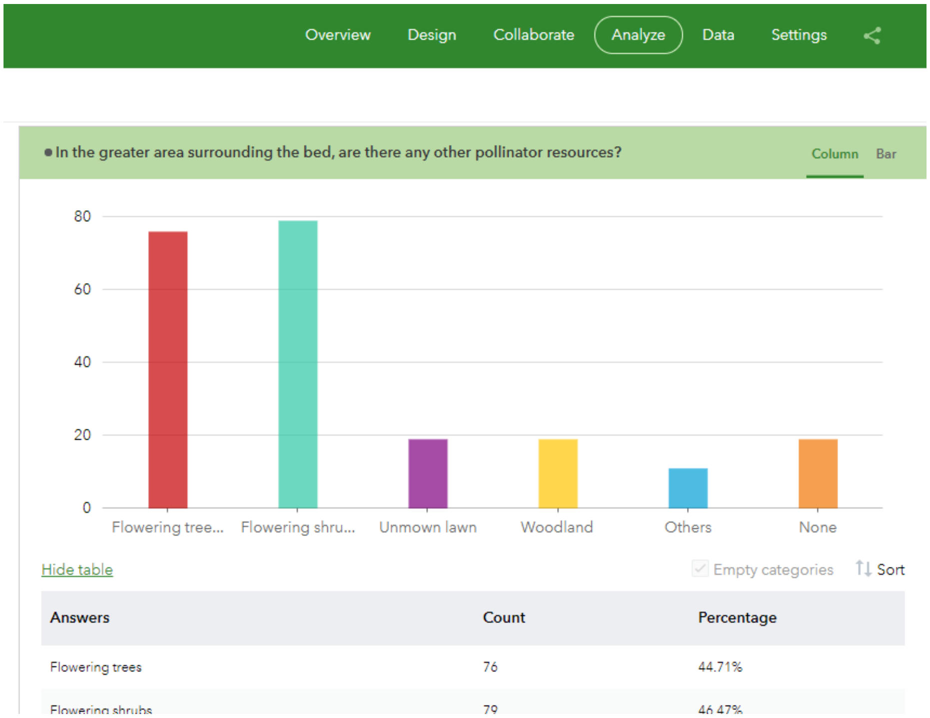


Figure 3.19 “Analysis” of the survey

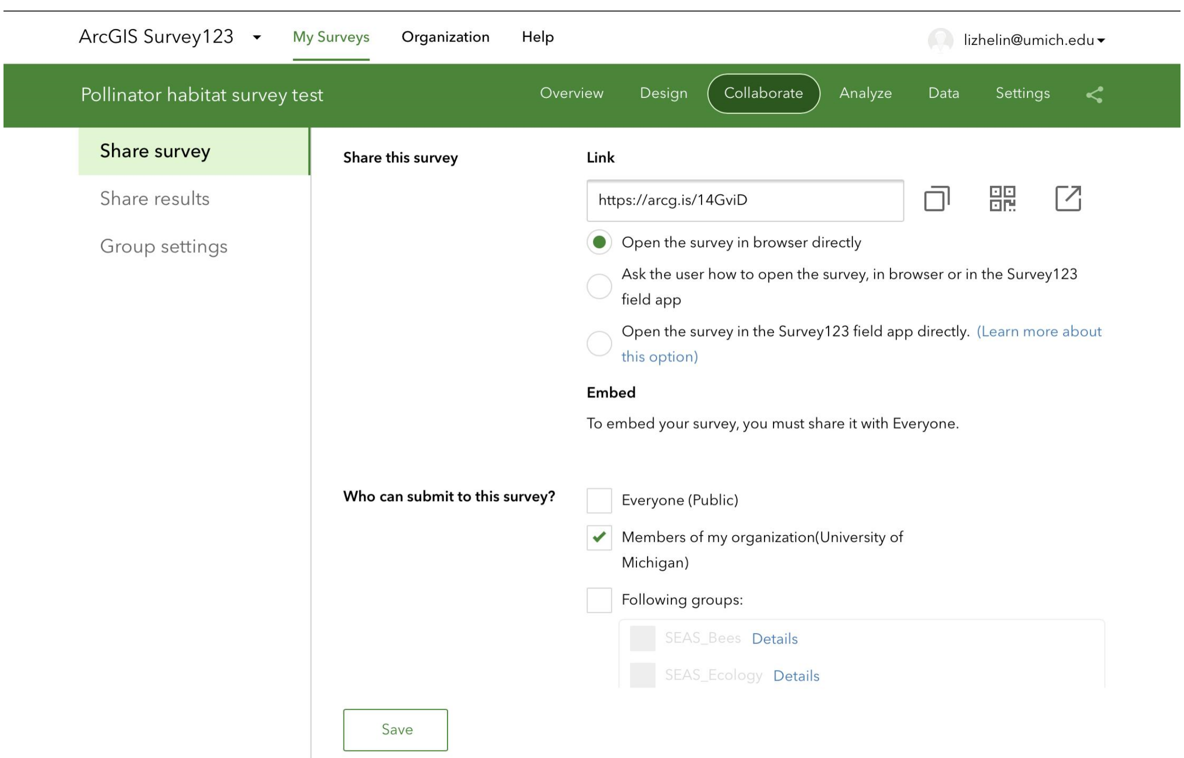


Figure 3.20 “Collaborate” of the survey

ArcGIS Online

The assessment and the data could also be managed through ArcGIS Online, which is a cloud-based mapping platform developed by Esri. This means anything created under an Esri account can be managed and shared through ArcGIS Online. As Survey123 is an Esri's product, a folder (Figure 3.21) under "My content" in ArcGIS Online with the same name of our survey was automatically created on the day we published our survey through Survey123. There are three main components in this folder: 1. The "web map" (Figure 3.22), 2. the data collected that can be visualized on ArcGIS online, where all the symbologies can be edited, for instance we use different colors to show the abundance, and 3. the "form" which is the survey itself. Clicking "form", opens the survey in the Survey 123 web app. The "feature layer" (Figure 3.23) is where the data (geospatial information of pollinator habitats) is stored and can be easily downloaded, shared, and opened through ArcMap or ArcGIS Pro to do further analysis. Additionally, accessibility and editing to the data can be managed through the "Settings" (Figure 3.24) of the feature layer. For example, the box of "Enable Sync" must be checked to enable offline editing so that surveyors can download the survey beforehand and fill out the survey without internet connection.

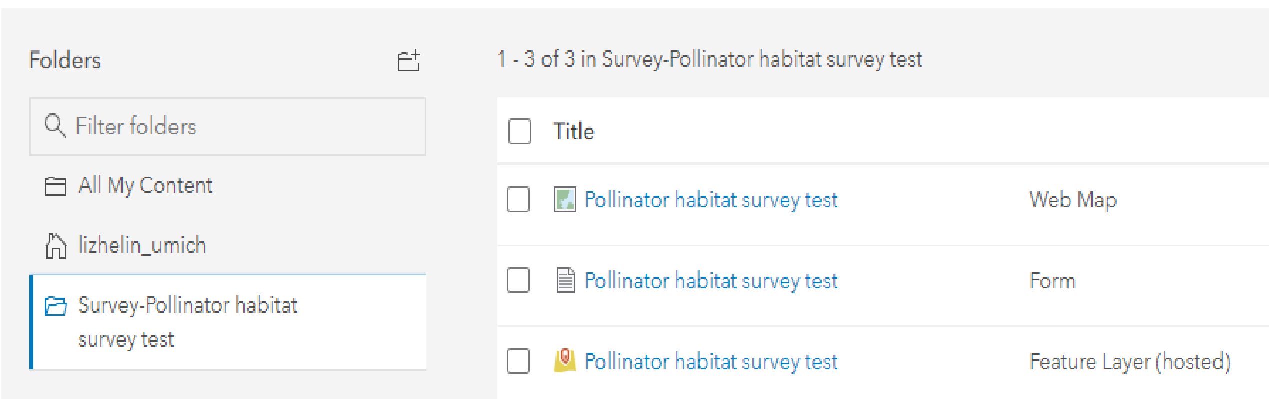


Figure 3.21 The survey folder in ArcGIS Online

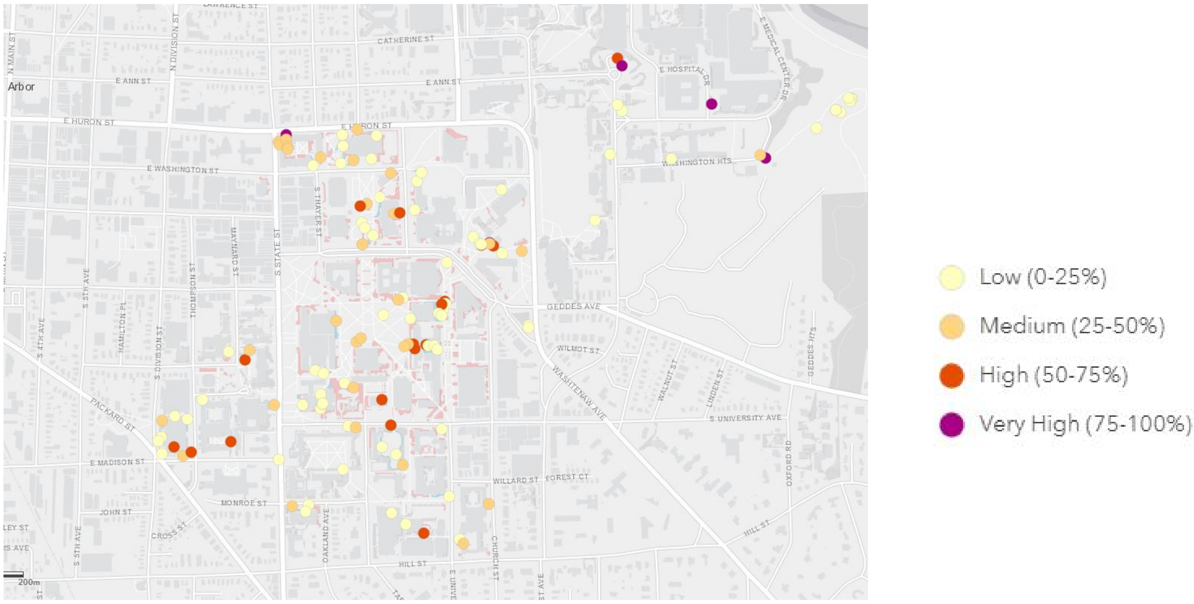


Figure 3.22 "Web map" of the Habitat Assessment

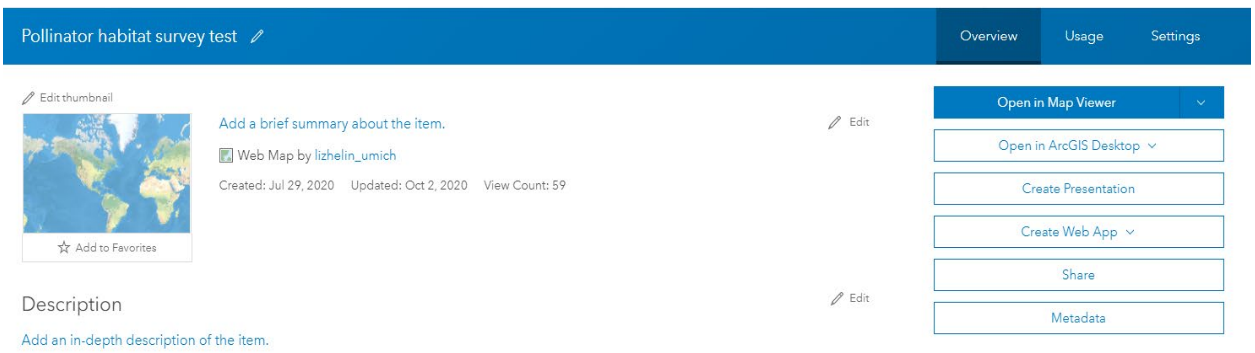


Figure 3.23 "Feature layer" of the Habitat Assessment

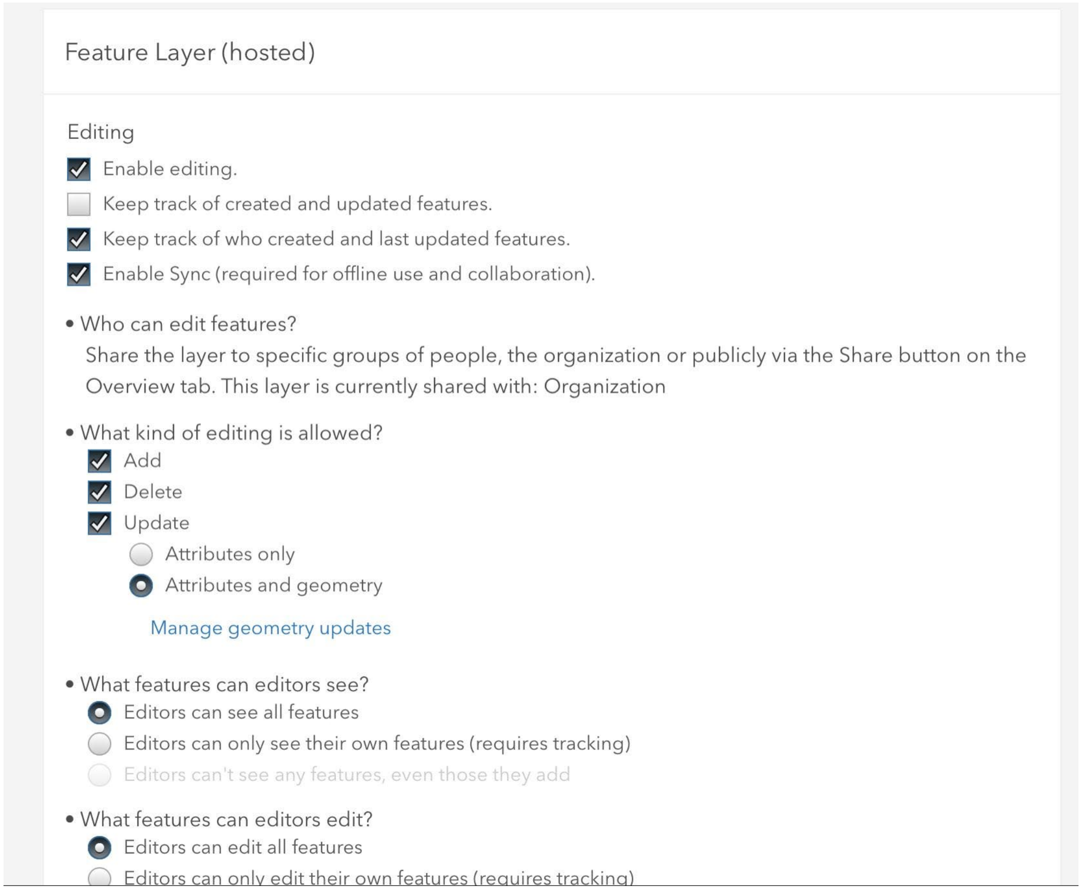
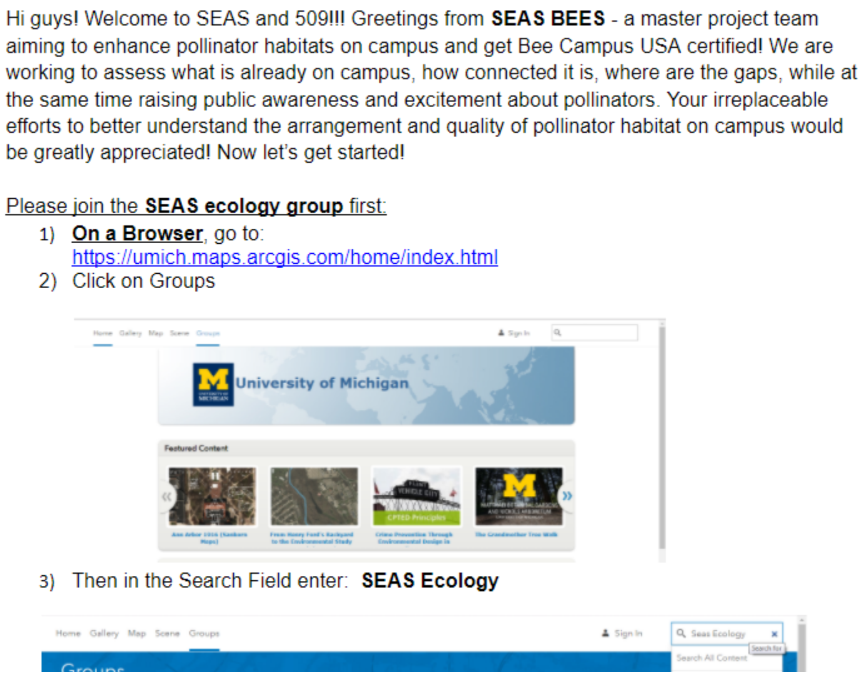


Figure 3.24 Settings of "Feature layer"

Piloting and iterative revision:

After the test version of the Campus Pollinator Habitat Assessment tool was completed and published, our team members, horticulturalists from UM Ground Services and more than 50 students from a SEAS fall 2020 course (EAS 509) piloted the survey and submitted in total 170 records. Before the piloting process began, a guide for using Campus Pollinator Habitat Assessment (Figure 3.25) was distributed to the surveyors, including how to download the field app and edit the survey offline. To improve the accuracy of the geospatial data (locations), a polygon layer of green spaces on campus was displayed in Arc Collector (Figure 3.26) and used as a reference. The surveyors were required to check the "OBJECTID" of the green space surveyed and input it into the "OBJECTID" question set in the survey.



Hi guys! Welcome to SEAS and 509!!! Greetings from **SEAS BEES** - a master project team aiming to enhance pollinator habitats on campus and get Bee Campus USA certified! We are working to assess what is already on campus, how connected it is, where are the gaps, while at the same time raising public awareness and excitement about pollinators. Your irreplaceable efforts to better understand the arrangement and quality of pollinator habitat on campus would be greatly appreciated! Now let's get started!

Please join the **SEAS ecology group** first:

1) **On a Browser**, go to: https://umich.maps.arcgis.com/home/index.html
2) Click on Groups

3) Then in the Search Field enter: **SEAS Ecology**

Figure 3.25 Instructions to students for using pollinator habitat survey as part of fall 2020 pilot
https://docs.google.com/document/d/1YKT61Il9VSUY4VKeoQz9qYYDXvHygge3/edit

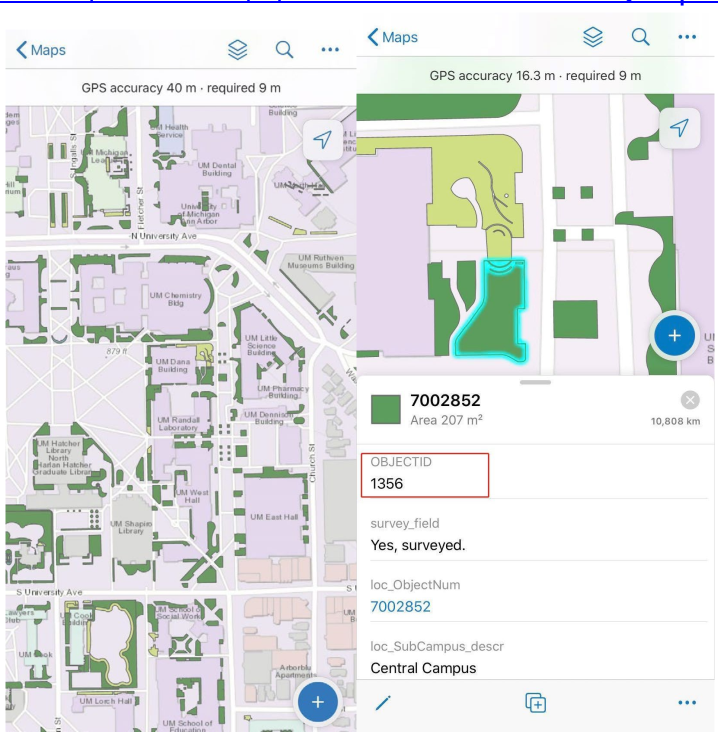


Figure 3.26 Polygon layer of green spaces on campus displayed in Arc Collector

After analyzing the data collected, we were delighted to find that the questions in our assessment covered the important aspects of pollinator habitat that we sought to measure, which helped us identify the quality of existing pollinator habitats across campus. However, refinements could still be made for improving the usability of the assessment tool. For data collectors, some questions need rephrasing or more explanatory information to help the surveyors better understand the questions and the options, which could improve the accuracy and reliability of the data. For data users, some less relevant/direct questions could be deleted to make the entire assessment more targeted and straightforward. Then the overall data collected would be more effective and easier to analyze. More details of the result of analysis and recommendations on enhancing and managing pollinator habitats on campus will be discussed in the next chapter.

Conclusion and recommended next steps

Generalizability

The Campus Pollinator Habitat Assessment tool was designed to have general applicability. Both the selection of questions and the process of data collection and analysis were intended to service a wide range of sites and audiences. Apart from the Ann Arbor campus, this assessment tool is expected to work for other Midwest campuses and urban green spaces (vegetation beds, rain gardens, etc.). For campuses and cities that are not in the Midwest, it would be very easy to replicate the assessment by simply changing the plant species into their native/local species. Then, consulting the local literature on pollinators, obtaining some general recommendations on enhancing and managing their habitats.

Limitations

While broadly applicable, there are still some limitations of this Campus Pollinator Habitat Assessment tool:

- The plot should be restricted to small size, developed urban landscapes to ensure the effectiveness of the data. The assessment is designed for developed landscapes in urban contexts and based on surveyors' observations on the plot. In particular, to monitor existing pollinator activities, the surveyors are asked to do a quick observation within a 1*1 foot quadrant. Even though the area of the quadrant could be edited to fit a new site, sites that have large or undeveloped landscapes (e.g. farms, natural areas) are not recommended since it would require a more systematic observation with multiple observation spots, and data collected from one spot may not be representative.

- The geospatial data collected may not be accurate enough. The accuracy of the geospatial data mainly depends on the devices used during the surveying process. For example, many of the data points were recorded using a cellphone, which is only accurate to 9 meters. A few invalid locations (lack of match with the OBJECTID) were found during data analysis. This may cause invalid data collection and might be a result of unstable internet connections. Therefore, more detailed instructions, for example, "Please double check your location information before submitting the survey and manually change it if it was incorrect" are needed to improve the reliability of the geospatial data.
- Creating and managing a survey through Survey 123 (ArcGIS Online) will cost Esri credits. Any data storage, use of analysis tools through ArcGIS Online will cost Esri credits. Using Survey 123 is equivalent to using ArcGIS Online since the data is stored in ArcGIS Online. Different types of subscriptions will give different amounts of credits to an account, otherwise the users need to purchase Esri credits for using premium services. Therefore, instead of creating and managing a survey under personal accounts, individuals are recommended to use the survey shared by organizations, such as UM, who have Esri subscriptions.

Works cited

Figure 3.3 Habitat Assessment Guide for Pollinators in Yards, Gardens, and Parks, published by The Xerces Society
https://www.xerces.org/publications/habitat-assessment-guides/habitat-assessment-guide-for-pollinators-in-yards-gardens

Figure 3.7 Bees: An Identification and Native Plant Foraging Guide by Heather Holm (2017); Pollinators of Native Plants: Attract, Observe and Identify Pollinators and Beneficial Insects with Native Plants by Heather Holm (2014).

Figure 3.11 Video tutorials of Survey 123 Connect
https://www.esri.com/en-us/arcgis/products/arcgis-survey123/resources

CHAPTER 4 – **PRELIMINARY ANALYSIS OF HABITATS ON CAMPUS AND ONGOING ADAPTIVE MANAGEMENT RECOMMENDATIONS**

Introduction

Collecting data over time on the quantity, quality, and arrangement of pollinator habitat will allow for effective and informed enhancement of pollinator habitat across a campus. In the previous chapter we describe how we created a pollinator habitat assessment tool in Survey 123. This data collection tool can allow for the next steps of data analysis, taking action, and iteratively continuing this process in the adaptive management of habitat on campus. In this chapter we show how pilot Survey123 data can give guidance on important variables and data relationships to explore in future analyses as data collection continues. The information presented is a first step toward informing actions and priorities with a better understanding of which pollinators are on campus, where, and what habitat and landscape features are they responding to.

In this chapter we also set the Survey 123 data within a larger framework for how data collection and analysis can continue. Specifically, we propose three tools to gather long-term data on pollinator habitat, populations, and movement across campus that will inform future landscape decisions by Grounds Services (Figure 4.1). First, the Survey123 tool can be used by students, staff, faculty, and community scientists to collect fine-scale data on campus across seasons and over multiple years. This data layer will describe site-specific, garden-level characteristics of the landscaping and pollinator population. Second, fluorescent dye experiments can be used by students or volunteers to document dynamic pollinator movement between beds and show connections (or lack thereof) across campus. This movement data will build an understanding of which pollinators are actually moving between which gardens, and the garden characteristics data can then be used to understand why — which landscape characteristics encourage or discourage pollinator habitat connectivity. Finally, the fine-scale and connectivity data layers can be combined with coarse-scale data in a Habitat Suitability approach to understand pollinator distributions across campus and prioritize areas for increased connectivity or new habitat creation. This coarse-scale data can include available spatial data on landscape level variables that influence pollinators, including impervious surface, tree canopy, aspect, proximity to water, and land cover. This three-tool approach combines data at different spatial and temporal scales to understand current pollinator habitat quality which can be used to highlight gaps for new habitat creation or improvement.

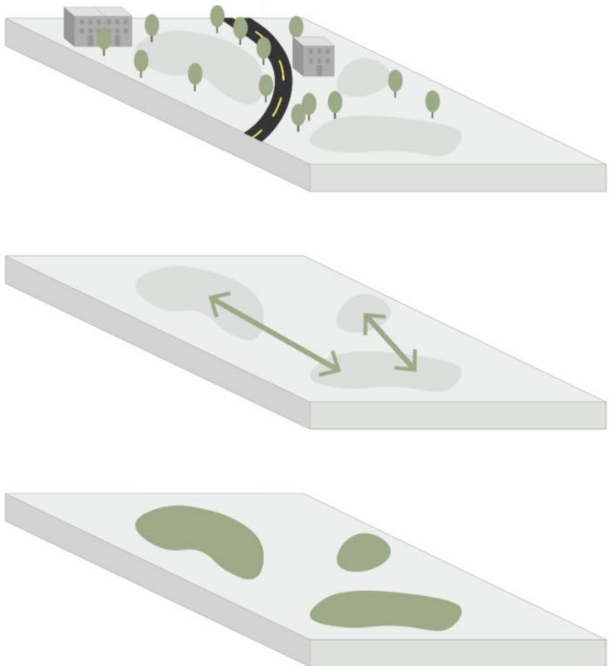


Figure 4.1 Diagram of data layers which can be used individually and in combination to inform future pollinator habitat decisions.

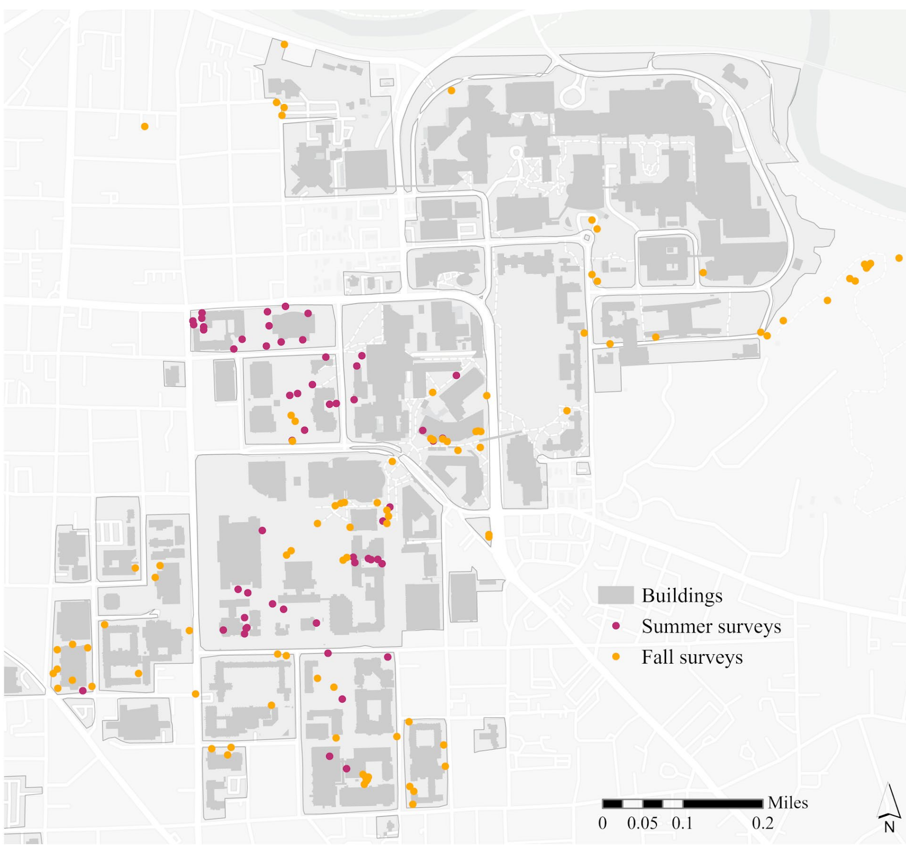
Site-level Data: Using Survey123 Field Data to quantify pollinator populations and habitat on campus

Using the newly developed Survey 123 tool, we were able to obtain an informative, though limited, snapshot of pollinator habitat on campus. Our initial data are from August and September 2020. In August, two team members assessed several gardens between East Huron Street and South University Avenue on central campus. Additional data was collected across campus in September by approximately 100 students working in pairs in EAS 509, an introductory Ecology lab course in SEAS. These data represent a pilot study only. Given the large number of green spaces across campus, the changes that can occur over time in plantings and pollinator activity, data collection will need to be ongoing. We recommend that the field survey is repeated across seasons and over multiple years to get a more complete picture of campus habitat and to monitor for changes over time. Specifically, the limitations of the pilot data set to keep in mind are:

- The pilot data was collected in Summer (August) and Fall only. This likely underestimates the number of different pollinator species observed and the pollinator abundance, which varies throughout the season.
- Several questions were modified or added between the Summer and Fall season, making direct comparison difficult.
- The intended primary users of the survey are not plant or pollinator experts, so data may include errors in identification.
- Only a small percent of the total green spaces across campus were sampled, and the focus was on sampling as many sites as possible across the two seasons. Many sites were not sampled in both summer and fall. For example, the North Quad area was not sampled in fall, leading to an apparent lack of fall pollinators.

Despite these limitations, we were able to assess several aspects of the pollinator habitat on campus. Below, we present a first look at the pollinator species present on central campus and discuss which species are more abundant and where, then speculate on what habitat variables may drive these observations. We also discuss initial floral density and structural resources data and demonstrate how it can be used to inform future pollinator habitat decisions on campus.

Figure 4.2 Summer surveys (pink) focused on the area between North and South University Avenues. Fall surveys (orange) had a wider distribution across central and medical campuses.



Campus pollinator populations

The pilot study produced 771 pollinator observations of over 20 different pollinator species and/or groups (Figures 4.2 and 4.3). Because the survey questions changed from pollinator *families* to pollinator *groups* mid-summer (to make the survey easier for a wider range of experience levels) only general comparisons can be made across seasons.

Bees, specifically, large bees (including honey, bumble, and carpenter) were abundant on central campus across seasons. In summer, this group represented approximately 26.4% of the observed pollinators, while in fall, this increased to 68.7% of observed pollinators. We certainly cannot rule out that large-bodied bees are easier to see and are also more familiar to the general public. However, butterflies on average are larger bodied and familiar as well, but butterflies were rare across both seasons (summer: 3.8% of observations; fall: 1.7% of observations). The most abundant summer pollinators observed were sweat bees (39.3%) and many of these were observed to be green sweat bees of the *Agapostemon* genus (Figure 4.3). Our early results align with many studies that suggest bees are well-represented in urban pollinator populations (see Chapter 2).

Several pollinator groups were less frequently observed in fall than in summer, which likely reflects a normal seasonal shift in both overall abundance and certain groups. Nearly half of the fall surveys (46%) observed no pollinators, and the average species richness of pollinators observed in summer was higher (1.68 species per survey) than in fall (1.15 species per survey). Weather conditions during the fall surveys were cool and wet, which may have discouraged pollinator activity; however, our data suggest pollinator abundance was not related to temperature (R^2 = 0.002). Small, dark bees (including Halictidae and others) were abundant in summer surveys (44.7% of observations) but comparatively rare in fall surveys (8.2% of observations). The same trend was observed in butterflies, leafcutter bees (14.4% summer; 6% fall), and beetles (3.1% summer; 2.3% fall). This trend makes sense biologically for leafcutter bees (*Megachilidae* family), as most in this family are active from spring to early summer (Holm, 2014). Wasps represented 12.1% of summer observations, which decreased to just 10.0% of fall observations, but this decrease is likely underestimated as the category of “wasps” was not an option on the summer survey. The summer wasp numbers were generated from a few surveyors that made notes in the comments. We want to add here that many wasps are important pollinators and do not necessarily represent a threat to human safety. Both social and solitary wasps are docile while using plants for foraging on nectar resources or as hunting grounds for small insect prey (Holm, 2014).

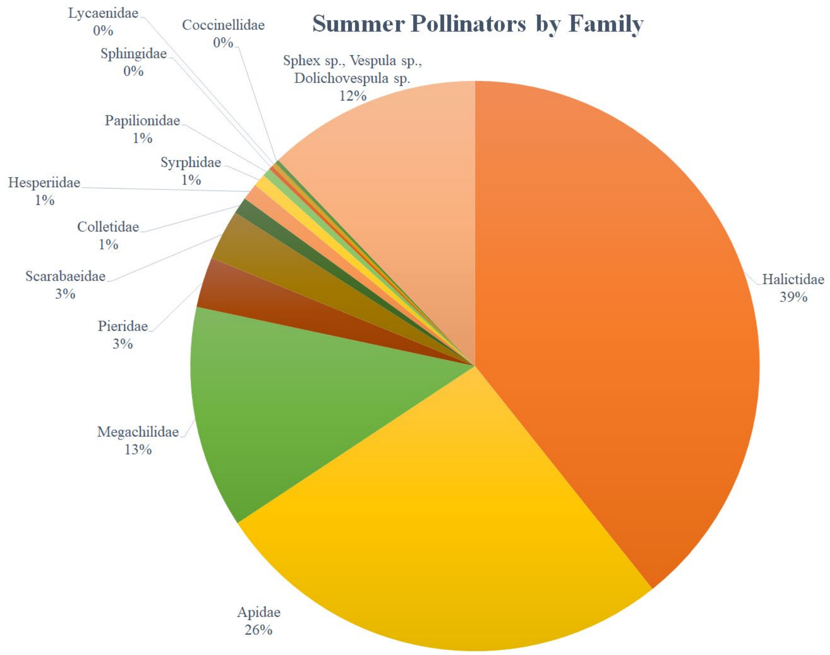


Figure 4.3 Pollinators observed by family during summer (August) pilot survey.

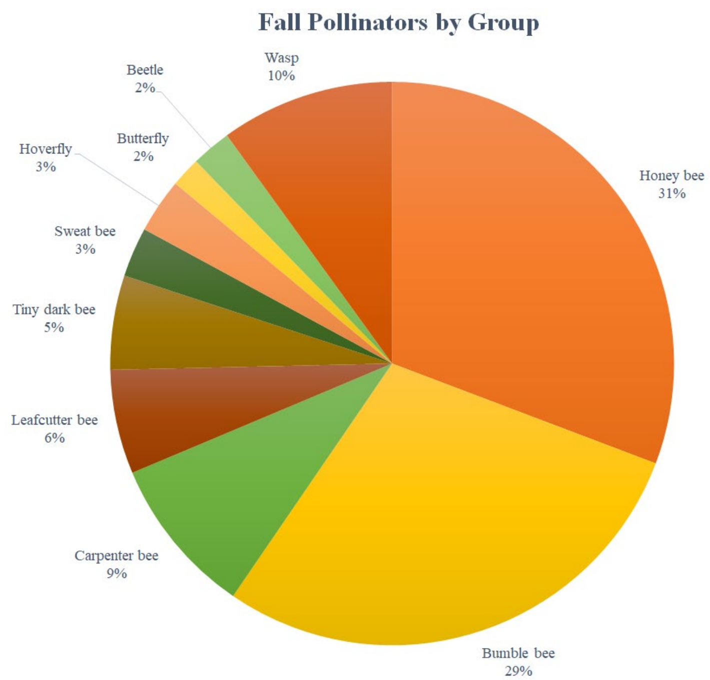


Figure 4.4 Pollinators observed by group during fall (September to October) pilot survey. Note that color coding does not necessarily align with that in Figure 4.3. For example, Honey bees are not Halictidae, but part of Apidae.

The pilot data indicate several campus pollinator hotspots; some appear shared across multiple pollinator types and others that are unique to certain species. Both bumble bees and European honey bees were abundant and well-distributed across campus sites, though surveys identified a shared hotspot. In fall, the bumble bee observations were fairly well distributed across central campus (Figure 4.5), with the exception of a hotspot at the Reader Center where surveyors observed 20 bumble bees and 20 European honey bees at this apparent hotspot (Figure 4.5). From surveyor data and photos, we see that this bed featured a "very high" floral density of many native plants including New England aster (*Symphyotrichum novae-angliae*) and Canada goldenrod (*Solidago canadensis*) as well as a non-native stonecrop variety (likely Sedum 'Autumn Joy') that features shallow nectaries and large "landing areas" known to attract pollinators. Another hotspot is indicated near East Quad and the Ross School of Business, but this appears specific to wasps (Figure 4.6), which suggests that certain local, site-scale characteristics may attract certain pollinators more than others. It is important to mention here that the apparent lack of pollinators north of North University Ave. may simply reflect that few surveys were performed in that area in the fall (Figure 4.2). This example demonstrates an important use of the survey data to identify campus hotspots, learn which pollinators are using (or not using) these areas, and gain insights into which specific site-level features of the garden beds are attracting abundant pollinators.

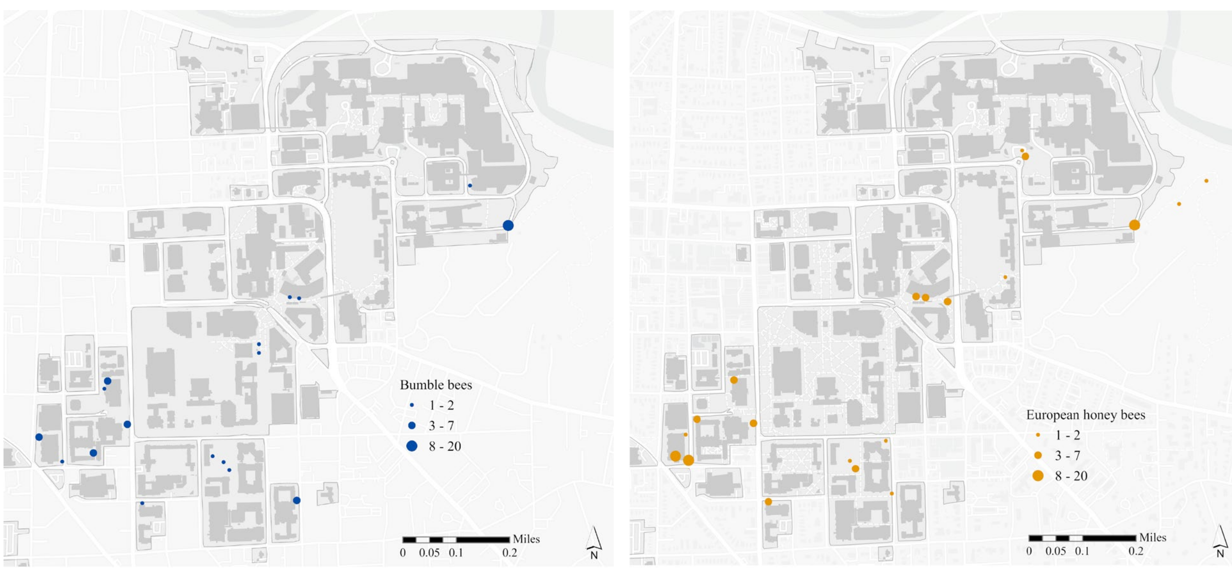


Figure 4.5 Fall bumble bee (left) and European honey bee (right) observations on central campus indicate a shared hotspot at the Reader Center.

Figure 4.6 Fall wasp observations on central campus indicate a hotspot near East Quad and the Ross School of Business that may be unique to wasps.

Garden beds that support a higher number of pollinator species are potential hotspots for pollinator diversity and thus may provide insights into site level characteristics that are mutually attractive to many pollinators. It is important to mention that a high number of species is not always necessarily the goal as these species hotspots may indicate a generalist pollinator assemblage that may not include specialist species. The highest observed species richness (6 species) during the pilot survey was at East Quad. Other comparatively species-rich (5) areas included the Martha Cook courtyard, Ingalls Mall, and the Reader Center.

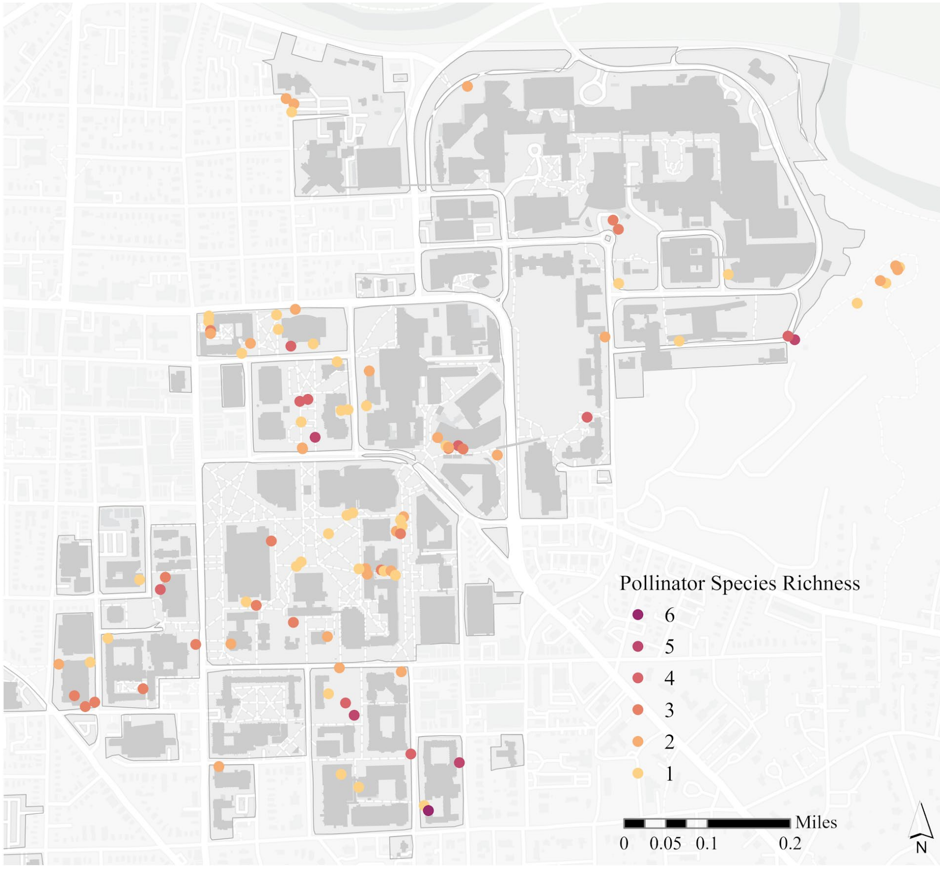


Figure 4.7 The highest observed species richness (6 species) was at East Quad. Other comparatively species-rich (5) areas included the Martha Cook courtyard, Ingalls Mall, and the Reader Center.

The East Quad site that attracted the most pollinator species is a "pollinator garden" that features all native plants including Canada goldenrod (*Solidago canadensis*) (see Figure 4.8). By referencing the surveyor submitted photos, also shown in Figure 4.8, we identified several plant species were attracting pollinators at East Quad (Table 4.1).

This mix of native, nativar, and non-native ornamental plants suggests that plants of many origins can provide pollinator foraging resources. These species in particular appear to be highly attractive to pollinators and aesthetically appropriate for use in campus landscapes, making them an excellent choice for future plantings. The appearance of Canada goldenrod twice aligns with expectations that goldenrods are pollinator "superfoods," along with asters and sage. Other commonalities across most of these sites include at least a medium (25-50%) floral density, two floral shapes that usually include a composite flower, and yellow flowers. The shallow corollas and large "landing pads" provided by composite flowers are known to attract a variety of pollinator body sizes and tongue lengths (see Chapter 2). While not conclusive, this small data sample gives a starting point to understanding which plant species, planting density, and flower colors may attract a variety of pollinators in campus gardens.

Figure 4.8 A selection of photos submitted by surveyors at gardens with high pollinator species richness.

Table 4.1 Plant species observed attracting pollinators at East Quad

Location	Plant(s)	Plant origin
East Quad (west)	Canada goldenrod (*Solidago canadensis*)	Native to US
East Quad (east)	Threadleaf coreopsis (*Coreopsis verticillata*)	Nativar
Martha Cook courtyard	Hydrangea variety (*Hydrangea paniculata*)	Not native to US
Ingalls Mall	Sage variety (*Salvia* sp.) Ligularia variety (*Ligularia* sp.)	Not native to US Not native to US
Reader Center	Canada goldenrod (*Solidago canadensis*) New England aster (*Symphyotrichum novae-angliae*) Stonecrop variety (*Sedum* sp.)	Native to US Native to US Not native to US

Table 4.2 Characteristics of plants attracting pollinators at East Quad

	East Quad (west)	East Quad (east)	Marth Cook courtyard	Ingalls Mall	Reader Center
Floral density	Medium	Medium	Medium	Low	Very High
# of shapes	2 Composite, umbel	1 Composite	2 Umbels, nodding	2 Composite, tubular	2 Composite, umbel
# superfoods	1	0	0	1	1
# colors	4 Yellow, pink, violet, green-white	1 Yellow	1 green-white	2 Yellow, violet	4 Yellow, pink, blue, violet

Campus floral and structural resources

Floral density is often cited as the most important variable for urban pollinator habitat (see Chapter 2); however, our pilot data suggests either the overall floral density on campus is truly low or the survey methodology needs improvement for surveyors to accurately capture this key variable. Our pilot data indicate that most garden beds on central campus rank as having low % Cover by flowers in summer (N=30) and fall (N=50) (Table 4.3). Very few garden beds were categorized as “Very High” flowering density in summer (N=2) and there were no garden beds that fell into this category in fall. This suggests two possibilities: 1) floral density is actually low across much of central campus, or 2) the survey language is unclear, and surveyors were unable to accurately assess floral density. To investigate this potential disjunct, we compared garden bed photographs taken by the surveyors to the surveyor’s assessment of % Cover (Figure 4.9). This sample comparison suggests there is variability in surveyors’ interpretation of the “high” cover category (50-75%). One possible explanation is that surveyors may be interpreting “percent area of flowers blooming” to include the entire flowering plant or individual flowers blooming. Clarifying the wording of this question in future iterations will make the question easier to understand and increase data accuracy. While the final wording of the question will need more user testing, we suggest the following possible alternate wording in the survey to capture floral density:

- “Considering the entire bed area, estimate the proportion of open flowers per square foot.”
- “Is there an area within this bed that has at least x flowers per square foot?”
- “Is there an area within this bed with a dense cluster of flowers?”

Through this photo verification process, we were able to identify areas of improvement for survey language. This analysis also confirms the need for measuring variables, such as floral density, throughout the season to capture seasonal and surveyor interpretation variation.

Table 4.3 Number of Central Campus garden beds in each floral density category in summer and fall.

Flowering Density	Summer	Fall
Very High (75-100%)	2	0
High (50-75%)	8	7
Medium (25-50%)	16	14
Low (0-25%)	30	35
None (0%)	n/a	15

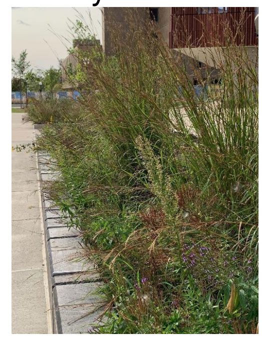
Photo 1 Surveyor 1 	Photo 2 Surveyor 2 	Photo 3 Surveyor 3 
“High”	“High”	“High”

Figure 4.9 A comparison of three surveyors’ interpretations of % Cover using survey data and surveyor-submitted photographs.

Being able to visualize the spatial distribution of floral densities across campus can highlight the potential for creating pollinator corridors. For example, in summer, there is a line of garden beds with “High” flowering density starting at South University Ave. and heading northeast through the Biological Sciences Building (Figure 4.10). Although buildings may restrict direct pollinator movement, this could highlight an opportunity to facilitate movement and connectivity by increasing floral resources along pathways and foundation plantings in this general area.

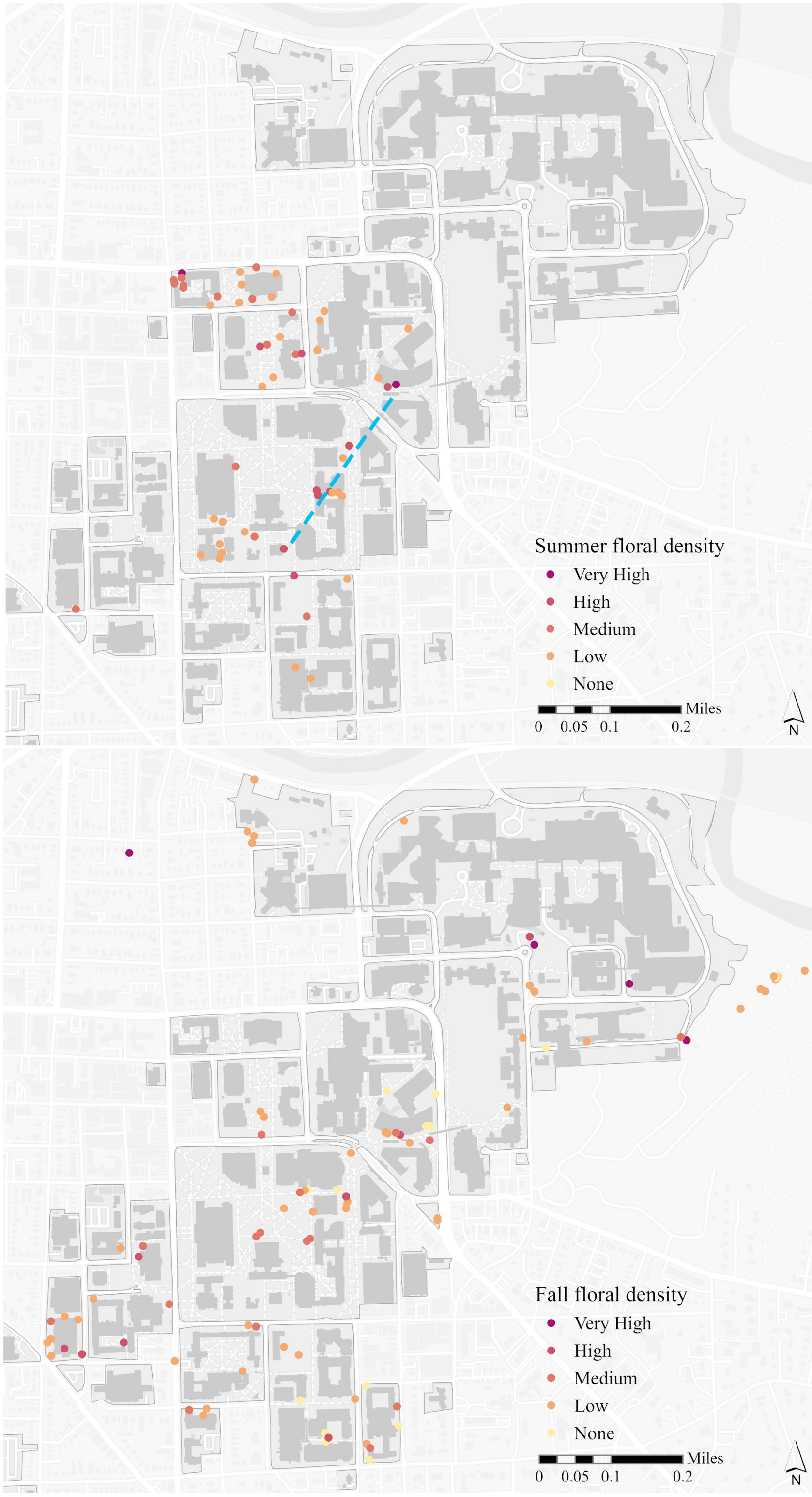


Figure 4.10 Flowering density of garden beds on Central Campus surveyed in Summer (top) and Fall (bottom). A new category of "None (0%)" was added to the survey in Fall.

In addition to floral resources, nesting and overwintering substrates including leaf litter and cut stems >15” tall are key habitat features that support pollinators’ full life cycles. Leaf litter was overall sparse (N=31) to absent (N=31) across seasons with very few sites providing abundant leaf litter resources (N=7) (Figure 4.11). The presence of some leaf litter later in summer suggests this leaf litter remained on site from the previous fall and may have provided overwintering substrate for pollinators, particularly for *Lepidoptera* (butterflies and moths). For highly maintained areas on campus, leaf litter is likely not aesthetically appropriate, but these data suggest that there are some, likely less-visible, locations on campus where small patches of leaf litter have been left. The same holds true for cut stems that support stem-nesting bees, which are present on almost half of the sites surveyed, with 16 sites reporting even “abundant” cut stems >15” (and 16 sparse and 37 absent). Stem resources are not limited to certain areas on campus but instead occur in numerous locations (Figure 4.12), which is beneficial in terms of reducing parasite loads as opposed to if these resources were concentrated in one place like a bee hotel (see Chapter 2). We recommend that less-visible areas on campus are identified and maintenance instructions should include leaving some leaf litter and cut stems to support overwintering pollinators.

Figure 4.11 Abundance and distribution of leaf litter on central campus.

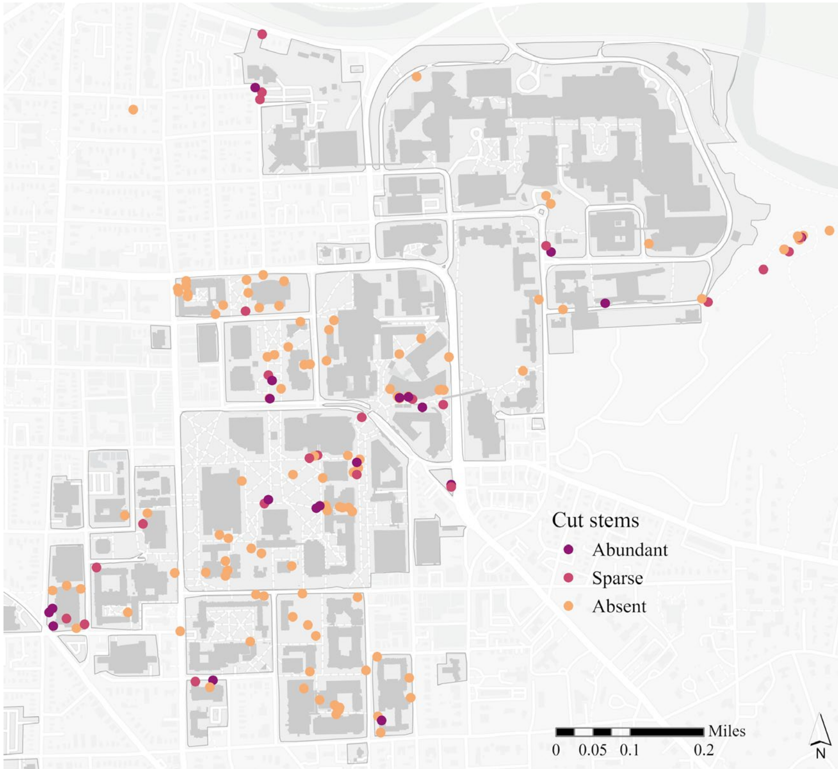


Figure 4.12 Abundance and distribution of cut stems >15" on central campus.

Relationships between Pollinators & Habitat

Research suggests that both higher floral density and planting with native plants increase pollinator abundance and diversity (Chapter 2), but we did not find evidence for either in the pilot data. Floral density does not relate significantly to pollinator abundance (density explains only 8% of the variation in the total number of pollinators observed during the survey time; Figure 4.13). However, plots with medium to high density do tend to have some of highest numbers of pollinators. A more objective or refined measure of floral density (see discussion above) as well as more observations may allow for a better test of the relationship between floral density and pollinator activity on campus. The percent of native plants in a bed was also not related to pollinator abundance (Figure 4.14). This result may reflect that correctly identifying native plants is challenging, and our survey data may include errors in plant identification. The percent of native plants was also an "expert" level question, so we have fewer data to analyze (only 84 surveys out of 162 were completed by "experts"). A thorough floral inventory of campus landscaping by qualified botanists would improve the accuracy of identifying native plants and allow for a better test of how native plantings affect pollinator visitation on campus.

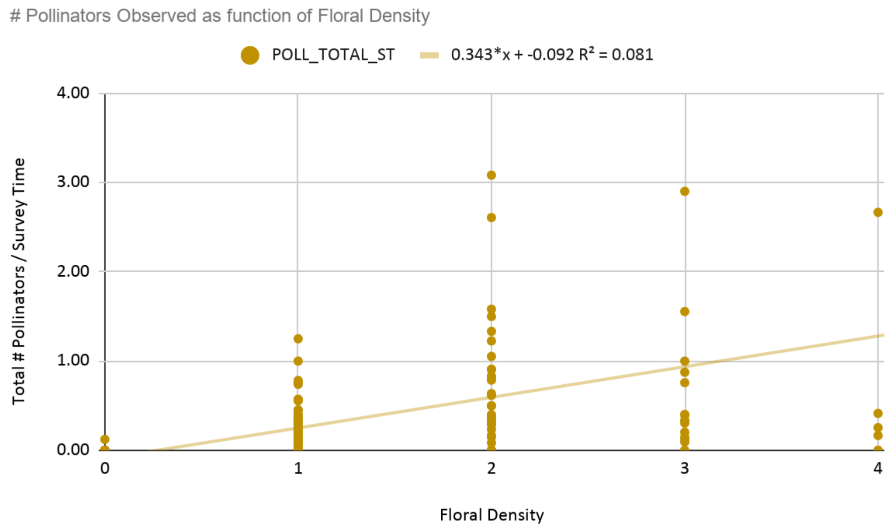


Figure 4.13 Pilot data suggest no relationship between floral density and pollinator abundance (R^2 = 0.081)

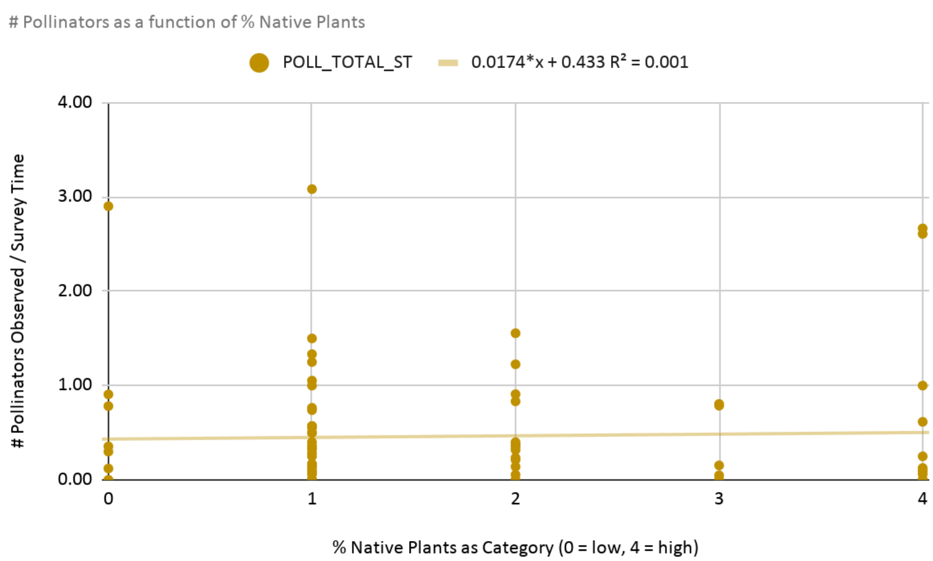


Figure 4.14 Pilot data suggests no relationship between native plant abundance and pollinator abundance (R^2 = 0.001)

Connectivity Data: Fluorescent dye studies

While the site-level Survey 123 data can provide valuable information about the quality of pollinator habitat at each site and across the campus landscape, the actual movement of pollinators can be tracked with another approach: the use of fluorescent dye. We created a Michigan Sustainability Case, "Pollinators, Connectivity, and Corridors - Pollinator Pathways: The Path to Successful Conservation" on the LearnGala online platform (*https://www.learngala.com/cases/d144a303-a7b8-48e2-b3bd-8031213294da/*.) This digital case serves as an educational data collection and analysis tool. It explains the concepts of pollinator corridors and pathways, how they play an essential role in pollinator conservation and habitat success, and how to track pollinator movement. Specifically, it describes the pollinator connectivity experiment that we conducted during the summer of 2020 at the Samuel T. Dana Building garden as well as the two garden plots and bee hotel outside of the Biological Sciences Building.

We explored actual pollinator movement and connectivity within each garden as well as the bee hotel by applying non-toxic fluorescent dye using wooden toothpicks to the anthers and inner petals of flowering plants. This way, any pollinator who visited those flowers would carry the dye to another flower, allowing us to see its movement. We also applied the non-toxic fluorescent dye to the inner edges of the middle layer of the bee hotel located at the bottom of the Biological Sciences Building. We strategically placed the fluorescent dye in locations where one end of a garden plot had been given dye, leaving all other regions within the garden untouched with dye. By doing this, we were able to discover if pollinators were moving across the entirety of a specific pollinator habitat. The dye was applied during the day followed by us returning at night with a portable UV black light to scan over the flowers of each garden and the hotel. We visibly observed if and where the pollinators moved and transferred the dye to the untouched flowers and the bee hotel.

The results of this experiment demonstrated that there is in fact strong movement and connectivity of pollinators within each garden plot. The movement can be seen in Figure 4.16 as arrows representing the direction of movement of pollinators within each garden plot and bee hotel. We found that the fluorescent dye had been transferred from flowers within one region of the garden at the Samuel T. Dana Building to another region that we had not placed the dye. We found similar results within the garden plots of the Biological Sciences Building as well as within the bee hotel. This relatively simple experiment was able to successfully illustrate the connectivity of pollinators within each garden plot and within the bee hotel that we tested for and could be repeated to more closely track movement in this and other areas. This approach can be used by students and other interested groups in the future to analyze and explore the connectivity between different gardens on campus, and even how campus spaces connect with non-UM properties. Data collected from experiments like this can greatly enhance our understanding of the effectiveness of pollinator habitats as well as corridors and pathways on campus.

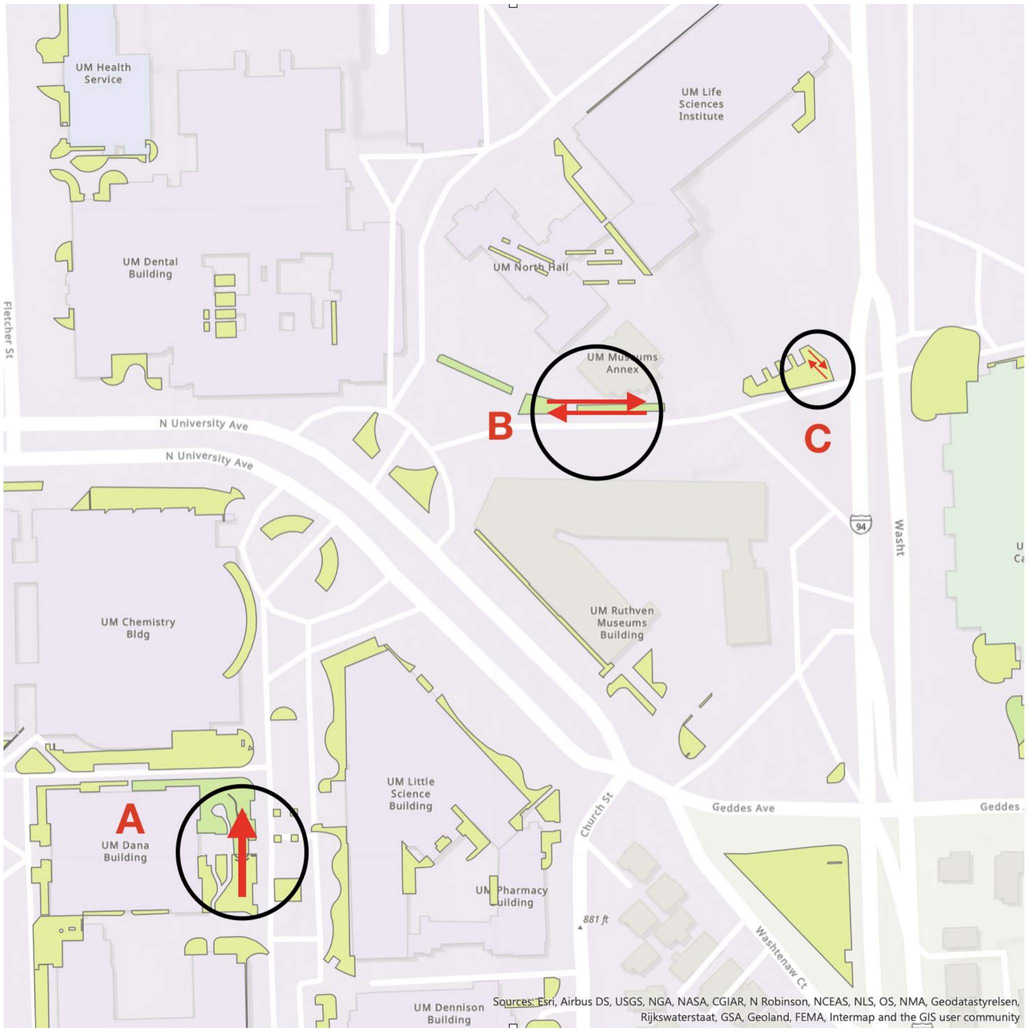


Figure 4.16. Fluorescent dye experiments showed movement within each garden.

Combining Site and Landscape-level Data: Habitat Suitability Analysis

A habitat suitability analysis (HSA) is one analytic tool that can combine site- and landscape-scale data to quantify the quality of pollinator habitat across the campus landscape. With data collected by the campus pollinator habitat assessment over multiple seasons and years and related landscape-scale data, areas of high quality can then be prioritized for expansion or enhanced connectivity with nearby, perhaps isolated, patches. Specifically, HSA combines spatial habitat data layers that have been weighted based upon each habitat characteristic's importance for pollinators, then calculates and visualizes the total score of each potential habitat (green space on campus). The scores represent how "healthy" the habitat (green space) is. Future management could then be developed based on the level of "health" (score) of each habitat (green space).

A Habitat Suitability Analysis for UM campus could, for example, use some of the most important site-scale variables included in the campus pollinator assessment: floral resources (assessed as the percent of flower blooming, and diversity of superfood plants of each planting bed), the diversity of nesting and overwintering support, and the number of pollinators observed (who and how often). Each category of each variable could be given a different score based upon its importance to pollinators. All of these factors will represent site-scaled data and represent 60% of the entire analysis. In our literature review, we discussed the fact that landscape-level variables affect pollinator populations as well, but not as strongly as site-level characteristics. Therefore, 40% weight of the entire analysis could be given to the landscape-level variables. To explore what some possible landscape-level variables are, we review a HSA model for bumble bees in the city of Madison, Wisconsin: *Suitability Evaluation and Neighborhood Design for Pollinator Habitat, City of Madison, Wisconsin* (Tian, 2016). Three landscape-scale variables that are crucial for high-quality pollinator habitat were included in the HSA model for bumble bees:

1. *Soil drainability*. For underground nesting bee species, like bumblebee, soil drainability is considered to be an important variable of nesting habitat. Generally, a moderately well drained soil environment can not only provide underground nesting bees with relatively good air circulation conditions, but also mitigate the possibility for the nest to be flooded by the runoff retained in soils after rainfall. Therefore, well-drained soil (e.g., Group A) is an important component of high-quality pollinator habitat.
2. *Aspect & Sun exposure*. Native pollinators have a preference for south facing slopes since in the northern hemisphere south facing slopes usually receive the most sunlight. According to *ATTRA | Sustainable Agriculture Program | Shop*, n.d, most native bees which thrive in sun and dry soils prefer south facing slopes to slopes of other aspects. Further, based on the theory of (Dauber et al., 2003) south facing slopes tend to have higher floral diversity and more food resources (e.g., pollen and nectar) in areas with more sunlight. Flat areas are considered to be the least attractive to pollinators since they receive the least sunlight compared to slopes of aspects regardless of north or south hemispheres.
3. *Water proximity*. Water is needed not only to maintain cellular balance and body temperature of adult bees, but to feed brood and maintain the hive temperature on hot days (Page et al., 1995) Generally, bees' and beehives' need of water can be met by the collection of nectar. However, in some cases, bees have to "intentionally collect water from nearby lakes, ponds, or streams when nectar supply is deficient or during hot and dry weather"(Härtel & Steffan-Dewenter, 2014) Therefore, it is theoretically easier for bees to condition their body

temperature when flying and to enhance their adaptability to climate changes if they nest or forage closer to water bodies. Specifically, less than 800 ft is considered as an ideal distance between water and beehive.

These three landscape-scaled variables of high-quality pollinator habitat are relatively general, and the data should be easy to find in a local GIS data library. More variables can be included in HSA in the future if necessary. The scores given to each category of each variable should be customized depending on the intention of the analysis. By comprehensively analyzing both landscape-scaled variables and important site-scaled variables included from campus pollinator habitat assessment, higher-quality pollinator habitats on campus can be prioritized and further be enhanced and/or connected with nearby green spaces. Therefore, HSA can be an effective tool using ground-truth data (collected by campus pollinator habitat assessment tool) to enhance and manage pollinator habitats on campus in the long run.

Conclusions and Recommendations

This chapter provides guidance on using three tools for analyzing existing campus habitat and pollinator populations for future decision-making: the Survey 123 pollinator habitat assessment survey, fluorescent dye studies to text for pollinator movement, and Habitat Suitability Analysis. With additional data collection, these tools can be used to answer the following questions:

Site-scale

- Campus Pollinators
  - What pollinators are on campus?
  - Which pollinators are abundant/rare on campus?
  - How does the pollinator community change seasonally?
  - Where do we see an abundance of pollinators? A high diversity?
  - Do different species have different spatial occurrences?
- Campus Habitat
  - What floral resources (abundance/diversity) are on campus and where are they?
  - Of the beds that are “high” blooming, what plant species are present?
  - Where are other habitat resources on campus?
  - What superfoods/specialist/larval habitat is on campus & where?
  - How do resources change seasonally and spatially?
- Relationship between Pollinators & Habitat
  - How do floral resources influence pollinator abundance and diversity?

- Do beds with more native plants (or “nativars”) attract greater pollinator abundance or diversity?

Connectivity

- Pollinators on Campus
    - Are pollinators present/moving within gardens on campus?
    - Are pollinators present/moving between gardens on campus?
- Pollinator Habitats on Campus
    - Are pollinator habitats on campus close enough in proximity to promote connectivity between gardens?
    - Are pollinator habitats on campus too far away from each other to promote connectivity between gardens?
    - Should there be additional pollinator gardens installed between already-existing pollinator habitats to enhance connectivity between gardens and overall pollinator movement across campus?
    - Would installing bee hotels adjacent to already-existing pollinator habitats on campus increase connectivity between pollinator gardens?
- Pollinator Corridors on Campus
    - What current pollinator habitats already exist on campus as pollinator corridors?
    - Where can future pollinator habitats be installed on campus to further increase pollinator corridors?
    - Can the installation of bee hotels between pollinator gardens act as buffers that strengthen pollinator corridors on campus?

Landscape-scale

- What is the overall quality of pollinator habitats considering both site- and landscape-scale variables?
    - Which green spaces/patches should be prioritized to be enhanced? In what ways?
    - Which green spaces/patches should be prioritized to be connected with others? With which one(s)?
    - To fill the “gaps”, where should the new pollinator habitats be located?

Recommended Next Steps

Based on our limited pilot data analysis and observations so far, we recommend several management actions and additional research to improve pollinator habitat resources on campus. For pollinator groups that are not well-represented on campus, providing targeted habitat improvements such as host plants for butterflies and foraging resources for specialist bees may support these relatively rare species. Despite the aesthetic challenges of leaving cut stems and piles of leaves, there was a surprising abundance of structural habitat resources on campus. We recommend that less-visible areas on campus are identified and maintenance instructions adjusted to include leaving some leaf litter to support overwintering pollinators. As floral density, diversity, and seasonal availability are important factors that influence the pollinator community in urban landscapes (see Chapter 2) gaining a more detailed understanding of the floral resources on campus would improve the understanding of campus pollinator habitat. With this in mind, we also recommend a floral inventory of landscape plants to quantify the availability of seasonal pollen and nectar resources and identify any gaps in flowering phenology. To make future recommendations, we suggest using the three proposed tools to conduct additional research with the following priorities:

1. Adjust survey questions to increase data accuracy (e.g., floral density question) and then use the Survey 123 campus habitat assessment to thoroughly survey all central campus sites across all growing seasons and over at least two years to gain a baseline understanding of the local pollinator community.
2. Complete replications of the fluorescent dye connectivity study within and between all pollinator habitat sites across campus to better understand pollinator movement, connectivity, and corridors
3. Identify crucial site- and landscape- scale variables and obtain reliable data to do regular HSAs for continuously monitoring the quality of pollinator habitats on campus and informing working directions of landscape-scale pollinator conservation.

Overall, these on-the-ground actions and research approaches can inform adaptive management of the campus landscape over time to create an evolving mosaic that integrates pollinator conservation with campus aesthetics.

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CHAPTER 5 – **CAMPUS POLLINATOR HABITAT DESIGN AND MAINTENANCE RECOMMENDATIONS**

Introduction

Suburban landscapes and those who maintain them face enormous pressure to achieve conflicting maintenance and social expectations. Suburban landscaping practices, especially within large, land-owning institutions, are often limited by important safety and maintenance requirements. In addition, aesthetics is a key cultural aspect of suburban landscapes, so clean, legible design is paramount to meeting social expectations. These expectations and requirements can limit design creativity, often resulting in simplified, "cookie cutter" landscapes that replicate the same ubiquitous plant species in parking lots and border plantings across the country. When viewed through the compound eyes of a pollinator, these homogenous landscapes offer little diversity of flower shapes, seasonal food resources, or nesting and overwintering substrates. These constraints can instead be seen as opportunities for creative solutions that have the potential to transform our cultural norms of what urban landscapes look like and who they serve. By broadening our plant palette and integrating landscape function goals into these plantings, we can achieve all cultural, safety, maintenance, and aesthetic expectations while supporting local ecologies, sequestering carbon, capturing stormwater, reducing urban heat island effect, and celebrating a strong sense of place.

Combining the cultural needs of campus landscapes with pollinator-friendly garden characteristics suggested by the literature (see Chapter 2) we are left with a key question: What do pollinator-friendly campus landscapes look like in practice and how are they maintained? This chapter provides samples of easy-to-replicate garden designs for use in four common landscape scenarios on campus. Using two of these designs as a starting point, our team designed and installed a new pollinator garden at the Museum of Natural History in October 2020. This experience is included here as a Case Study with advice for integrating educational value with an internship position and programming through the Museum of Natural History. We include pollinator-friendly maintenance recommendations for use in this and other campus landscapes. We also emphasize the essential relationships and people that made this new garden possible. By fostering these relationships between people and local landscapes, we believe that a pollinator-friendly campus achieves multiple benefits of building resilient local ecologies, supporting human health and wellness, and reconnecting people with nature.

Design Typologies

In this section we aim to provide four replicable garden typologies that provide multifunctional benefits to people and pollinators in a campus or suburban setting. A typology describes a design solution for a particular set of conditions. The proposed typologies represent planting templates for four common site conditions seen across the University of Michigan's Central Campus in Ann Arbor, MI. These recommendations meet the main goals of:

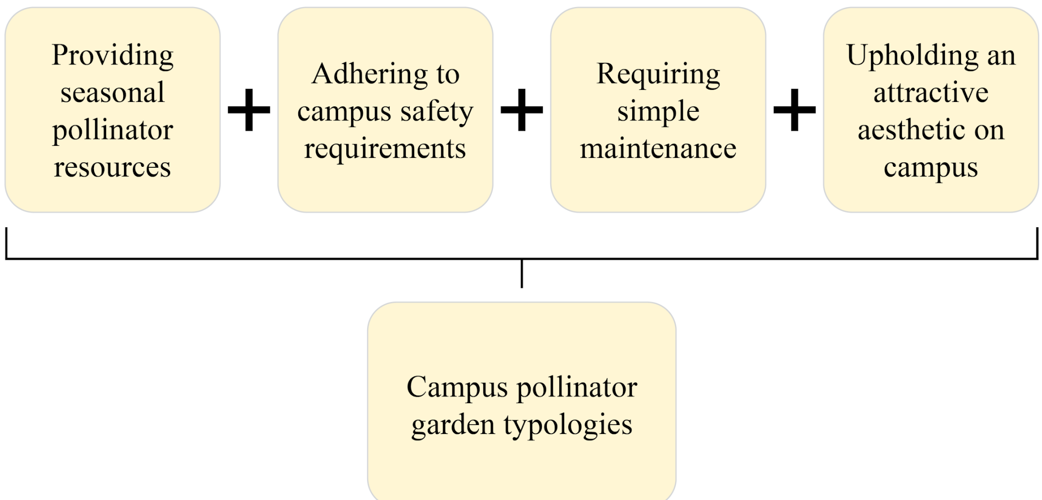


Figure 5.1 Guiding principles for creating campus pollinator garden typologies.

Each typology meets four main goals of addressing pollinator needs, campus safety, ease of maintenance, and cultural aesthetics (Figure 5.1). There are many key features of pollinator-friendly landscapes that are supported by research (see Chapter 2). The features most frequently found to be important were considered in creating these typologies, which include high floral diversity and abundance, high diversity and density of native plants, sufficient floral resources throughout the growing season, and diverse floral shapes. In terms of vegetation height, the UM Division of Public Safety and Security requires that vegetation height be less than 3 feet or canopy height greater than 6 feet to provide clear visibility on campus. The typologies also consider ease of maintenance by using seven species or less planted at a high density that will form a tightly growing mass to shade out weeds. Several cultivated native plants (i.e., "nativars") are used that have been selected for superior landscape performance characteristics, such as drought tolerance, tidy habit, or more attractive blooms. Finally, the designs feature plants that are visually attractive, including beautiful flowers and foliage, with an emphasis on plants that provide multiple seasons of interest. These ecological and social goals inform the proposed typologies, creating design solutions that provide multiple, campus-specific benefits.

The typologies provide design solutions for four common site conditions on campus that can be easily replicated or modified as needed. Each typology is 200 sq. ft. in size as this area is easy to replicate and useful for Grounds Services to apply in a variety of campus locations. The 200-square-foot templates can be repeated to fill a larger garden bed or spread across a larger landscape to provide a cohesive look. As such specific landscape designs are not already available, we created four layouts with lists of additional plant species that can be substituted within each topology. We propose four typologies:

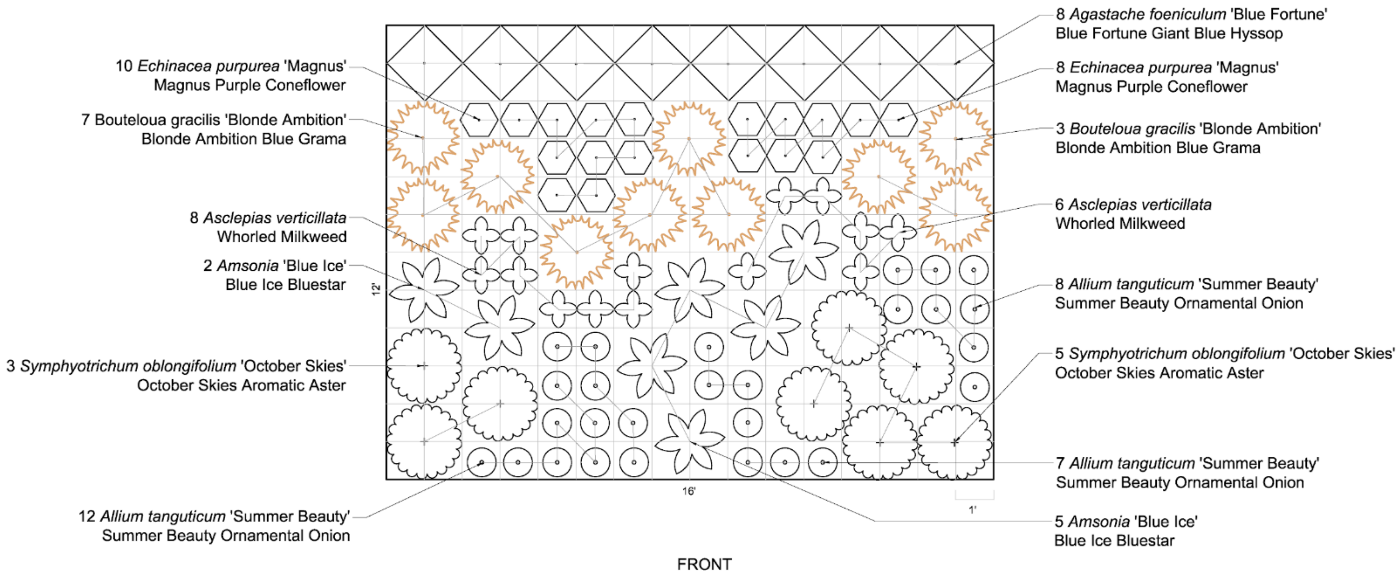
Typology 1: Full sun, medium moisture, high visibility (e.g., showy sidewalk garden)

Typology 2: Shade, dry, high visibility (e.g., under tree canopy)

Typology 3: Part sun, frequently wet (e.g., rain garden)

Typology 4: Shade, medium moisture, low visibility (e.g., foundation hedge)

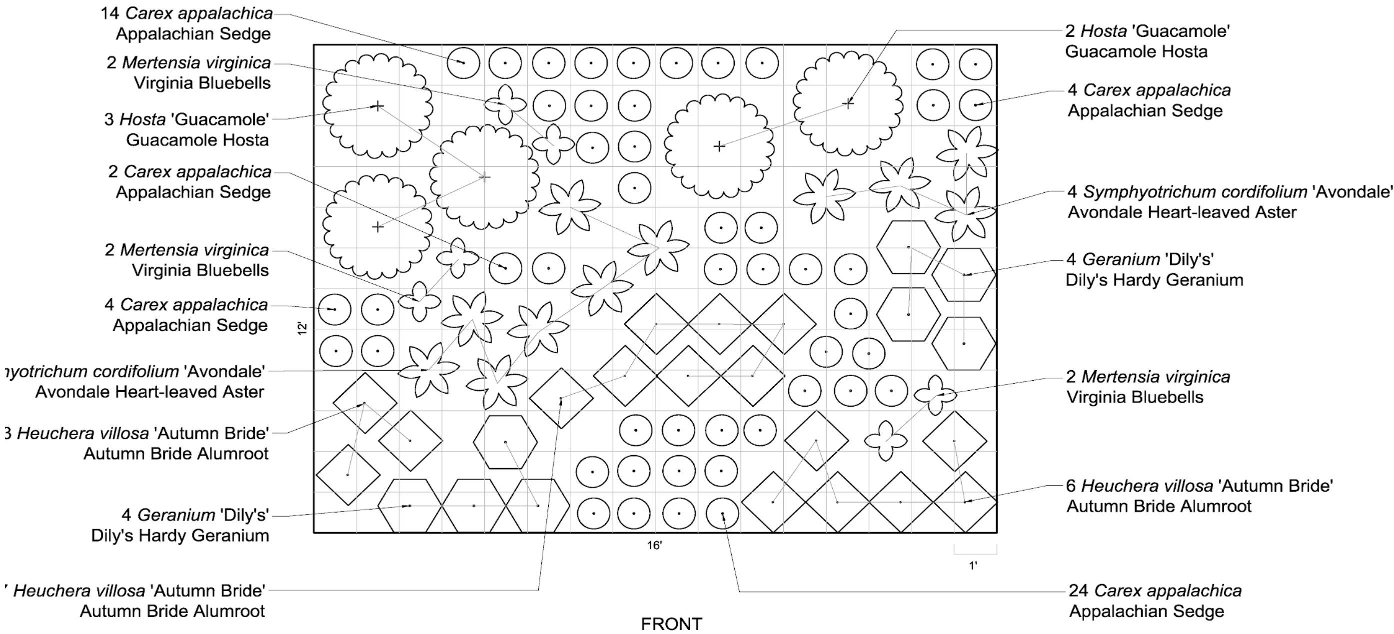
Typology 1: Full sun, medium moisture, high visibility (e.g., showy sidewalk garden)



Form	Common Name	Botanic name	Qty.	Size	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Grass	Blonde Ambition blue grama	*Bouteloua gracilis* 'Blonde Ambition'	10	#1	S - PSh	Dry - Med	2.5'	2'	Aug - Oct	Green	wind-pollinated	Y	Y	Clump grass provides overwintering substrate	Butterflies, moths, large carpenter bees, hummingbirds
Flowering	Blue Fortune anise hyssop	*Agastache foeniculum* 'Blue Fortune'	8	#1	S - PSh	Med	2 - 3'	1.5 - 2'	July - Oct	Purple	tubular	Y	N	Nectar source	Bumble bees, small resin bees, leafcutter bees, long-horned bees
	Summer Beauty ornamental onion	*Allium tanguticum* 'Summer Beauty'	27	#1	S	Dry - Med	1.5 - 2'	1'	July - Aug	Pink	umbel	Y	Y	Nectar and pollen source	Bumble bees, honey bees, butterflies, and moths
	Blue Ice bluestar	*Amsonia* 'Blue Ice'	7	#1	S - PSh	Dry - Med	1'	1.5 - 2'	May - June	Blue	tubular	Y	Y	Nectar source	Butterflies and moths
	Whorled milkweed	*Asclepias verticillata*	14	4" pot	S - PSh	Dry - Med	2'	1'	July - Aug	White	umbel	Y	Y	Larval host for monarch and queen butterflies. Nectar and pollen source.	Honey bees, bumble bees, sweat bees, wasps, syrphid flies, butterflies, skippers
	Magnus purple coneflower	*Echinacea purpurea* 'Magnus'	18	#1	S - PSh	Dry - Med	2.5 - 3'	1'	June - Sept	Pink	composite	Y	Y	Nectar and pollen source	Mining bees*, long-horned bees, sweat bees, green sweat bees, leafcutter bees, bumble bees, butterflies, beetles
	October Skies aromatic aster	*Symphyotrichum oblongifolium* 'October Skies'	8	#1	S - PSh	Dry - Med	1 - 1.5'	1.5 - 2'	Sept - Oct	Purple	composite	Y	Y	Nectar and pollen source. Larval host for 109 species of caterpillars.	Metallic green sweat bees, long-horned bees, sweat bees, small carpenter bees, mining bees*, bumble bees, cellophane bees*

* specialist pollinator
Designs by Rachelle Roake

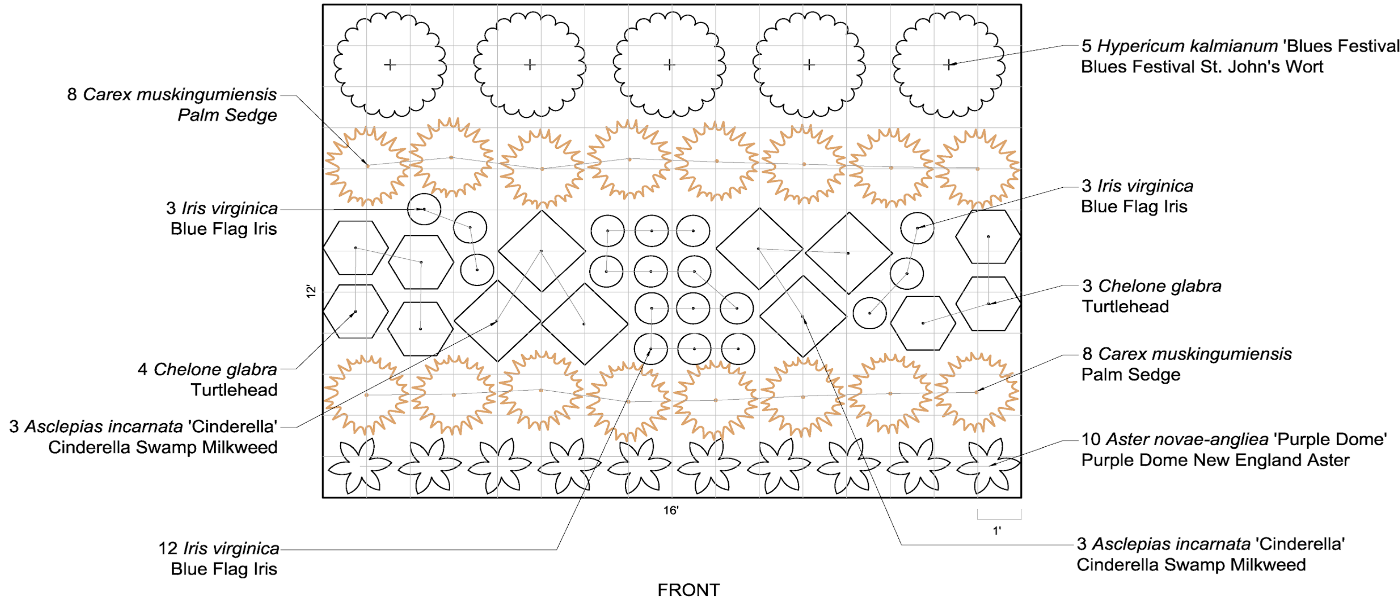
Typology 2: Shade, dry, high visibility (e.g., under tree canopy)



Form	Common Name	Botanic name	Qty.	Size	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Grass	Appalachian sedge	*Carex appalachica*	48	4" pot	PSh - Sh	Dry - Med	1'	1'	May	Green	wind-pollinated	Y	Y	Larval host for 36 species of caterpillars	
Flowering	Dily's hardy geranium	*Geranium* 'Dily's'	8	#1	S - PSh	Med	1'	1.5'	June - Sept	Pink	open/cup	Y	Y	Nectar and pollen source	Small carpenter bees, sweat bees, mason bees, mining bees, bumble bees, cuckoo bees, syrphid flies
	Autumn Bride alumroot	*Heuchera villosa* 'Autumn Bride'	16	#1	S - PSh	Med	2'	1.5'	Aug - Sept	White	tubular	Y	Y	Nectar and pollen source	Sweat bees, cellophane bees*
	Guacamole hosta	*Hosta* 'Guacamole'	5	#1	PSh - Sh	Med	1.5'	2.5 - 3'	Aug - Sept	White	tubular	N	Y	Nectar and pollen source	Bees, hummingbirds
	Virginia bluebells	*Mertensia virginica*	6	bare root	PSh - Sh	Med	1 - 2'	1'	Apr - May	Blue	tubular	Y	N	Early spring pollen and nectar source	Bumble bees, honey bees, mason bees, bee flies, butterflies, skippers, sphynx moths, sweat bees
	Avondale heart-leaved aster	*Symphyotrichum cordifolium* 'Avondale'	11	#1	S - PSh	Med	2 - 3'	1'	Aug - Sept	Lavender	composite	Y	Y	Larval host for 109 species of caterpillars	Long-tongued and short-tongued bees, wasps, flies, skippers, butterflies, beetles

* specialist pollinator
Designs by Rachelle Roake

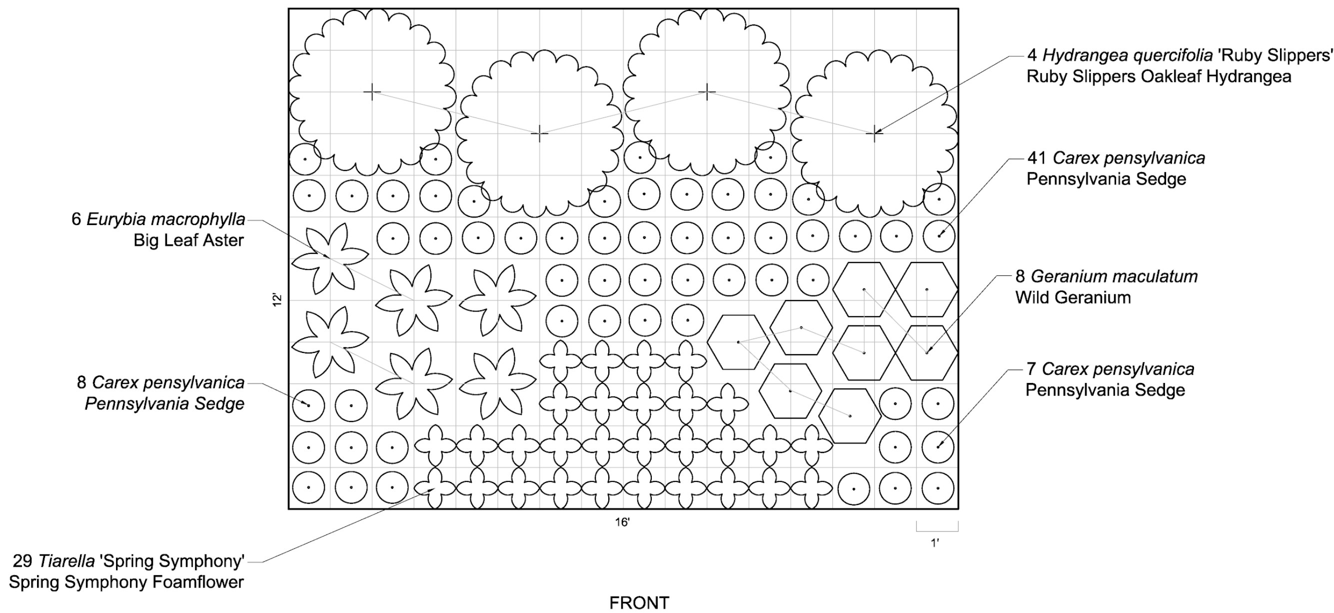
Typology 3: Part sun, frequently wet (e.g., rain garden)



Form	Common Name	Botanic name	Qty.	Size	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Grass	Palm sedge	*Carex muskingumiensis*	16	4" pot	S - Sh	Med - Wet	2'	2'	May - June	Green	wind-pollinated	Y	Y	Larval host for 36 species of caterpillars	
Flowering	Cinderella swamp milkweed	*Asclepias incarnata* 'Cinderella'	6	#1	S - PSh	Med - Wet	3 - 4'	2 - 3'	July - Aug	Pink	hood	Y	Y	Larval host for monarch and queen butterflies. Nectar resources only.	Butterflies and moths including skippers, monarchs, fritillaries, sulphurs, whites, and swallowtails. Variety of bees, wasps, ants, beetles, flies, and bugs.
	Purple Dome New England Aster	*Aster novae-angliae* 'Purple Dome'	10	#1	S - PSh	Med - Wet	1.5'	1.5'	Sept - Oct	Purple	composite	Y	Y	Nectar and pollen source. Larval host for pearl crescent and Canadian sonia moth.	Butterflies and moths, mining bees*, small carpenter bees, leafcutter bees, bumble bees, honey bees, long-horned bees, cuckoo bees,
	Turtlehead	*Chelone glabra*	7	4" pot	S - PSh	Wet	2 - 4'	1 - 2'	Aug - Sept	White	bilabial	Y	N	Nectar. Larval host for Baltimore checkerspot butterfly.	Bumble bees, two-spotted long-horned bees
	Blue Flag Iris	*Iris versicolor*	18	4" pot	S - PSh	Med - Wet	2.5'	1'	May - July	Blue	tubular	Y	Med	Nectar and pollen source	Bumble bees, long-horned bees, butterflies and moths
Shrub	Blues Festival Kalm's St. John's Wort	*Hypericum kalmianum* 'Blues Festival'	5	#5	S - PSh	Med - Wet	3'	3'	June - Aug	Yellow	open/cup	Y	Y	Pollen. Larval host for black arches moth and gray half-spot moth.	Leafcutter bees, sweat bees, green sweat bees, syrphid flies, bumble bees, banded long-horned beetles

* specialist pollinator
Designs by Rachelle Roake

Typology 4: Shade, medium moisture, low visibility (e.g., foundation hedge)



	Common Name	Botanic name	Qty.	Size	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Grass	Penn sedge	*Carex pensylvanica*	56	4" pot	PSh - Sh	Dry - Med	1'	1.5'	Apr - May	Green	wind-pollinated	Y	Med	larval host (eyed brown, Appalachian brown, dion skipper, broad winged skipper, mulberry wing, dun skipper)	
Flowering	Wild geranium	*Geranium maculatum*	8	4" pot	F - PSh	Med	1.5'	1'	May - June	Pink	open/cup	N	N	nectar, pollen, larval host (leafmining moth, white-marked tussock moth)	Mining bees*, small carpenter bees, sweat bees, mason bees, mining bees, bumble bees, cuckoo bees, syrphid flies, thick-headed flies, fruitworm
	Big leaf aster	*Eurybia macrophylla*	6	4" pot	PSh - Sh	Dry - Med	1 - 3'	2'	Aug - Oct	Lavender	composite	Y	Med	Larval host for silvery checkerspot, pearl crescent butterfly, and goldenrod hooded owlet. Late pollen and nectar	Mining bees*, bumble bees, yellow-faced bees, long horned bees, green sweat bees, small sweat bees, syrphid flies
	Spring Symphony foamflower	*Tiarella cordifolia 'Spring Symphony'*	29	#1	PSh - Sh	Med	0.5 - 0.75'	1'	Apr - June	Lt. Pink	tubular	Y	N	Early spring pollen and nectar source	
Shrub	Ruby Slippers oakleaf hydrangea	*Hydrangea quercifolia 'Ruby Slippers'*	4	#5	S - PSh	Med	3 - 4'	4 - 5'	June - July	White - Pink	tubular	Y	Y	Early summer pollen and nectar source	

* specialist pollinator
Designs by Rachelle Roake

Case Study: Planning and implementation of pollinator habitat enhancement at the Museum of Natural History

The intent of this Case Study is to provide a concrete example of the implementation of a campus pollinator-friendly garden using a modified version of Typologies 1 and 4. Here we give a description of why this site was selected, how the garden was created, and how it can be maintained, including specific guidelines for summer interns who will care for the garden during its first few seasons.

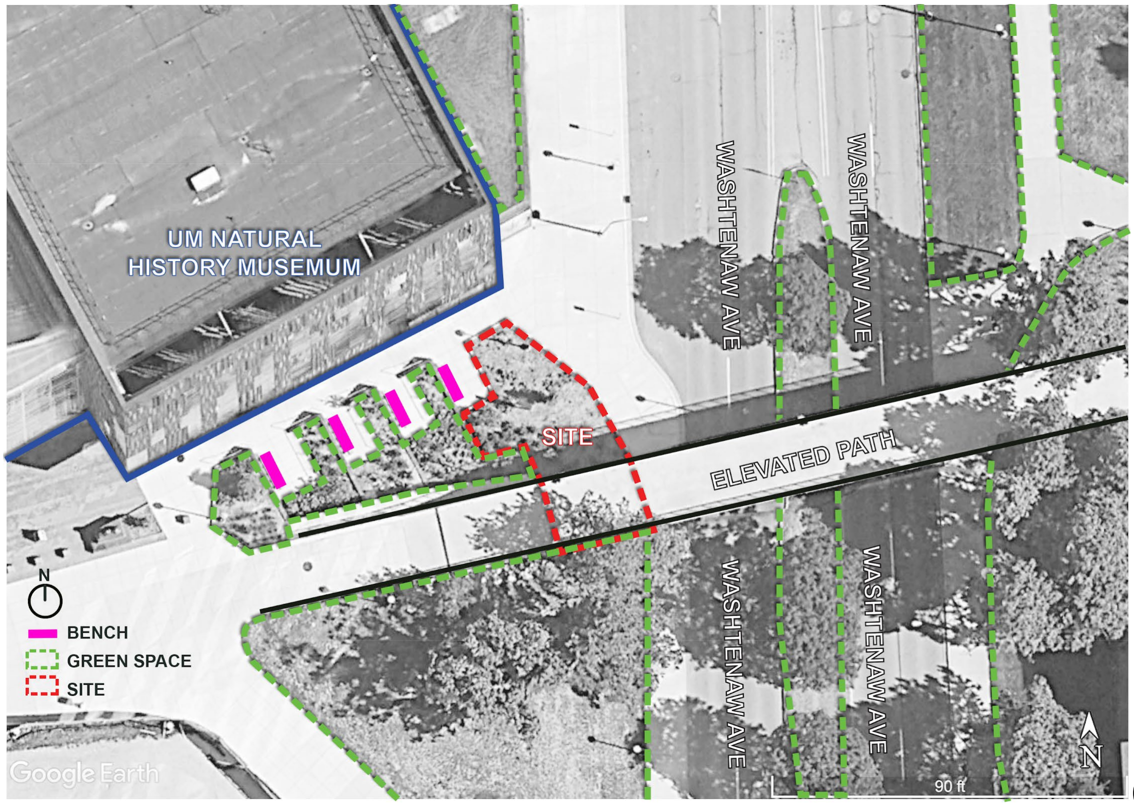
After conducting field surveys of central campus (see Chapter 3) and identifying an existing habitat corridor (see Chapter 4), our team collaborated with Grounds Services and Museum of Natural History staff to design and implement a native pollinator garden to expand the existing pollinator hotspot and facilitate pollinator movement across the landscape. While the native pollinator gardens at the main entrance of the Museum of Natural History were thriving and full of pollinators, the gardens around the Washtenaw Avenue entrance had failed, leaving large patches of bare mulch in a highly visible area (Figure 5.1). The original intent of this garden was to show prehistoric plant assemblages, including ferns and redwood trees, as an educational display; however, when the irrigation lines were shut off for a nearby construction project, many of the drought-intolerant plants died on the exposed site. Based on its proximity to the pollinator hotspots at the Museum of Natural History main entrance and the Dana Building (see Chapter 4), it was identified as an ideal candidate for pollinator habitat improvement.

Figure 5.2 After irrigation lines were shut off for nearby construction, many of the drought-intolerant plants died, leaving bare mulch and few floral resources for pollinators in a highly visible area of the Museum of Natural History gardens.

Landscape design rationale & process

The design team assessed landscape context, site conditions, the previous site design, and client needs to determine a suitable plant species list and layout (Figure 5.2). Plant species were selected for site condition preferences, drought tolerance, compact and tidy form, and pollinator resources (Table 5.1). Key features selected to support pollinators include high floral diversity and abundance, all native plants, floral resources throughout the growing season, and floral shape diversity. This list was further refined by local nursery availability, transplant availability, Museum of Natural History staff aesthetic preferences, and Grounds Services recommendations.

The most successful landscape designs consider not only the physical context, but also the historic and cultural context of a site. Transplants from County Farm Park have historic significance to the Museum of Natural History, as they originated from the former pollinator garden that welcomed visitors to the Ruthven Building, which housed the Museum of Natural History until 2017 (*"A Safe Haven for Our Garden"*, 2017). Mary Duff-Silverman, Museum of Natural History Docent and Master Gardener, planted the garden in 2004 and volunteered to maintain the space through its transition to County Farm Park and back to the Museum's new location at the Biological Sciences Building. A relationship such as this, between one dedicated person and one special place, is rare. It is this personal connection to a campus landscape that we hope to inspire through this project; the ultimate goal is to create strong bonds between ecosystem health and human health.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HISTORY MUSEMUM
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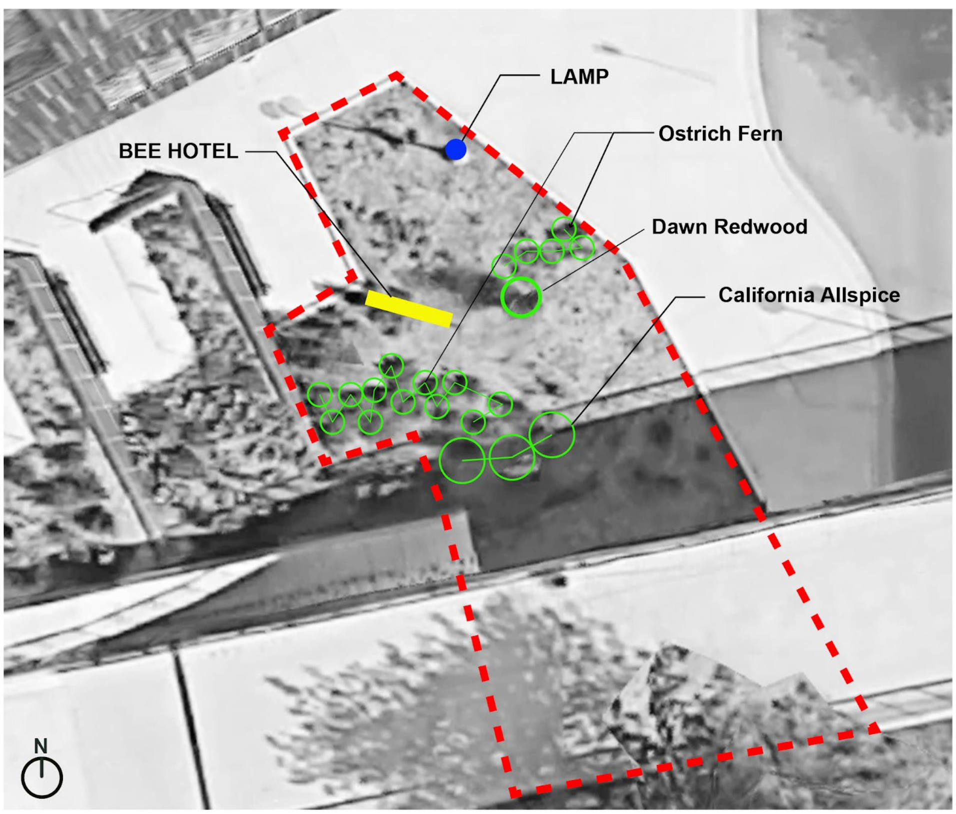
(A)


LAMP
BEE HOTEL
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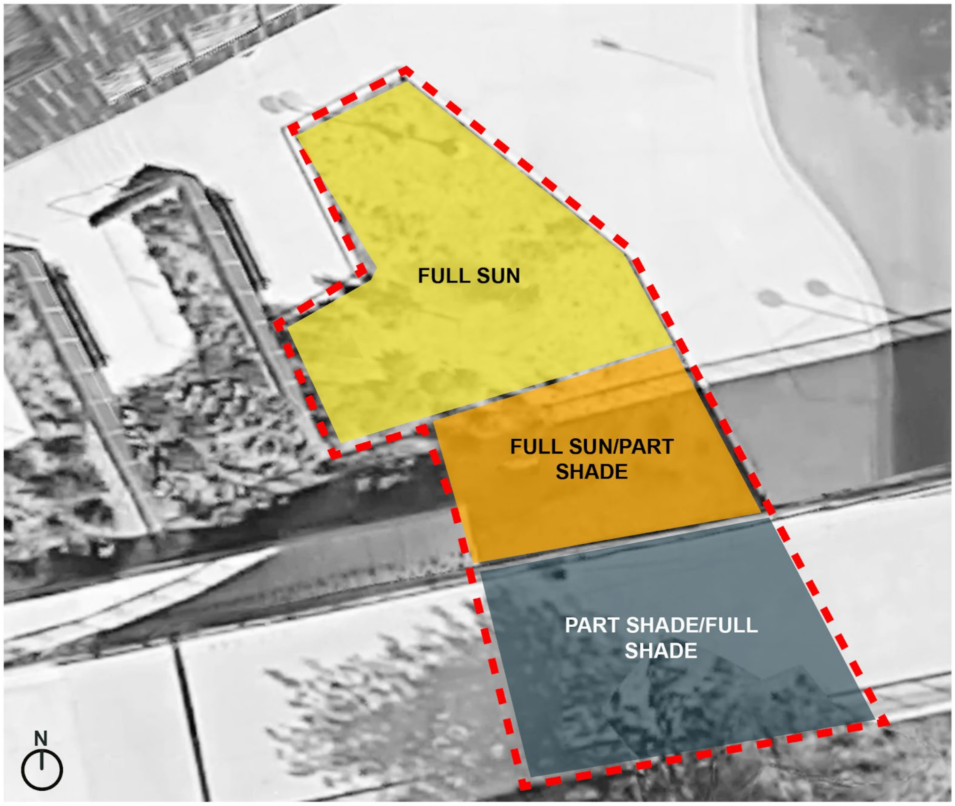

(C)

Figure 5.3 As part of our design process, the site analysis considered context (A), existing features (B), and light and moisture availability (C).

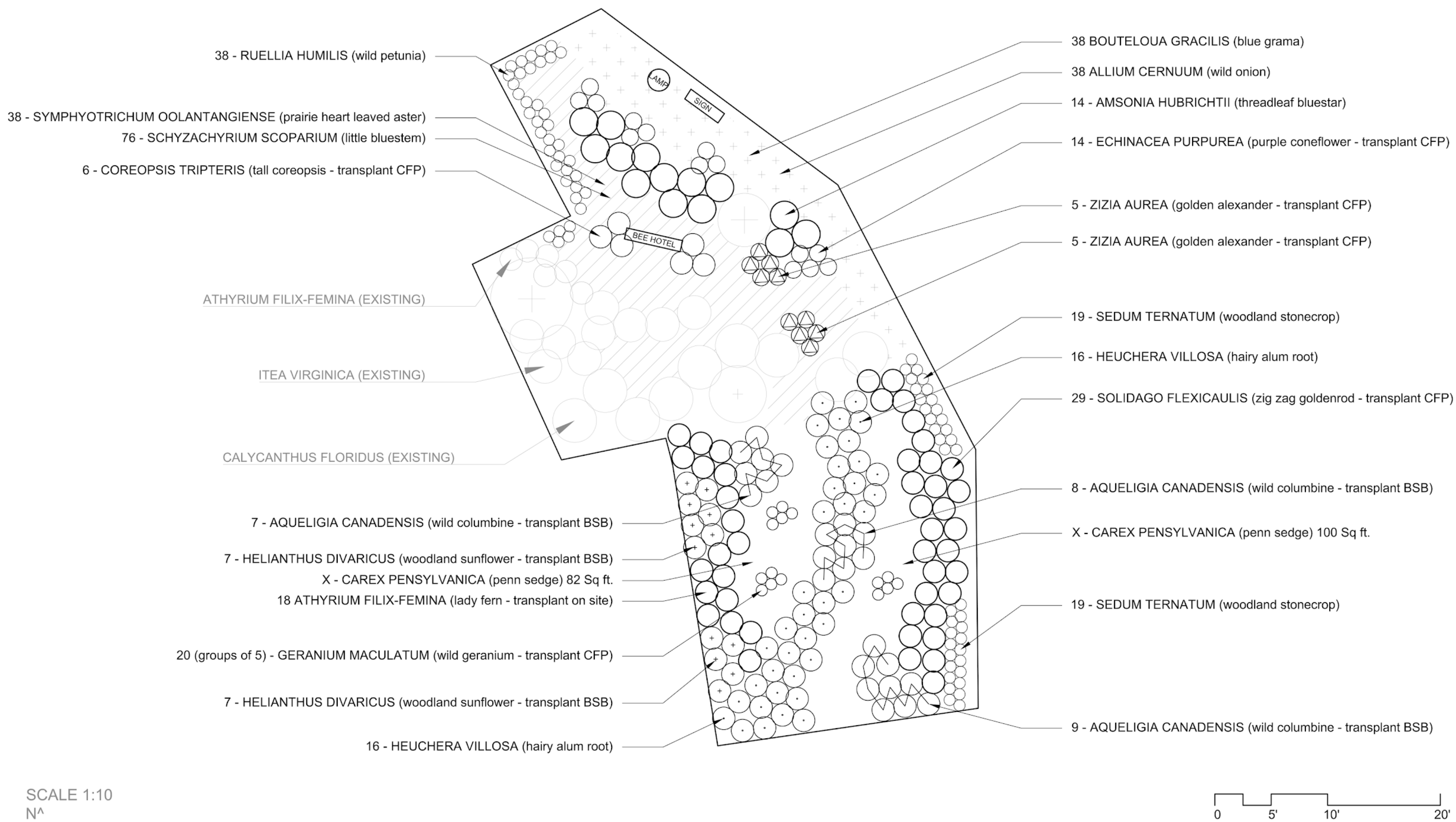

Figure 5.4 Fall 2020 Planting plan for Biological Sciences Building Pollinator Garden.

Table 5.1 Plant characteristics & pollinator resources chart for the plants chosen for pollinator enhancement of the Biological Sciences Building Pollinator Garden. Plants are sorted by bloom time to illustrate how chosen plants provide nectar and/or pollen resources throughout the growing season.

Common name	Botanic name	Form	Ht (ft.)	W (ft)	Bloom time	Bloom color	Flower shape	Pollinator resource	Pollinators
Penn sedge	*Carex pensylvanica*	Grass	1’	1.5’	Apr - May	Green	wind-pollinated	larval host (eyed brown, Appalachian brown, dion skipper, broad winged skipper, mulberry wing, dun skipper)	
Wild columbine	*Aquilegia canadensis*	Flowering	2'	2’	May - July	Red	nodding	nectar, pollen, larval host (columbine duskywing butterfly, columbine borer moth)	Bumble bees, bumble bee queens, sweat bees, long-tongued bees, hummingbirds
Golden Alexander	*Zizia aurea*	Flowering	2.5'	1.5’	May - June	Yellow	compound umbel	nectar, pollen, larval host (black swallowtail, Ozark swallowtail, rigid sunflower borer)	Mining bees*, mason bees, bumble bees, sweat bees, yellow-faced bee, small carpenter bee, potter wasp, paper wasp, syrphid flies, tachinid flies, azure butterflies, ebony bugs, soldier beetles
Wild geranium	*Geranium maculatum*	Flowering	1.5'	1’	May - June	Pink	open/cup	nectar, pollen, larval host (leaf mining moth, white-marked tussock moth)	Mining bees*, small carpenter bees, sweat bees, mason bees, mining bees, bumble bees, cuckoo bees, syrphid flies, thick-headed flies, fruitworm beetle
Woodland stonecrop	*Sedum ternatum*	Flowering	0.5'	1’	May - June	White	open/cup	nectar, pollen	Small bees, mining bees, wasps, flies
Purple coneflower	*Echinacea purpurea*	Flowering	3'	1.5’	June - Aug	Purple	composite	nectar, pollen	Bumble bees, leafcutter bees, butterflies (monarchs, red admirals, sulphurs, fritillaries, swallowtails), banded long-horn beetle
Wild petunia	Ruellia humilis	Flowering	1'	1.5’	June - Aug	Lavender	tubular	nectar, pollen, larval host (common buckeye)	Sweat bees, small carpenter bees, green sweat bees, syrphid flies, leafcutter bees, butterflies, moths
Threadleaf blue star	*Amsonia hubrichtii*	Flowering	3'	2.5’	July	Blue	tubular	Nectar	Long-tongued bees, carpenter bees, hummingbird moths, butterflies, hummingbirds

Common Name	Botanic name	Form	Ht (ft.)	W (ft)	Bloom time	Bloom color	Flower shape	Pollinator resource	Pollinators
Wild onion	*Allium cernuum*	Flowering	1.5'	1’	July - Aug	Pale pink	nodding	nectar, pollen	Leafcutter bees, small resin bees, sweat bees, bumble bees, cellophane bees, soldier beetles, tumbling flower beetles, syrphid flies
Blue grama	*Bouteloua gracilis*	Grass	1.5'	2’	July - Aug	Green	wind-pollinated	nesting & overwintering habitat	
Woodland sunflower	*Helianthus divaricatus*	Flowering	4'	2’	July - Aug	Yellow	composite	nectar, pollen	bumble bees, long-horned bees, sweat bees, spotted cucumber beetle, soldier beetles, syrphid flies, butterflies
Tall coreopsis	*Coreopsis tripteris*	Flowering	5'	2’	July - Sept	Yellow	composite	nectar, pollen	Small carpenter bees, leafcutter bees, small resin bees, cuckoo bees, long-horned bees, sulphur butterflies, moths, beetles, wasps, syrphid flies, ants
Little bluestem	*Schizachyrium scoparium*	Grass	3'	1.5’	Aug	Green	wind-pollinated	nesting & overwintering habitat, larval host (Indian skipper, crossline skipper, cobweb skipper, hobomok skipper, dusted skipper)	
Prairie heart leaved aster	*Symphyotrichum oolentangiense*	Flowering	2.5'	1.5’	Aug - Sept	Blue	composite	nectar, pollen, larval host (pearly crescent, silvery checkerspot, gorgone checkerspot, northern crescent)	Mining bees*, small carpenter bees, leafcutter bees, bumble bees, long-horned bees, cuckoo bees, green sweat bees, bee flies, syrphid flies, soldier beetles
Hairy alum root	*Heuchera villosa*	Flowering	2'	2’	Aug - Sept	White	tiny, nodding	nectar, pollen	Small sweat bees, green sweat bees
Zig zag goldenrod	*Solidago flexicaulis*	Flowering	1.5'	2’	Aug - Sept	Yellow	composite	nectar, pollen, larval host (bilobed dichomeris, brown hooded owlet, twirler moth)	Mining bees*, sweat bees, yellow-faced bees, green sweat bees, bumble bees, thread-waisted wasp, carrot wasp, syrphid flies, soldier beetles
Lady fern	*Athyrium filix-femina*	Fern	2'	2’	None	None	spore		

Garden Implementation

On a sunny October day, 12 volunteers planted nearly 400 native plant plugs and transplanted 30 native plants from County Farm Park, a nearby Washtenaw County Park and project partner (Figure 5.4). Native plant plugs were purchased from Feral Flora (Ann Arbor, MI) and Wildtype Nursery (Mason, MI) and brought on site the day of planting. Museum of Natural History staff purchased the plants using a garden endowment fund and a team member coordinated and transported the plants. The day before planting, team members worked with Grounds Services to borrow tools and work with two employees to dig up and transport plants from County Farm Park. Plants were stored temporarily near the tool shed at the Dana Building parking lot. On the planting day, one team member and a staff member from the Museum of Natural History arrived early to begin plant layout before volunteers arrived so that volunteers could begin as soon as possible. The planting plan was painted onto the pre-mulched ground using grass marking paint and metal flags for labels. When volunteers arrived, they borrowed gloves, shovels, and trowels and began planting the plugs where they lay on the ground. Some volunteers transplanted more plants from the main entrance gardens while others helped with watering. One team member took photographs of the event, while others helped with planting and layout. The team provided snacks and drinks for everyone for a mood and energy boost. Including layout and cleanup, the planting event lasted just six hours. Staff from the Museum of Natural History and Grounds Services watered the new planting as needed, but the fall planting date meant that most plants went dormant soon after planting, therefore limiting watering requirements. We recommend this efficient planting procedure for future events.

Figure 5.5 Photos from the volunteer planting day by Beth Weiler. Upper left: Plant plugs were laid out according to the plan before volunteers arrived. Upper right: Volunteers working to plant the garden. Bottom left: Volunteers followed the paint and flags to easily know where to plant. Bottom middle: Museum of Natural History Director of Education Kira Berman was essential to getting the garden approved, purchased, and planted. Bottom right: Team members Zoe Bliss (left) and Savanna Delise (right) working together to plant the garden.

Future Maintenance

The new pollinator garden will be maintained by a summer intern at the Museum of Natural History to provide valuable educational experience for not only the intern, but the summer camp students as well. Maintaining a garden is a valuable educational experience for young interns who will likely carry this hands-on nature experience with them throughout their lives. Caring for a living garden can build independence and foster a land stewardship ethic that is valuable for mental and physical well-being. As part of this experience, we recommend providing a garden journal for the intern to document dates and descriptions of work completed, seasonal changes in the garden, and interesting pollinator observations. Writing and sketching are great practices to help reflect and learn from observations that may otherwise be fleeting. Incorporating some of these writings, sketches, or photographs into a newsletter, Instagram account, or other social media outlet will further promote these campus pollinator-friendly efforts. The intern will also be expected to lead summer education programming with young school children, so this presents an excellent opportunity for the intern to build intimate knowledge of the pollinator garden which they can then share with summer camp students. In addition to the garden layout and plant list included in this chapter, we include a sample intern job description and maintenance guide in Appendix A. We believe that giving an intern this valuable responsibility will build a strong foundation for this and future pollinator garden efforts on campus.

Pollinator-friendly Maintenance Plan

A Culture of Stewardship

Shifting the culture of landscaping to one of intimate knowledge and care of individual spaces is a necessary foundation for maintaining a diversity of pollinator-friendly landscapes across campus. Traditional landscaping practices today seem to revolve around mechanized efficiency and distancing ourselves from the plants and soil. These practices include broad-spectrum, long-lasting herbicides; thick, broad swaths of mulch between widely spaced plants; motorized, gas-powered trimmers and leaf blowers; and simple, cookie-cutter plantings with only the hardiest of non-native, ornamental plants. Not only do these practices limit or even harm pollinators (see Chapter 2), but they also limit our personal, physical connection to the land as well. By shifting the culture of landscaping to one of personal stewardship that celebrates the differences across our gardens instead of homogenizing landscapes by the lowest common denominator, we can foster site-specific care and knowledge of the plants and animals that live here. We believe that building a culture of stewardship across campus centered around pollinators is a self-reinforcing cycle; one that will improve pollinator habitat, attracting more pollinators, which can inspire pride and strengthen relationships between the people who care for the habitat, and so on. Through this cycle we can build a campus community of stewards that celebrate and share local victories for pollinators and people.

War on Weeds

Garden maintenance often equates to weeding, but one goal of the designs is to provide natural weed suppression using a layered, tightly spaced planting that maximizes pollinator resources. Essentially, this approach uses living plants instead of manual labor, mulch, landscaping fabric, or chemicals to suppress weeds. This has the added benefit of providing more plant material per square foot, which provides more habitat for pollinators. However, this plant-based weed suppression does not take effect until after the young plants are well-established which can take *up to three years*. During that time, hand weeding is essential to remove annual or biennial weeds. This hand weeding does not have to be time or labor intensive. If well-timed and performed frequently enough to remove weeds while they are small, weeding can be a simple, even enjoyable task. With positive reframing, working in the garden can provide a time for mindfulness, mental restoration, and stress reduction (Hunter et al., 2019). The following maintenance recommendations are largely paraphrased from *The Know*

Maintenance Perennial Garden by Roy Diblik (Diblik, 2014), which emphasizes *knowing* your plants as a way to reduce garden maintenance.

Pollinator-friendly Maintenance Practices

Maintenance Practices: We have identified two checklists of research-based, pollinator-friendly practices that we recommend as operational tools for Grounds Services staff, which are presented in Appendix B. The practices presented in the lists are not specific to campus landscapes, but we felt that the campus context does not require significant changes to the existing recommendations. Below summarizes these practices in detail.

- Chemical Use: Limit herbicide use and eliminate pesticide use.
- Spring Maintenance: As soon as the soil is workable and plants begin emerging, use a Dutch push hoe every 2 - 3 weeks to eliminate weed seedlings. A Dutch push hoe allows the user to remain upright and use less force to reduce back strain and speed the weeding process. Watch a video here (https://www.youtube.com/watch?v=kPp-VCwVzKA). If standing vegetation remains, trim stems to a minimum of 8” above ground. Hollow stems will serve as nesting sites for cavity-nesting bees throughout the spring, summer, and into fall (Figure 5.6). If fresh mulch is applied, leave some patches of bare soil exposed behind shrubs or other less visible places to allow ground-nesting bees access to soil.
- Summer Maintenance: Continue weeding with a Dutch push hoe every 2 - 3 weeks where possible, especially for new plantings. Hand weeding will become a more effective method as the number of weed seedlings dwindle. Keep an eye out for invasive woody species that may need targeted, spot-treatment with herbicide.
- Fall Maintenance: Where aesthetically acceptable, leave plant stems standing through winter as these serve as valuable over-wintering habitat for pollinators. Where a fall trim is needed, cut stems no shorter than 15” wherever possible (see Chapter 2). In less formal areas, leave a layer of fallen leaves for butterfly larvae to pupate over winter (Figure 5.7).

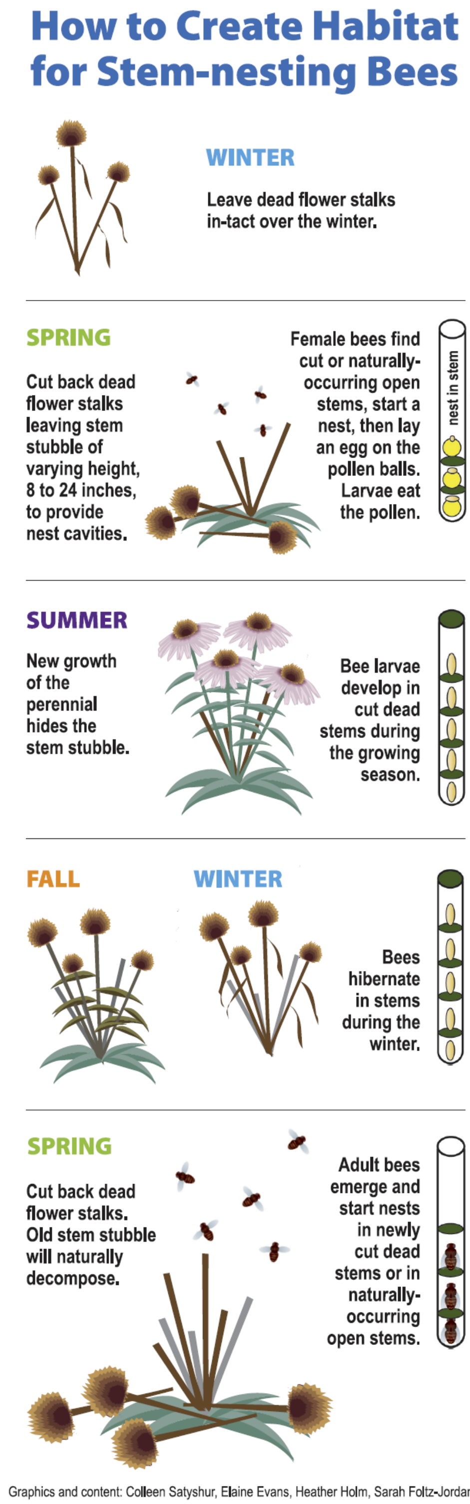

Figure 5.6 To support stem-nesting bees throughout the year, stems should be left standing throughout the winter, then cut back to 8-24" in spring (Plant Lists & Posters, n.d.)

Figure 5.7 Pollinators that benefit from leaf litter include queen bumble bees and luna moths. Left: Queen (individual on the right) common eastern bumble bees (Bombus impatiens) *often overwinter an inch or two underground, under a thin layer of leaf litter. Photograph by Jacy Lucier, distributed under a CC-BY 4.0 license. Right: Luna moth* (Actias luna) *cocoons are camouflaged to blend in with dry fallen leaves. Image courtesy of The American Museum of Natural History, distributed under a CC-BY 2.0 license.*

Conclusions and Recommendations

Supporting pollinators on campus landscapes requires careful integration of planting choices, aesthetics, cultural expectations, and maintenance. It is clear from the research that urban areas with higher floral diversity and floral abundance tend to have higher pollinator abundance and/or diversity (see Chapter 2). While overall pollinator abundance and diversity are greatest in landscapes with native plants, not all native plants are aesthetically appropriate or adapted to urban conditions, making integration of native plants possible, but challenging. In addition, many non-native, ornamental plants serve the dual purpose of providing pollinator resources (e.g., nectar, pollen, structure) and signaling important social cues, including legibility and familiarity, that influence the acceptance, care and longevity of gardens. Thus, to support pollinators on campus through planting design, we recommend the following practices that combine what we know from research with the more practical needs and realities of the campus setting:

- Incorporate high densities of flowering plants.
- Incorporate high diversity of flowering species by varying the species in each bed across the landscape.
- Utilize species with flowering times that span the entire growing season, including, beneficial spring bulbs, and late-blooming fall flowers.

- In areas with high aesthetic and maintenance requirements, utilize non-native, ornamental or "nativar" plants that provide pollinator resources.
- In areas with lower aesthetic and maintenance requirements, utilize as many native plants as possible.
- Seek out native plants that are well-adapted to harsh conditions of urban environments. Some desirable characteristics include salt, heat, and drought tolerance and higher pH tolerance.
- Where appropriate, use plants as "living mulch" to maximize plant resources and reduce weeding and watering requirements.
- Look for opportunities to "improve the matrix" between garden beds. Consider bee-friendly lawns, flowering trees, and functional planters that can provide additional support between garden beds.

This chapter provides a summary of pollinator-friendly design and offers several templates; however, several research-based resources exist for inspiration. An extended list of plants considered for the University of Michigan's Ann Arbor Campus can be found in Appendix C. While not all pollinator plant lists are supported by research (see Chapter 2), we recommend the following excellent plant and design resources:

Plant Lists

- *Pollinators of Native Plants* by Heather Holm
- *Bees: An Identification and Native Plant Forage Guide* by Heather Holm
- Pollinator Plant Lists and Posters by Heather Holm
- Pollinator Plants for the Great Lakes Region by The Xerces Society
- Native Flowering Plants that Attract Beneficial Insects by Michigan State University Extension
- Plants for Pollinators by Lady Bird Johnson Wildflower Center and The Xerces Society

Resilient Urban Design

- *Planting in a Post-wild World* by Thomas Rainer and Claudia West
- *The Know Maintenance Perennial Garden* by Roy Diblik

Although the University has established relationships with certain plant nurseries, expanding the plant sourcing options to include local native plant nurseries and land preserves will provide more locally adapted plants and build strong relationships. As demonstrated in the case study above, we were able to move transplants from the local

County Farm Park (managed by Washtenaw County Parks) and source plants from two local native plant nurseries. Building these local partnerships not only strengthens the University's relationship within the region, but also serves to build a supportive community for pollinator habitat that expands beyond the campus boundary. This network of relationships is explored more in detail in Chapter 6. For a list of local native plant nurseries, please see Appendix D.

To facilitate intimate knowledge and stewardship, we propose the future development of an easy-to-access system of illustrated planting plans that garden interns and Grounds Services maintenance staff are required to review. Each garden should have an associated planting plan that includes photos of individual species as well as a series of seasonal photographs showing intended form. These plans should be updated regularly to incorporate changes such as die-off or replanting. To build and manage this system (and provide a valuable learning experience) we propose building an internship program with the Landscape Architecture department at the School for Environment and Sustainability. Ideally, this could be a digital system that allows any employee to view information of any nearby garden while in the field. There is potential to integrate this information into a larger digital maintenance system that manages open/closed work tickets.

In conclusion, supporting pollinator-friendly landscapes on campus provides multifunctional benefits in the ecological and social realms. Pollinator gardens do not have to be "wild" and unkept. By providing key habitat factors that influence pollinators in designs that respond to local site conditions and cultural expectations, pollinator-friendly landscapes can be functional, beautiful, welcoming parts of a campus landscape.

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CHAPTER 6 – **BUILDING AWARENESS AND CELEBRATING ACHIEVEMENTS ON CAMPUS THROUGH POLLINATOR-RELATED EVENTS, RESOURCES, AND CURRICULAR INTEGRATION**

Introduction

While collecting and analyzing data to enhance pollinator habitat on campus is essential, its value is realized by the people who are interested and engage in pollinator-related activities on campus. In this chapter, we explicitly address the next critical components of our project - engaging in outreach and education to raise awareness and create durable pollinator-friendly habitat (Figure 6.1). To holistically address this part of the project, in this chapter we 1) describe the existing efforts and interest in pollinators on campus, 2) highlight some unique deliverables produced by the project team that fill in gaps in these existing efforts, and 3) describe future opportunities that can sustain these stewardship efforts in the long-term. Together these activities align with what is needed for the University of Michigan to achieve Bee Campus USA certification through the Xerces Society for Invertebrate Conservation.

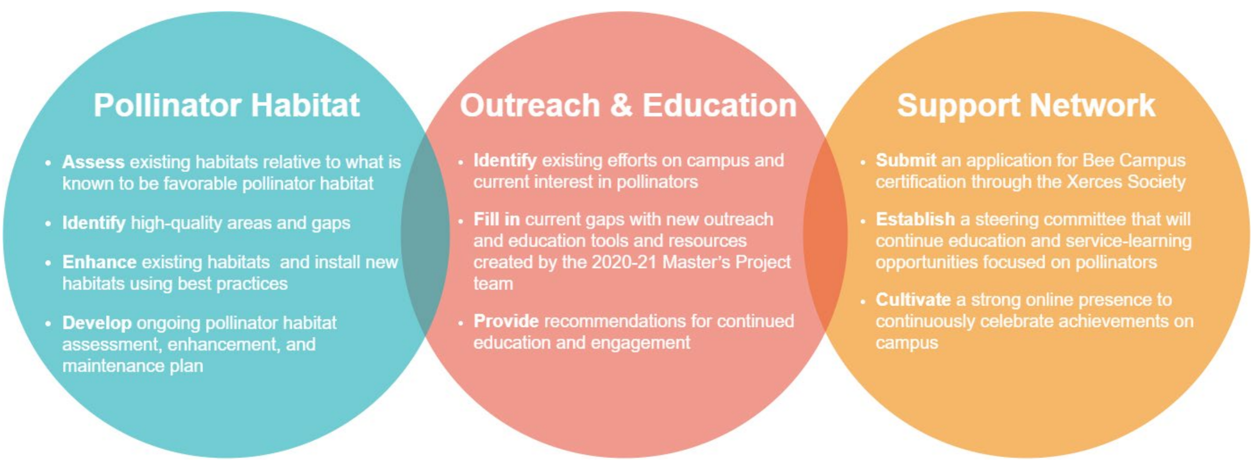


Figure 6.1 An overview of our project goals

Existing efforts on campus and current interest in pollinators

Current pollinator-friendly management of UM landscapes

The University of Michigan's Office of Campus Sustainability (OCS) is dedicated to actively contributing towards the implementation of the University's six sustainability goals (Figure 6.x). In particular, the sustainability goal of reducing chemical application to campus landscapes supports pollinator conservation efforts, given that harmful pesticide use is a major driver of pollinator declines (Chapter 2).

UM Sustainability Goals

Reduce greenhouse gas emissions by 25%

Reduce vehicle carbon output per passenger trip by 30%

Reduce the amount of water sent to landfills by 40%

Purchase 20% of U of M food from local and sustainable sources

Protect Huron River water quality by minimizing runoff from impervious surfaces and reducing chemical applications to campus landscapes by 40%

Invest in sustainability culture programs to educate our community, track behavior, and report on the progress over time

Figure 6.2 Six long-term sustainability goals adopted by The University of Michigan (source: https://ocs.umich.edu/sustainability-goals/)

As a response to the sustainability goals released by the Graham Sustainability Institute and OCS, Grounds Services increased their efforts to contribute to a more sustainable and pollinator-friendly campus (Figure 6.3):

Grounds Services Sustainability Practices

Organic and low-impact herbicides and fertilizers where possible. 80% of campus lawns are managed using organic fertilizer.

Improving soil quality to reduce the need for fertilizer and supplemental irrigation

Expanding natural areas and planting native trees and shrubs

Prescribed burns and the use of goats to control invasive plants

Figure 6.3 Ways in which Grounds Services has increased their efforts to contribute to a more sustainable and pollinator-friendly campus (source: https://cgs.fo.umich.edu/our-teams/building-grounds-services/grounds-services-team/grounds-services-sustainability/)

Both in terms of pesticide reduction and additional plantings, Grounds Services has already increased pollinator-friendly habitats on campus. They reduced chemical applications by 54% in 2020 (UM Sustainable Grounds, n.d.), despite an increase in the amount of managed greenspace, surpassing the original goal of 40% set forth by the campus sustainability goals in 2011. Numerous efforts have also already been made to create habitats designed to support pollinators on campus, such as rain gardens and prairie plantings, especially on north and east campus, and pollinator gardens near the Natural History Museum and East Quad. Additionally, they have begun to reduce the frequency of mowing on various parts of campus, as less mowing supports a higher diversity of bee species. They have also converted areas that used to have turf into more diverse and tall meadow, such as the area in front of the Power Center. They continue to partner with various sustainability organizations on campus (e.g., OCS, the Graham Sustainability Institute) to support these pollinator stewardship efforts.

Golf courses have the potential to serve as important pockets of habitat for all types of pollinators. Areas that are considered “out-of-play” and can be supplemented with pollinator-friendly plants and serve as important corridor habitat for a diverse array of pollinator species. A golf course at University of Michigan, Radrick Farms Golf Course, has adopted several practices that support pollinator conservation. Some pollinator-friendly practices they implemented include increased natural areas on the course, the installation of beehives, decreased chemical applications, and controlling invasive species on the property.

Matthaei Botanical Gardens and Nichols Arboretum also contribute a vast array of opportunities for pollinator education and awareness. Matthaei Botanical Gardens have showcase gardens that feature pollinator-friendly plants and numerous restored native landscapes that support pollinators. They also offer educational programs and classes on their property that already incorporate or could easily incorporate pollinators. Nichols Arboretum contains a rich diversity of pollinator-friendly plants and landscapes. Nichols Arboretum is also very close to campus and is easily walkable for laboratory courses. The habitat created by these two organizations is designed to strike a balance between aesthetic beauty and ecological function that is needed to maintain current interest in pollinator stewardship (see chapter 2). The various gardens and landscapes can also act as a living laboratory for future pollinator studies.

Existing Faculty Research and Courses Related to Pollinators

In addition to existing pollinator-friendly efforts on the campus landscape, there are also several research and courses at UM that could or do contribute to building awareness about pollinators. Faculty research and academic courses at UM advance the field of pollinator biology, provide learning opportunities for students, and contribute to building awareness about pollinators. Faculty engaged in this field focus on topics including, but not limited to, pollinator biology, pollinator ecology, food systems, and plant biology. Table 6.1 lists out some of the key faculty working in these areas who are or could be potential partners in celebrating on-campus pollinator achievements and providing knowledge and understanding around pollinators.

Table 6.1 Some of the key UM researchers involved in pollination-related projects directly or via the students they advise.

UM Researchers	**Role and/or Research area**
Erica Tucker	Museum Curator, Entomology
Jeremey Moghtader	Campus Farm manager
Ivette Perfecto	Professor, Sustainable food systems
John Vandermeer	Professor, Ecology of agroecosystems
Virginia Murphy	East Quad Faculty Director
Joan Nassaur	Professor, Landscape Architecture

Additionally, the University of Michigan offers several courses related to pollinator ecology that could both educate students about pollinators, as well as serve as potential partners in implementing pollinator habitat enhancement and awareness-building. These fall into 4 major categories (Table 6.2).

Table 6.2 Examples of UM pollinator-related courses

Category	**Examples**
About insects or plants	EEB 443 Entomology, EAS 501.003 Herbaceous Flora and Ecosystems, BIO 230 Plant Biology, EEB 420 Plant Evolution
General ecology	EAS 509 Ecology: Concepts and Applications, EEB 381 General Ecology Lecture, EEB 372 General Ecology Lab
Agroecology/Farming	EAS 553 Diverse Farming Systems, EEB 498 Ecology of Agroecosystems
Landscape Architecture	EAS 691 Planting Design, EAS 590 Ecological Site Design

These wide-ranging courses showcase how pollinator-related topics can fit into a larger curriculum. For example, a course such as “Diverse Farming Systems” focuses broadly on the elements within sustainable food systems, which include a healthy population of pollinators. Similarly, “Ecology of Agroecosystems”, focuses on ecological principles as they relate to agricultural landscapes, and pollinators are a vital component of this landscape.

Any introductory or mid-level biology or ecology course about insects or plants, such as “Entomology”, “Herbaceous Flora & Ecosystems”, “Plant Evolution”, or “Plant Biology”, also encompasses pollinators in some way in the course material. Courses with labs, such as “Ecology: Concepts and Applications” and “General Ecology Lab”, have the unique opportunity to incorporate hands-on pollinator-related activities.

The Master of Landscape Architecture program at SEAS is unique for its emphasis on ecological design. Several studio-based courses, including “Planting Design” and “Ecological Site Design”, teach plant biology and landscape ecology principles that directly influence pollinators on the landscape (see Chapter 2). These studio courses culminate in a half- or full-semester final project that could provide an opportunity for students to design a suite of new pollinator-friendly gardens on campus. This design work could be paired with another department course, EAS 591 Materials and Methods, as a design-build project where students bring these designs to life as exemplified by the Dana Gardens.

Student Organizations and Programs

A strong, sustainable student presence in the pollinator conservation space is essential for meaningful impact, which makes student organizations and programs especially important. At the University of Michigan multiple student organizations play an active role in pollinator conservation. These organizations provide important continuity in pollinator conservation and awareness efforts, especially in light of a transient student body.

A sampling of these student organizations include: UM Bees, the University of Michigan Sustainable Food Program (UMSFP), and the Campus Farm. UM Bees focuses on promoting, propagating, and protecting honey bees which, although not native to Michigan, are still important pollinators and this organization raises awareness about the process of pollination in general. UMSFP serves as the umbrella organization for many student organizations that work with food systems. Pollinator-friendly practices such as organic farming and reducing pesticide use are important tenets of healthy and equitable food systems. The Campus Farm serves as a student-led organization that provides food for students at the University of Michigan that implement the above pollinator-friendly farming practices. These student organizations serve as a platform for educational activities and resources.

The Greater Ann Arbor Community and Other Bee Campuses

A strong presence outside of the University of Michigan's campus is also essential for meaningful impact. The University of Michigan is situated in the heart of Ann Arbor and as such, there must be a resounding interest in pollinators outside of its boundaries. One way the greater Ann Arbor community is involved in pollinator stewardship is through The Washtenaw County Food Policy Council's Pollinators Policy Action Team. This subcommittee "convenes to recommend and support that institutions within the county take measures to preserve our essential pollinator populations" (Washtenaw Food Policy council website). Similarly to the goals of this project, this subcommittee, headed by Ann Hubbard, is focused on collaborating with the city's largest stakeholders including UM, Eastern Michigan University, St. Joseph Mercy Hospital, Washtenaw County public schools, and Washtenaw County municipalities to "support, pledge, and implement organizational policies to protect pollinators by using best landscape management practices, as well as increasing pollinator habitat areas" (Washtenaw Food Policy council website). Some accomplishments they have achieved thus far are Bee City USA certification (in both Ann Arbor and Ypsilanti) and a successful Bee Safe Neighborhood Campaign. Another effort seen in the greater Ann Arbor Community is through a “gardens” working group looking to develop a central park with pollinators in mind. This group wants to create pollinator-friendly habitat in the heart of Ann Arbor and use this habitat for educational purposes, teaching the community about its benefits. Despite the contributions of these organizations, there is still much room to get more involved in the greater Ann Arbor community.

Two other campuses in Southeast Michigan, The University of Michigan at Dearborn and Washtenaw Community College, have already achieved Bee Campus USA certification and can serve as valuable resources for sharing lessons learned. We reached out to these campuses (University of Michigan at Dearborn: David Susko, Washtenaw Community College: Sandy McCarthy) to talk about best practices for increasing awareness around pollinator-related issues and maintaining a sustainable presence on campus after the project’s completion.

University of Michigan--Dearborn and Washtenaw Community College - both Bee Campus affiliates - recommend a strong online presence, a sustainable pot of funding, and participation on scale that is larger than academics and scholars to earn and maintain Bee Campus certification.

We also learned the importance of having clear, well-thought-out event evaluation metrics. For every event that is held, it is essential to document how many people attended and have a mechanism for incorporating continued communication. This could be in the form of a post-event survey or a sign-in sheet where participants leave their contact information if they want to hear more about upcoming events and the work that is being done. These informational chats further increased our appetite for finding unique ways to build awareness regarding pollinators on University of Michigan’s main campus.

New outreach and education tools and resources created by the 2020-21 Master’s project team

To complement existing means of pollinator conservation at the University of Michigan, our 2020-2021 interdisciplinary team created education and outreach tools and resources that support the university’s sustainability goals as well address the requirements necessary for Bee Campus USA certification. Our project directly advances campus-wide pollinator conservation through the completion of several unique deliverable that can serve as future tools and resources to strengthen pollinator knowledge and increase community conservation efforts:

- Created a Survey123 Pollinator Habitat Assessment tool that integrates data collection with opportunities for outreach and student course work
- Enhanced a centrally located pollinator habitat that celebrates best practices and can serve as a “living laboratory”
- Created several multimedia education tools for engaged learning about pollinators
- Received approval for Bee Campus USA certification
- Established a UM Pollination Website as a resource hub and ongoing communication platform

Survey123 Pollinator Habitat Assessment Tool

We created the Pollinator Habitat Assessment Tool using the Survey123 platform specifically to combine data collection with an educational experience for the user (see Chapter 3). The Survey123 app allows easy access via a mobile device and has offline data capabilities, making it an ideal tool for students or community scientists. The assessment tool was piloted in the lab course, EAS 509 Ecology: Concepts and Applications. We found from the pilot, that the tool has the power to integrate data collection skill-building into a specific course. Using this tool independently around campus gave students valuable field experience that is often limited to off-campus field trips to distant natural areas. In the future, students can use the easily downloadable data for course exercises in statistical or spatial analysis.

Survey 123 is generally considered a useful platform for data collection and analysis and is widely used in the practitioner community. So far, the survey we created using this tool has given us data on what types of pollinators exist on campus, what campus habitat looks like, and the relationship between the two. The tool provided the opportunity for an initial gap analysis using certain metrics (e.g., bed size, floral resources, tree resources, etc.), but more data will have to be collected for further analysis. We had the opportunity to present the development of this habitat assessment tool and initial data analysis at the 2021 January Stewardship Network Conference. In collaboration with another project team who also used the tool for their project, we compared and contrasted the different educational opportunities provided by Survey 123 and how it has the potential for widespread application. We recommend continuing to engage with external partners and practitioners to share University of Michigan achievements through conference avenues such as the Stewardship Network Conference, where we reached over 60 area practitioners!

Pollinator Habitat Enhancement at the Biological Sciences Building and Signage Recommendations

In October 2020, the team installed a new pollinator garden to extend an existing pollinator corridor and provide a new 'living laboratory' experience at the heart of central campus. The design team worked with Grounds Services and the Museum of Natural History to renovate the existing perennial bed at the Washtenaw Avenue entrance of the Biological Sciences Building (Figure 6.2; Chapter 5). The 1,700-square-foot space now features 17 native plant species that are intended to provide seasonal foraging, nesting, and overwintering resources for diverse pollinator species. Students, faculty, and museum visitors and local residents can use the Pollinator Habitat Assessment Tool to simultaneously gather data and learn about how this garden does (or does not) fulfill pollinators' needs. The garden can also provide a living laboratory experience by bringing classroom curricula to life on topics including urban pollinator species, pollinator habitats, ecosystem services, and pollinator habitat best management practices. We also propose a method of tracking pollinator movement using fluorescent dye (Chapter 4) that could be used by students to test the garden's ability to provide "steppingstone" habitat across campus and learn about landscape ecology principles. The new pollinator garden offers a centrally located, living laboratory space to use our proposed educational tools in hands-on educational activities to engage and inspire the next generation of pollinator champions.

Going beyond campus boundaries, the garden installation also offers learning and engagement opportunities to the surrounding community. Since the University of Michigan's Ann Arbor campus is intertwined with the downtown area of the city, many local residents utilize the campus landscapes. A key next step we recommend for other pollinator gardens across all campus boundaries is to incorporate educational signage that facilitates engaged learning for anyone passing by. It is important that the signage includes images and descriptions of the pollinators and plants present within each garden specific to site location. Images on the signage will not only help individuals identify the types of plants and pollinators they are seeing, but it will also educate them on what types of flowers and plants attract specific types of pollinators. Including a scannable QR code that links to our project webpage, pollinator resource hub website, and Survey123 habitat assessment on the signage as well will create an outdoor space for members and non-members of the university as a way to learn about pollinators and their habitats on the Ann Arbor campus while simultaneously contributing to pollinator conservation efforts through engagement with our online outreach and education tools.

We also recommend including the Bee Campus USA logo on garden signage, as this allows individuals to recognize that the university is a member of the Bee Campus USA initiative. With included signage that takes into account these recommendations, residents of Ann Arbor will have the opportunity to walk throughout campus, engage with our pollinator habitats, learn about the types of pollinator species and plants that are present within that garden location, and engage in conservation efforts. Creating this additional signage could be a course project for students in the Behavior, Communication, and Education field of study in SEAS as an application of best practices in environmental education or it could be accomplished by a future master's project also working towards enhancing campus-wide pollinator conservation efforts.

Figure 6.4 Photo of the Pollinator Garden Installation located near the Biological Sciences Building by Rachelle Roake (October 17, 2020)

Digital Multimedia Education and Communication Tools

Using digital platforms to share engaging educational information is an important, complimentary tool for increasing communication beyond audiences in our physical vicinity. Digital media allows us to connect with communities outside of our own and fosters an online space where individuals from around the world can come together in an accessible platform to learn, share, and communicate with each other about topics that are meaningful to them. We created several digitally accessible learning tools to strengthen pollinator awareness and engagement efforts: A skill-sharing video and two multi-media Michigan Sustainability Cases.

We developed a 15-minute skill-sharing video for the 2020 virtual Earthfest event to teach those within and beyond our campus community about pollinator conservation through specific tips on how to create a sustainable and healthy pollinator garden at home. The video goes through each tip with engaging visuals and narration (Figure 6.5). Earthfest is an event organized by representatives from the UM Office of Campus Sustainability, the School for Environment and Sustainability, Student Life, and Graham Sustainability that celebrates the University of Michigan's sustainability initiatives across campus and serves as a platform to educate and engage the audience about environmental sustainability.

While the 2020 Earthfest event was conducted digitally from September 14th-September 18th due to the COVID-19 pandemic and social distancing guildines, students, faculty, and staff still had the opportunity to share materials they created on sustainability topics online. Our video serves as an important addition to the 2020 Earthfest event as it has a direct focus on how to engage in pollinator conservation practices and fit within the theme of other student-created videos for the 2020 Earthfest event focusing on topics such as sustainable eating, composting, the University of Michigan Sustainable Food Program, the Campus Farm, and the Matthei Botanical Gardens and Nichols Arboretum. Our informational video can also easily be shared beyond the Earthfest event as a way to inform and engage individuals in practicing sustainable pollinator conservation at home and within their own community.

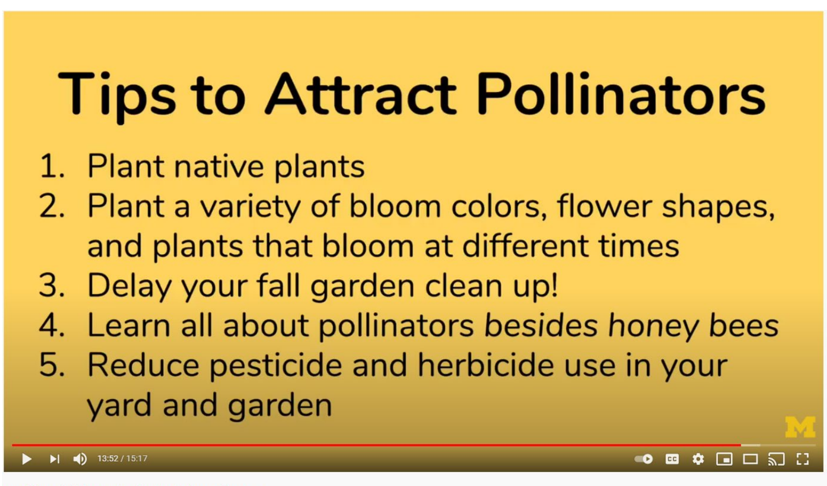
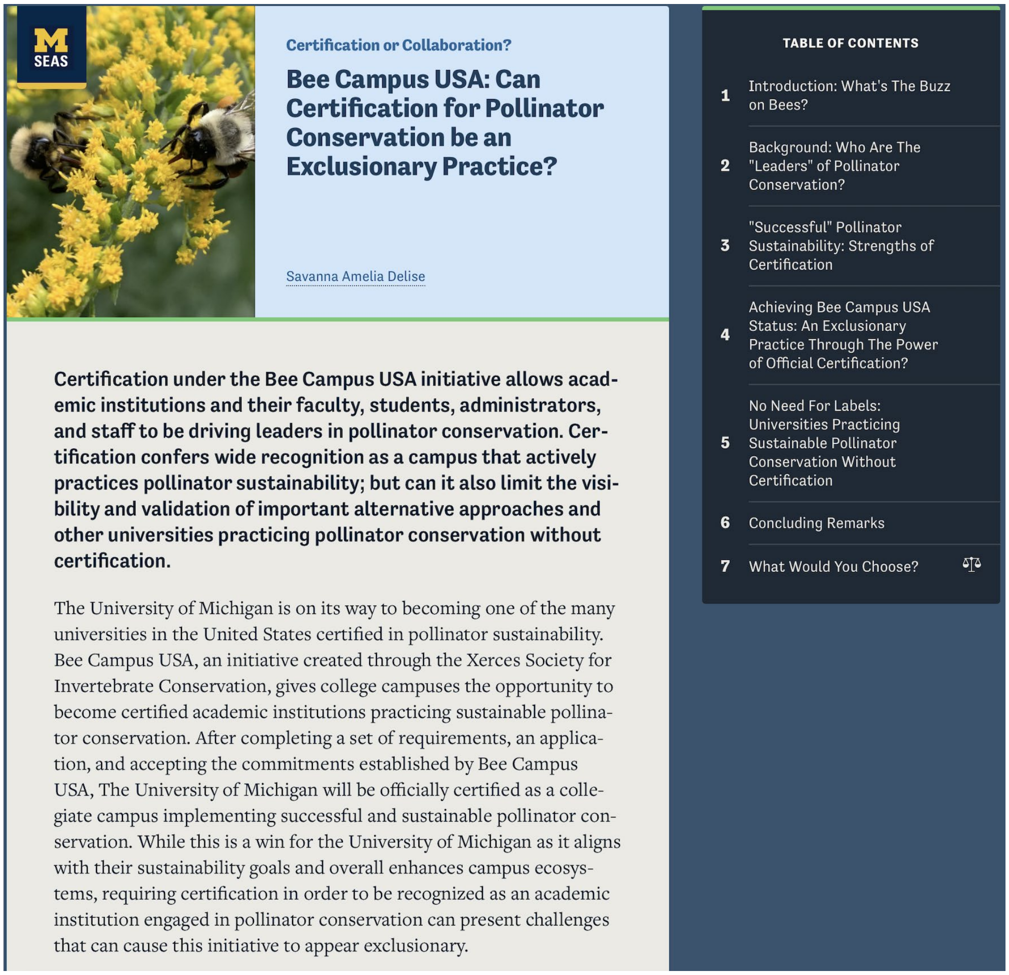


Figure 6.5. Snapshot of Earthfest Video "Tips for Attracting Pollinators from a UM SEAS Master's Project Group". https://www.youtube.com/watch?v=R92MuJ4Dp-U

Another way we connected with communities within and beyond campus boundaries was by creating two Michigan Sustainability Cases using the Learn Gala platform. Learn Gala is an open-access, online platform that allows individuals globally to learn about and engage in sustainability science through reading impactful cases, creating cases as innovative teaching tools, and by having conversations on the platform's forums in an interactive, inclusive community. The Learn Gala platform helps connect and convey research between researchers and community members, allowing for greater practice and community engagement efforts. We created two Michigan Sustainability Cases through the Learn Gala digital platform in order to offer individuals both within and beyond our community an opportunity to learn about pollinators through our project mission and goals.

The first of these cases (Figure 6.6), "Certification or Collaboration? Bee Campus USA: Can Certification for Pollinator Conservation be an Exclusionary Practice?" explores how acquiring Bee Campus USA certification as a university in order to be recognized as an academic institution engaging in sustainable pollinator conservation can be a potentially exclusive practice. Through an environmental justice lens, the case analyzes the ways in which certification in pollinator conservation can be a benefit to ecosystems and restoration practices but may not be attainable by all academic institutions. We used examples from our own experience of achieving Bee Campus USA certification, an initiative established by The Xerces Society for Invertebrate Conservation. Bee Campus USA certification confers wide recognition as a campus that actively practices pollinator sustainability, but it can also limit the visibility and validation of important alternative approaches and other universities practicing pollinator conservation without certification. Through this case, we educate the audience about the important role pollinating insects play in our environment and the "leaders" in pollinator conservation. Additionally, we teach the audience the advantages and disadvantages "official" certification in pollinator conservation may pose, as well as allow the opportunity for the reader to gain practice in decision-making for sustainability.


Certification or Collaboration?

Bee Campus USA: Can Certification for Pollinator Conservation be an Exclusionary Practice?

Savanna Amelia Delise

Certification under the Bee Campus USA initiative allows academic institutions and their faculty, students, administrators, and staff to be driving leaders in pollinator conservation. Certification confers wide recognition as a campus that actively practices pollinator sustainability; but can it also limit the visibility and validation of important alternative approaches and other universities practicing pollinator conservation without certification.

The University of Michigan is on its way to becoming one of the many universities in the United States certified in pollinator sustainability. Bee Campus USA, an initiative created through the Xerces Society for Invertebrate Conservation, gives college campuses the opportunity to become certified academic institutions practicing sustainable pollinator conservation. After completing a set of requirements, an application, and accepting the commitments established by Bee Campus USA, The University of Michigan will be officially certified as a collegiate campus implementing successful and sustainable pollinator conservation. While this is a win for the University of Michigan as it aligns with their sustainability goals and overall enhances campus ecosystems, requiring certification in order to be recognized as an academic institution engaged in pollinator conservation can present challenges that can cause this initiative to appear exclusionary.

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1 Introduction: What's The Buzz on Bees?

2 Background: Who Are The "Leaders" of Pollinator Conservation?

3 "Successful" Pollinator Sustainability: Strengths of Certification

4 Achieving Bee Campus USA Status: An Exclusionary Practice Through The Power of Official Certification?

5 No Need For Labels: Universities Practicing Sustainable Pollinator Conservation Without Certification

6 Concluding Remarks

7 What Would You Choose?

Figure 6.6 Learn Gala Michigan Sustainability Case: "Certification or Collaboration? Bee Campus USA: Can Certification for Pollinator Conservation be an Exclusionary Practice?" [*https://www.learngala.com/cases/35a5e4a4-2826-4f70-b0db-6cccf836d95e/*](https://www.learngala.com/cases/35a5e4a4-2826-4f70-b0db-6cccf836d95e/)

The second Michigan Sustainability Case we created through the Learn Gala platform, "Pollinators, Connectivity, and Corridors. Pollinator Pathways: The Path to Successful Conservation" (Figure 6.7) details the importance of pollinator corridors, pathways, and how to enhance pollinator environments as well as test for pollinator connectivity. In this case, we demonstrated what pollinator corridors and pathways are, their significance, and how to assess them. We discussed a field experiment that we conducted during the summer at the Samuel T. Dana Building and the Biological Sciences Building at the University of Michigan's Ann Arbor campus, testing for pollinator movement and connectivity using non-toxic fluorescent dye and an LED black light. Creating this case allowed us to share our experiment with the public, educating the audience on campus pollinator activity and habitat connectivity. This case can also be used to inform the installation of new pollinator gardens on campus, teach the readers how they can replicate the fluorescent dye connectivity experiment at home, and provide tips on how to install a high-quality pollinator habitats.

SEAS

Pollinators, Connectivity, and Corridors

Pollinator Pathways: The Path to Successful Conservation

Savanna Amelia Delise

Pollinators of all types are essential to our environment. Through the ecological services that pollinators provide, pollinators are essential for the reproduction of over 85% of the world's flowering plants, including more than two-thirds of the world's crop species. Beyond the necessity for pollinators in agriculture, pollinators are also important species in most terrestrial ecosystems. Approximately 25% of all birds, and of mammals, depend on insect pollinators for the fruits and seeds that are a major part of their diet. While pollinators are crucial to our environment, unfortunately, pollinators are at high risk to suffer from habitat loss, pesticide use, and introduced diseases in many places. Is there anything we can do to combat this detrimental loss?

This case aims to teach us the importance of caring for all pollinator ecosystems. In this case, we will learn how to help pollinators and their habitats thrive and succeed through the creation and use of pollinator pathways. Through a field study on pollinator connectivity, we will become aware of the necessity of pollinator corridors, and how an implementation of pollinator corridors within a landscape can drastically change the health and success of pollinators and their environments for the better.

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Figure 6.7 Learn Gala Michigan Sustainability Case: "Pollinators, Connectivity, and Corridors. Pollinator Pathways: The Path to Successful Conservation" *https://www.learngala.com/cases/d144a303-a7b8-48e2-b3bd-8031213294da/*

Approval for Bee Campus USA Certification

Our project supports the broader sustainability and engagement goals and activities of the UM Office of Campus Sustainability and UM Grounds Services, with specific goals of enhancing pollinator habitat and raising awareness of pollinators on campus, the various roles that pollinators play, and the importance of their conservation. Through our efforts, we obtained approval for Bee Campus USA certification, which includes a) creating a pollinator "work plan" for the University of Michigan with habitat improvements and management recommendations based on GIS and field assessments of pollinator habitat, b) developing pollinator-related curriculum, events, and a hands-on "living laboratory" in the form of pollinator habitat, and c) identifying champions to continue the work that we are starting with our project. As an affiliate of Bee Campus USA, the University of Michigan will receive wide recognition as an American academic university that is a leading champion in practicing successful and sustainable pollinator conservation. With the commitments we made to conserve native pollinators across campus, students, faculty, administrators, and staff can work together to successfully carry out these commitments and further enhance the university's campus to being a better place for pollinators and their habitats to thrive.

Website as Campus Pollinator Resource Hub and Communication Tool

Seeing the need for a central hub for UM-specific pollinator outreach and education, we created a website that acts as an online platform to engage campus faculty, students, and staff as well as the communities within the city of Ann Arbor about pollinator conservation efforts at the University of Michigan (Figure 6.6). Our website teaches the audience about past, present, and current pollinator conservation efforts on campus and connects online visitors with opportunities to get involved through our university's student-led organizations and programs relating to pollinator conservation. The website will be continuously maintained and kept up to date by our committee of pollinator champions working to promote campus-wide pollinator conservation efforts. Our website serves as an effective resource for digital communication, education, and engagement opportunities for those interested in adopting and learning positive, sustainable actions that contribute to successful pollinator conservation practices.

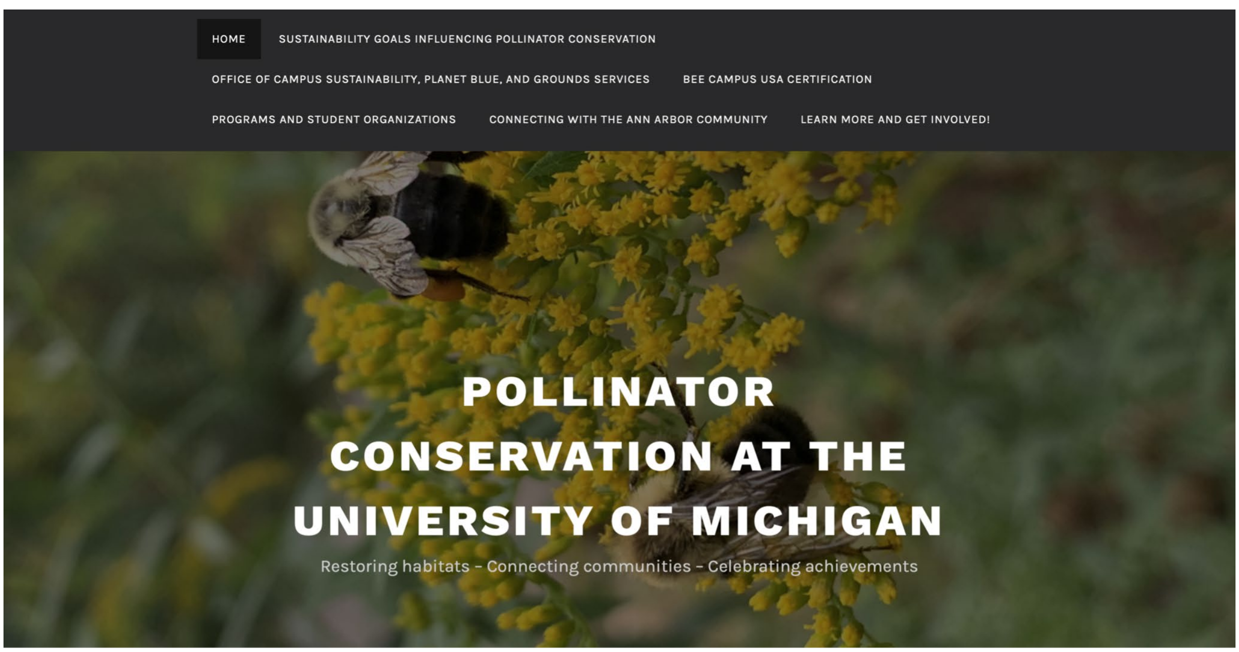

Figure 6.8 Pollinator Conservation at the University of Michigan Website
https://umichpollinators.com

Recommendations for continued achievement and engagement

Pollinator-themed campus events are essential outreach components that can spark continued interest and support throughout the university community. These events will provide opportunities to partner with the existing campus efforts and organizations discussed above and integrate the deliverables produced by the 2020-2021 project team highlighted in the previous section. Below we propose several potential events that could be tailored to the audiences and partners involved.

Pollinator Garden Bike Tour

This event would entail a guided bike tour of quality pollinator habitats at residences around Ann Arbor and even possibly the University of Michigan campus. The event could begin at County Farm park, who could be listed as an event partner, and then participants could travel to preselected homes in Ann Arbor in whatever order they chose, as well as featured gardens on campus. At each stop the homeowner would share details about their garden (e.g., the plants they have, where they bought them, and what value they bring to pollinators). This will hopefully inspire others to plant their own pollinator gardens at home. To encourage participation there could be a social media contest embedded in this event, where the person or group who posts the most images with a certain hashtag wins a prize at the end. One potential prize could be a t-shirt designed by a community member. This event could build community and serve as an opportunity to get outside and be active.

Walking Tour

This event would entail a guided tour by a trained individual (e.g., student, staff, campus organization, or community member) through the quality pollinator habitat on campus. This tour could include the new garden installation outside of the Museum of Natural History or existing pockets of quality habitat identified in Chapter 4, such as the Martha Cook Courtyard or Reader Center garden. Participants would be taught about how that garden provides quality pollinator habitat and the value pollinator habitat brings to University campuses. The tour could be integrated into an academic course or existing programs on campus. An example of a program this activity could be integrated into would be the Summer Camp held every year at the Museum of Natural History. The walking tour could also be integrated into a landscape architecture course as a site visit, for the purpose of later using the lessons learned as part of a final studio project.

Spring Cleaning/Garden Stewardship Event

We propose an annual garden stewardship event where volunteers conduct routine maintenance of the gardens outside of the Museum of Natural History. Careful and intentional maintenance of pollinator gardens is essential to uphold functionality and aesthetics. One of the major reasons why a newly installed garden fails is because it is not weeded properly during its first few years after installation. This event would ideally be held in the spring as the first few species are in bloom. This could be a great educational opportunity for University of Michigan students and the Ann Arbor community to learn more about the garden installation and about the other great pollinator habitat that exists on campus.

Guided Audio Tour

This event would entail a walking tour of quality pollinator habitats on campus with the same teaching points as the guided walking tour but can be done independently. Instead of being guided by a trained individual as in the walking tour, this activity would be guided by pre-recorded audio files. Similarly, to how in museums you can scan a barcode and you can hear all about the particular exhibit you are in. These audio recordings could be added to the signage that already exists via the addition of one of these barcodes and onto any new signage that is installed in the future. These barcodes will link the user to a pre-recorded transcription describing all of the great pollinator-friendly aspects of that particular garden.

Pollinator Photo Contest

This event would entail each participant to submit a photo of something pollinator-related (e.g., a pollinator, a pollinator on a plant, a pollinator garden, etc.). Then these photos could be evaluated by either an unbiased judge or by the public. The prize(s) could be pollinator-related and could come from a campus organization. One suggestion for this could be honey from the beehives at Radrick Farms Golf Course from their partnership with UM Bees. This way these organizations can get publicity for the event and would be encouraged to promote the event to their followers. Additionally, this event can be completely virtually, which allows for a wider range of participation.

Conclusions and Recommended Next Steps for the UM Bee Campus Committee

We took a multifaceted approach to achieving our project's education and awareness goals. First, we described existing efforts and interest in pollinators on campus. Then, we discussed some unique deliverables produced by the project team that fill in gaps in these existing efforts. And finally, we conclude with describing future opportunities that can sustain these pollinator stewardship efforts in the long-term. We conclude that a combination of looking at current efforts, filling in existing gaps, and suggesting future opportunities is how the University can continue to build awareness and education surrounding pollinators on campus.

Moving forward, we pass the torch onto the Bee Campus USA committee to continue working towards a pollinator-friendly campus. This committee consists of faculty, staff, and student champions. Their role is to do the following:

Bee Campus USA commitments

Create and enhance pollinator habitat on campus by increasing the abundance of native plants and providing nest sites

Reduce the use of pesticides

Offer courses or continuing education opportunities that incorporate pollinator conservation

Offer service-learning projects to enhance pollinator habitat

Display signage focused on pollinator conservation

Maintain an online presence for Bee Campus USA activities

Figure 6.9 Bee Campus USA commitments set forth by the Xerces Society for Invertebrate Conservation (Source: https://beecityusa.org/bee-campus-usa-commitments/)

We helped assemble the initial committee member composition to include people who had been involved in the pollinator data collection and/or habitat enhancement efforts in the past year, or who could serve as important partners for future directions given their expertise and role at the University. These members will contribute not only their skills, knowledge, and connections, but are in an excellent position to enact real change to the vibrant pollinator-friendly efforts that are already underway at the University. We recommend that future committee members include the course instructors, organizations, or researchers reviewed above in "Existing efforts on campus and current interest in pollinators." While the certification requires at least one faculty, one staff, and one student on the committee, we suggest that the committee continue to have at least one member representing: the Office of Campus Sustainability, Grounds Services, and the SEAS Landscape Architecture Program. We also think it is important that a GIS administrator be added to the committee or work closely with the committee to manage the Survey123 habitat assessment.

Beyond the future education and awareness activities the initial UM Bee Campus committee may be interested in pursuing, we recommend the following vital next steps:

1. Establish a permanent home for the UM Pollinator website hub for continued engagement with pollinator-related activities on campus.
2. Build funding for annual renewal of certification into the fiscal budget of OCS or Grounds and achieve the President's approval to finalize the certification process with Xerces.
3. Install recommended garden signage to promote the newly created habitat at USB.
4. Continue networking with existing efforts and organizations, especially integrating Survey 123 data collection into curricular and grounds activity to allow for richer analysis and adaptive management.

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3. https://xerces.org/sites/default/files/2018-05/06-001_02_XercesSoc_Making-Room-for-Native-Pollinators.pdf
4. https://ocs.umich.edu/sustainability-goals/
5. https://washtenawfoodpolicycouncil.wordpress.com/policy-action-teams/pollinator-policy-workgroup/
6. https://mbgna.umich.edu/
7. https://annarborcommunitycommons.org/groups/garden-committee/

APPENDICES

Appendix A. Museum of Natural History intern information

Sample job description for student intern.

No experience with gardening necessary but a sincere interest in developing a deep understanding of plants is essential. Requires attention to fine detail and interest in learning plant identification. Physical ability to work outdoors, in hot or cool conditions is required. All tools and a garden journal will be provided. The selected candidate will also lead several garden-related educational activities with summer camp students.

Intern Maintenance Guide

In spring, before weeding:

Spend at least one hour getting to know the garden layout, both on paper, and by studying a copy of the planting plan while in the garden. Use plant photos but remember that plants often look different when they are young versus when they flower. The young leaves may not even resemble the leaves of mature plants. Note that only cool-season plants will be emerging in early spring and many will naturally decline in summer. Warm-season plants may be visible if there are old stems present, but new growth may not emerge for several weeks or until the soil warms. Depending on the time of year, some plants may not be visible. Some plants may have shifted slightly from the planting plan. Look for similarities and differences between plants you know are in the right place, and plants that are not where you expected. If needed, place a small flag in each of the intentionally planted plants. This will highlight which plants to avoid when weeding.

Weeding:

Do not weed until you have studied the planting design thoroughly. See previous section

Use Dutch push hoe every 2 - 3 weeks. Watch How to Use a Dutch Push-Pull Hoe by Roy Diblik (Roy Diblik, 2020). Trace around the perimeter of each plant to disturb young weed seedlings. This should take approximately 1 hour. There should be roughly 1’ of unplanted area between the planting and the sidewalk. This area can be weeded with vigor!

In June (or when planting becomes too dense for the Dutch push hoe) switch to hand-pulling weeds. There should not be as many to pull if spring weeding is thorough.

Watering:

Watering is especially important in the first year after planting. The garden will need to be watered every 4 - 7 days depending on the weather. The best way to monitor for watering needs is to get a rain gauge. The garden needs a little over 1” of rain per week. You can also stick your finger in the soil around the base of a few plants to test for soil moisture an inch or more under the surface. If the rain or sprinklers aren’t providing enough water, hand watering will be needed. Apply roughly 1” of water during each watering.

Appendix B Maintenance checklists

XERCES SOCIETY for Invertebrate Conservation

CHECKLIST OF ACTIONS
To Promote Pollinators In Yards, Gardens & Parks

KEY:
- Promotes foraging resources
- Helps protect pollinators from pesticide exposure
- Promotes nesting and overwintering habitat
- Contributes to pollinator conservation in your community

LANDSCAPING

- [ ] Plant a **native** wildflower garden that includes species that bloom in succession all season long and are high-value to pollinators (species with ★ on **Table 1**, page 12).
- [ ] Plant **native** bunchgrasses; these plants are food for rare butterflies and also help provide nesting sites for bees.
- [ ] Reduce lawn footprint by converting as much as possible to *flowering* habitat.
- [ ] Plant **spring**-blooming **native** wildflowers, such as woodland ephemerals in shady areas.
- [ ] Plant **spring**-blooming **native** shrubs and trees, such as willows (*Salix*), maples (*Acer*), and native fruit trees and shrubs.
- [ ] Plant **summer**-blooming **native** wildflowers, such as blazing star (*Liatris*), bee balm (*Monarda*), and numerous others.
- [ ] Plant **summer**- or **fall**-blooming **native** shrubs, such as wild roses (*Rosa*) or meadowsweet (*Spirea*).
- [ ] Plant **fall**-blooming **native** wildflowers, such as asters (*Symphyotrichum*), native sunflowers (*Helianthus*), and goldenrods (*Solidago*).
- [ ] Plant **native** trees that serve as important host plants for a wide variety of butterflies and moths (species with [symbol] on **Table 1**, page 12).
- [ ] Plant **native** milkweed (*Asclepias*), violets (*Viola*), pawpaws (*Asimina*), or other regionally appropriate plants that provide critical food for specialist butterflies and moths.
- [ ] Plant species known to provide food for specialist bees in your region (species with [symbol] on **Table 1**, page 12).
- [ ] Gradually replace perennial and annual landscaping that provides little value to wildlife (e.g., daylilies, hostas, pansies) with more diverse **native** wildflower plantings.
- [ ] If non-native plants are included in landscaping, choose varieties that are known to have value to pollinators (e.g., flowers with ample pollen or nectar) **AND** that are not invasive or aggressive.
- [ ] Remove invasive species from your landscape, as well as any non-native species that appear to be spreading into wild areas (e.g., butterfly-bush).
- [ ] Ensure that new landscaping plants were not treated with neonicotinoids or other related insecticides.

Why Plant Native?

Native plants have a very long history of naturally occurring in the wild ecosystems of a given area (pre-European settlement of the Americas). Non-native plants naturally occur in other parts of the world or the country, but may be grow well in your area as ornamental or garden plants. Some non-native plants have the tendency to escape into the wild and become invasive, replacing natives plants and causing serious ecological and economic problems. Although pollinators may find some nutritional value from non-native plants, native plants do the best job of supporting the widest array of native pollinators, given their long co-evolutionary history. In fact, roughly ⅓ of bee species will only collect pollen from particular native plants, and most butterfly and moth caterpillars can only feed on particular native plant leaves.

LAWN & YARD CARE

- [ ] Avoid pesticides (including herbicides, insecticides, and fungicides) on lawns and other landscaping; choose less harmful alternatives such as non-chemical controls.
- [ ] For mowed areas, reduce mowing frequency and increase mowing height, allowing flowering weeds to flourish.
- [ ] Leave dead wood on site, including dead logs, snags, and brush; consider planting flowers around these features, to add intention and aesthetic value.
- [ ] Leave leaf litter on-site—keep a thin layer of leaves on lawn; use the rest to mulch trees/ shrubs/ garden and/or rake to woodland edges if available.
- [ ] Leave bare spots or areas with patchy vegetation in lawn; avoid thick turf and sod.
- [ ] Avoid plastic mulch/ weed barrier, heavy wood chips, and treated wood chips.
- [ ] Leave dead wildflower stems standing over the **winter**; prune them back in **early spring** to 8–12" to create nesting sites for stem-nesting bees.
- [ ] Prune shrubs with pithy stems, to create nesting sites for stem-nesting bees.
- [ ] Leave some areas of lawn unmown to create tall grass habitat.
- [ ] Install a water feature (e.g., bird bath with stones to prevent insects from drowning) for pollinators that need water for nest building or other uses.
- [ ] Seed a "bee lawn" (incorporate clovers & other flowers into new or existing lawn).

FRUIT & VEGETABLE GARDENS

- [ ] Plant fruit trees and fruit-bearing shrubs, including **native** species when possible (e.g., blueberries [*Vaccinium*], currants and gooseberries [*Ribes*], elderberries [*Sambucus*], chokeberries [*Aronia*]—species with [symbol] on **Table 2**, page 12).
- [ ] Plant **native** raspberries/ blackberries (*Rubus*); prune in **early spring** to create nest sites for stem-nesting bees.
- [ ] For more continuous fruit and flowers, plant ever-bearing varieties of strawberries (*Fragaria*), raspberries, and other fruits.
- [ ] Plant a tea or herb garden and allow plants like basil (*Ocimum*), mint (*Mentha*), and lavender (*Lavendula*) to flower; most herbs do very well in containers if space is limited (see **Table 2**, page 12).
- [ ] Plant bee-pollinated vegetables like squash (*Cucurbita*) and tomatoes (*Solanum*) **and** allow pollinator-attractive culinary garden plants—such as lettuce (*Lactuca*) and mustard (*Brassica*)—to bolt in order to provide additional floral resources (see **Table 2**, page 12).
- [ ] Avoid pesticide use on fruit and vegetable crops; manage pests by using prevention strategies (e.g., crop rotation or selection of resistant varieties) and non-chemical pest control methods (e.g., hand-picking or insectary plantings to promote beneficial insects for natural pest control).

COMMUNITY ACTION

- [ ] Organize a neighborhood **native** plant or seed exchange (**never** share non-native plants that are aggressive / potentially invasive).
- [ ] Create habitat in community hubs (e.g., libraries, post-offices, schools, or senior centers) or in unused spaces like sidewalk medians.
- [ ] Volunteer with a local park to improve habitat (e.g., removing invasive species or collecting wildflower seeds).
- [ ] Provide signage to explain your pollinator conservation actions to your neighbors.
- [ ] Host a tour of your pollinator friendly yard or garden.
- [ ] Talk about pollinators and their habitat needs to your neighbors, friends, family, local businesses, schools, library, church, etc.
- [ ] Talk to your city officials or local colleges about signing a bee friendly resolution and/or getting certified as a Bee City USA or Bee Campus USA.
- [ ] Participate in a community science project, such as bumble bee or monarch monitoring (see *Resources*, page 11).

Print additional copies of this and other habitat assessment tools at: xerces.org/habitat-assessment-guides.

BEE CONSERVATION CHECKLIST: BENEFICIAL ACTIONS

NESTING HABITAT

- ☐ Prevent soil disturbance
- ☐ Prevent soil compaction
- ☐ Leave areas of bare soil, especially on slopes/banks
- ☐ Preserve existing ground-nesting sites
- ☐ Leave standing dead trees
- ☐ Leave or add downed logs
- ☐ Leave leaf litter
- ☐ Leave perennial flower stalk stubble when cutting down plant material in spring as potential sites for cavity-nesting bees
- ☐ Add or leave rocks with holes for nesting cavities
- ☐ Perform rotational prescribed burns in sections of a site with a multi-year time line

FORAGING RESOURCES

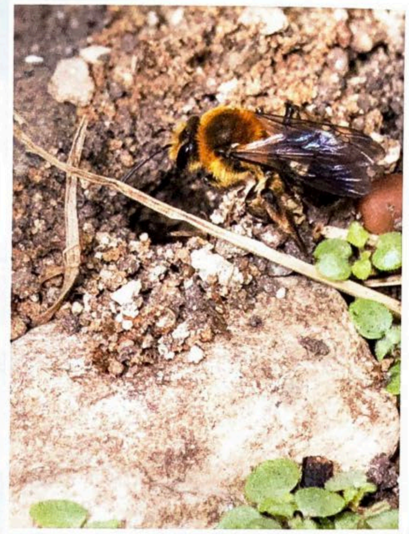
- ☐ Provide a continuous succession of flowering plants from spring through fall
- ☐ Plant a diversity of native plants with different flower forms and floral resources
- ☐ Plant specialist-specific native plants
- ☐ Provide a shallow source of water and refresh every 5-7 days (to kill mosquito larvae and prevent disease)

PLANT SELECTION & PLACEMENT

- ☐ Remove invasive plant species while minimizing soil disturbance
- ☐ Use local native plant communities as cues for plant selection
- ☐ Select plants native to the area/region
- ☐ Purchase locally grown native plants
- ☐ Replace a portion of lawn with forage plants
- ☐ Incorporate forage plants in the lawn
- ☐ Plant forage plants in masses to create better visual attractants
- ☐ Plant next to/expand/restore/connect existing native plant community fragments
- ☐ Connect/expand habitat corridors

PESTICIDE POISONING PREVENTION

- ☐ Purchase plants from retailers that do not use systemic insecticides during nursery production
- ☐ Use non-chemical methods to control pests
- ☐ Restrict or eliminate pesticide use, especially when forage plants are flowering



DESTRUCTIVE ACTIONS: PRACTICES TO AVOID

NESTING HABITAT

- ☐ Tilling soil
- ☐ Compacting soil by driving vehicles/equipment on landscape
- ☐ Creating large soil disturbances by scraping soil/uprooting large woody plants
- ☐ Cutting down dead trees
- ☐ Removing all leaves from the landscape
- ☐ Removing branches/downed logs
- ☐ Fragmenting existing habitat
- ☐ Increasing the size of the lawn
- ☐ Cutting down and removing plant material/stems in the fall
- ☐ Covering bare soil with mulch, plastic, or plants where nesting sites occur
- ☐ Covering the soil with plastic and/or landscape rock
- ☐ Performing a prescribed burn over the entire site in one season
- ☐ Not replacing liners/stems or cleaning man-made cavity nests every two years
- ☐ Destroying rodent holes

FORAGING RESOURCES

- ☐ Planting hybrids/cultivars bred for color change or double blooms that restrict pollinator access or offer fewer or no floral rewards
- ☐ Planting only annuals
- ☐ Mowing/spraying forage plants

PLANT SELECTION & PLACEMENT

- ☐ Planting/not removing invasive species
- ☐ Removing or applying herbicide to native forage plants
- ☐ Planting plants not locally grown or unsuitable to climate/region

PESTICIDE POISONING

- ☐ Using plants treated with systemic insecticides during nursery production
- ☐ Using insecticides
- ☐ Applying fungicides/herbicides to lawn where nesting sites or forage plants occur
- ☐ Using herbicides on forage plants
- ☐ Using rodent poison in burrows
- ☐ Applying pesticides in windy conditions producing spray drift

Appendix C Extended list of pollinator plants that were considered for the typologies for UM Ann Arbor Campus. Plants are organized by typology for ease of application based on site conditions. While native plants are preferred, many nativars are included here for use in more formal campus landscapes. For less formal areas, the straight native species is preferred.

Typology 1: Full sun, medium moisture, high visibility (e.g., showy sidewalk garden)

Form	Common Name	Botanic name	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Flowering	Blue Fortune anise hyssop	*Agastache foeniculum* 'Blue Fortune'	S - PSh	Med	2 - 3'	1.5 - 2'	July - Oct	Purple	tubular	Y	N	Nectar source	Bumble bees, small resin bees, leafcutter bees, long-horned bees
Flowering	Wild onion	*Allium cernuum*	S - PSh	Med	1.5'	1	July - Aug	Pale pink	nodding	Y	Y	nectar, pollen	Leafcutter bees, small resin bees, sweat bees, bumble bees, cellophane bees, soldier beetles, tumbling flower beetles, syrphid flies
Flowering	Summer Beauty ornamental onion	*Allium tanguticum* 'Summer Beauty'	S	Dry - Med	1.5 - 2'	1'	July - Aug	Pink	umbel	Y	Y	Nectar and pollen source	Bumble bees, honey bees, butterflies, and moths
Flowering	Blue Ice bluestar	*Amsonia* 'Blue Ice'	S - PSh	Med	1'	1.5 - 2'	May - June	Blue	tubular	Y	Y	Nectar source	Butterflies and moths
Flowering	Threadleaf blue star	*Amsonia hubrichtii*	S - PSh	Med	3'	2.5	July	Blue	tubular	Y	Y	nectar	Long-tongued bees, carpenter bees, hummingbird moths, butterflies, hummingbirds
Flowering	Whorled milkweed	*Asclepias verticillata*	S - PSh	Dry - Med	2'	1'	July - Aug	White	umbel	Y	Y	Larval host for monarch and queen butterflies. Nectar and pollen source.	Honey bees, bumble bees, sweat bees, wasps, syrphid flies, butterflies, skippers
Flowering	Tall coreopsis	*Coreopsis tripteris*	S	Dry - Med	5'	2	July - Sept	Yellow	composite	Med	Y	nectar, pollen	Small carpenter bees, leafcutter bees, small resin bees, cuckoo bees, long-horned bees, sulphur butterflies, moths, beetles, wasps, syrphid flies, ants
Flowering	Purple coneflower	*Echinacea purpurea*	S - PSh	Med	3'	1.5	June - Aug	Purple	composite	Y	Y	nectar, pollen	Bumble bees, leafcutter bees, butterflies (monarchs, red admirals, sulphurs, fritillaries, swallowtails), banded long-horn beetle
Flowering	Magnus purple coneflower	*Echinacea purpurea* 'Magnus'	S - PSh	Dry - Med	2.5 - 3'	1'	June - Sept	Pink	composite	Y	Y	Nectar and pollen source	Mining bees*, long-horned bees, sweat bees, green sweat bees, leafcutter bees, bumble bees, butterflies, beetles
Flowering	Walker's Low nepeta	*Nepeta x faassenii* 'Walker's Low'	S	Dry - Med	1.5 - 2'	2 - 3'	Apr - Sept	Lavender	tubular	Y	Y	Nectar and pollen source	Bumble bees, honey bees, small bees, butterflies
Flowering	Little Spire Russian sage	*Perovskia atriplicifolia* 'Little Spire'	S	Dry - Med	1.5 - 2'	2 - 2.5'	Aug - Sept	Purple	tubular	Y	Y	Nectar and pollen source	Bumble bees, honey bees, small bees, butterflies
Flowering	Wild petunia	*Ruellia humilis*	S	Dry - Med	1'	1.5	June - Aug	Lavender	tubular	Y	Y	nectar, pollen, larval host (common buckeye)	Sweat bees, small carpenter bees, green sweat bees, syrphid flies, leafcutter bees, butterflies, moths
Flowering	Caradonna meadow sage	*Salvia nemorosa* 'Caradonna'	S	Dry - Med	2 - 2.5'	1.5 - 2'	May - June	Purple	tubular	Y	Y	Nectar and pollen source	Bumble bees, honey bees, small bees, butterflies
Flowering	Autumn Joy sedum	*Sedum* 'Autumn Joy'	S	Dry - Med	1.5 - 2'	1.5 - 2'	Aug - Oct	Pink	umbel	Y	Y	Nectar and pollen source	Wide variety of bees and butterflies

Flowering	Solar Cascade Short's goldenrod	*Solidago shortii* 'Solar Cascade'	S - PSh	Dry - Med	2 - 3'	1 - 2'	Sept - Oct	Yellow	composite	Y	Y	Abundant nectar and pollen source	Long-horned bees, sweat bees, green sweat bees, bumble bees, leafcutter bees, small carpenter bees, mining bees*, wasps, butterflies, beetles, syrphid
Flowering	October Skies aromatic aster	*Symphyotrichum oblongifolium* 'October Skies'	S - PSh	Dry - Med	1 - 1.5'	1.5 - 2'	Sept - Oct	Purple	composite	Y	Y	Nectar and pollen source. Larval host for 109 species of caterpillars.	Metallic green sweat bees, long-horned bees, sweat bees, small carpenter bees, mining bees*, bumble bees, cellophane bees*
Flowering	Prairie heart leaved aster	*Symphyotrichum oolantangiense*	S - PSh	Dry - Med	2.5'	1.5	Aug - Sept	Blue	composite	N	Y	nectar, pollen, larval host (pearly crescent, silvery checkerspot, gorgone checkerspot, northern crescent)	Mining bees*, small carpenter bees, leafcutter bees, bumble bees, long-horned bees, cuckoo bees, green sweat bees, bee flies, syrphid flies, soldier beetles
Flowering	Golden alexander	*Zizia aurea*	S - PSh	Med - Wet	2.5'	1.5	May - June	Yellow	compound umbel	N	Y	nectar, pollen, larval host (black swallowtail, Ozark swallowtail, rigid sunflower borer)	Mining bees*, mason bees, bumble bees, sweat bees, yellow-faced bee, small carpenter bee, potter wasp, paper wasp, syrphid flies, tachinid flies, azure
Grass	Blue grama	*Bouteloua gracilis*	S - PSh	Dry	1.5'	2	July - Aug	Green	wind-pollinated	Y	Y	nesting & overwintering habitat	
Grass	Blonde Ambition blue grama	*Bouteloua gracilis* 'Blonde Ambition'	S - PSh	Dry - Med	2.5'	2'	Aug - Oct	Green	wind-pollinated	Y	Y	Clump grass provides overwintering substrate	Butterflies, moths, large carpenter bees, hummingbirds
Grass	Little bluestem	*Schizachyrium scoparium*	S	Dry - Med	3'	1.5	Aug	Green	wind-pollinated	N	Y	nesting & overwintering habitat, larval host (Indian skipper, crossline skipper, cobweb skipper, hobomok skipper,	

Typology 2: Shade, dry, high visibility (e.g., under tree canopy)

Form	Common Name	Botanic name	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Flowering	Dily's hardy geranium	*Geranium* 'Dily's'	S - PSh	Med	1'	1.5'	June - Sept	Pink	open/cup	Y	Y	Nectar and pollen source	Small carpenter bees, sweat bees, mason bees, mining bees, bumble bees, cuckoo bees, syrphid flies
Flowering	Hairy alum root	*Heuchera villosa*	S - Sh	Dry - Med	2'	2	Aug - Sept	White	tiny, nodding	Y	Y	nectar, pollen	Small sweat bees, green sweat bees
Flowering	Autumn Bride alumroot	*Heuchera villosa* 'Autumn Bride'	S - PSh	Med	2'	1.5'	Aug - Sept	White	tubular	Y	Y	Nectar and pollen source	Sweat bees, cellophane bees*
Flowering	Guacamole hosta	*Hosta* 'Guacamole'	PSh - Sh	Med	1.5'	2.5 - 3'	Aug - Sept	White	tubular	N	Y	Nectar and pollen source	Bees, hummingbirds
Flowering	Starry solomon's seal	*Maianthemum stellatum*	PSh	Dry - Wet	1 - 2'	1.5'	May - June	White	tubular	Y	Y	Mostly a pollen source, but also nectar	Azure butterflies, moths, beetles, small sweat bees
Flowering	Virginia bluebells	*Mertensia virginica*	PSh - Sh	Med	1 - 2'	1'	Apr - May	Blue	tubular	Y	N	Early spring pollen and nectar source	Bumble bees, honey bees, mason bees, bee flies, butterflies, skippers, sphynx moths, sweat bees
Flowering	Avondale heart-leaved aster	*Symphyotrichum cordifolium* 'Avondale'	S - PSh	Med	2 - 3'	1'	Aug - Sept	Lavender	composite	Y	Y	Larval host for 109 species of caterpillars	Long-tongued and short-tongued bees, wasps, flies, skippers, butterflies, beetles
Grass	Appalachian sedge	*Carex appalachica*	PSh - Sh	Dry - Med	1'	1'	May	Green	wind-pollinated	Y	Y	Larval host for 36 species of caterpillars	

Typology 3: Part sun, frequently wet (e.g., rain garden)

Form	Common Name	Botanic name	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Flowering	Canada anemone	*Anemone canadensis*	S - PSh	Med - Wet	1 - 2'	1.5'	June - July	White	cup	Y	N	Pollen source	Mining bees, small carpenter bees, small sweat bees, green sweat bees, leafcutter bees, yellow-faced bees, beetles, syrphid flies
Flowering	Cinderella swamp milkweed	*Asclepias incarnata* 'Cinderella'	S - PSh	Med - Wet	3 - 4'	2 - 3'	July - Aug	Pink	hood	Y	Y	Larval host for monarch and queen butterflies. Nectar resources only.	Butterflies and moths including skippers, monarchs, fritillaries, sulphurs, whites, and swallowtails. Variety of bees, wasps, ants, beetles, flies, and bugs.
Flowering	Purple Dome New England Aster	*Aster novae-angliae* 'Purple Dome'	S - PSh	Med - Wet	1.5'	1.5'	Sept - Oct	Purple	composite	Y	Y	Nectar and pollen source. Larval host for pearl crescent and Canadian sonia moth.	Butterflies and moths, mining bees*, small carpenter bees, leafcutter bees, bumble bees, honey bees, long-horned bees, cuckoo bees,
Flowering	Turtlehead	*Chelone glabra*	S - PSh	Wet	2 - 4'	1 - 2'	Aug - Sept	White	bilabial	Y	N	Nectar. Larval host for Baltimore checkerspot butterfly.	Bumble bees, two-spotted long-horned bees
Flowering	Little Joe Joe pye weed	*Eupatorium dubium* 'Little Joe'	S - PSh		3 - 4'	1 - 3'	Aug - Sept	Pink	composite	Y	N	Nectar and pollen source. Larval host for three-lined flower moth and ruby tiger moth.	Butterflies, bumble bees, cuckoo bees, leafcutter bees, honey bees
Flowering	Blue Flag Iris	*Iris versicolor*	S - PSh	Med - Wet	2.5'	1'	May - July	Blue	tubular	Y	Med	Nectar and pollen source	Bumble bees, long-horned bees, butterflies and moths
Flowering	Kobold blazing star	*Liatris spicata* 'Kobold'	S	Med - Wet	1.5 - 2'	1'	July - Aug	Magenta	composite	N	Y	Nectar and pollen source. Larval host for bleeding flower moth and blazingstar moth.	Bumble bees, leafcutter bees, long-horned bees, honey bees, bee flies, syrphid flies, skippers, monarchs, painted ladies, swallowtails, tiger moths
Flowering	Great blue lobelia	*Lobelia siphilitica*	S - PSh	Med - Wet	2.5 - 3'	1.5'	July - Sept	Blue	tubular	Y	N	Nectar and pollen source	Bumble bees (primary), digger bees, yellow-faced bees, green sweat bees, small carpenter bees
Flowering	Shenandoah switchgrass	*Panicum virgatum* 'Shenandoah'	S - PSh	Med - Wet	3'	2 - 2.5'	Aug - Sept	Green	wind-pollinated	Y	Y	Clump grass provides overwintering substrate	
Flowering	Dark Towers beardtongue	*Penstemon digitalis 'Dark Towers'*	S - PSh	Dry - Med	1.5 - 3'	1.5'	June - Aug	White	tubular	N	Y	Nectar and pollen source	Small- and medium-sized bees, mason bees*, leafcutter bees, sweat bees, bumble bees, syrphid flies, digger bees
Flowering	Broad-leaved mountain mint	*Pycnanthemum muticum*	S - PSh	Med	2 - 3'	2'	Aug - Sept	White	composite	Y	Y	Nectar and pollen source	Long-horned bees, green sweat bees, yellow-faced bees, small resin bees, bumble bees, great black wasps, beetles, banded hairstreak butterfly, ants
Grass	Palm sedge	*Carex muskingumiensis*	S - Sh	Med - Wet	2'	2'	May - June	Green	wind-pollinated	Y	Y	Larval host for 36 species of caterpillars	
Shrub	Blues Festival Kalm's St. John's Wort	*Hypericum kalmianum* 'Blues Festival'	S - PSh	Med - Wet	3'	3'	June - Aug	Yellow	open/cup	Y	Y	Pollen. Larval host for black arches moth and gray half-spot moth.	Leafcutter bees, sweat bees, green sweat bees, syrphid flies, bumble bees, banded long-horned beetles

Typology 4: Shade, medium moisture, low visibility (e.g., foundation hedge)

Form	Common Name	Botanic name	Light	Moisture	Height (ft.)	Width (ft.)	Bloom time	Bloom color	Flower shape	Deer resistance	Drought tolerance	Pollinator resource	Pollinators
Flowering	Big leaf aster	*Eurybia macrophylla*	PSh - Sh	Dry - Med	1 - 3'	2'	Aug - Oct	Lavender	composite	Y	Med	Larval host for silvery checkerspot, pearl crescent butterfly, and goldenrod hooded owlet. Late pollen and nectar	
Flowering	Wild geranium	*Geranium maculatum*	S - PSh	Med	1.5'	1'	May - June	Pink	open/cup	N	N	nectar, pollen, larval host (leafmining moth, white-marked tussock moth)	Mining bees*, small carpenter bees, sweat bees, mason bees, mining bees, bumble bees, cuckoo bees, syrphid flies, thick-headed flies, fruitworm
Flowering	Woodland sunflower	*Helianthus divaricus*	S - PSh	Dry - Med	4'	2	July - Aug	Yellow	composite	Y	Y	nectar, pollen	bumble bees, long-horned bees, sweat bees, spotted cucumber beetle, soldier beetles, syrphid flies, butterflies
Flowering	Alleghany pachysandra	*Pachysandra procumbens*	PSh - Sh	Dry - Med	1.5 - 2'	1 - 2.5'	May - Apr	White	tubular	Y	N	Early spring pollen and nectar source	
Flowering	Woodland stonecrop	*Sedum ternatum*	PSh - Sh	Dry - Med	0.5'	1	May - June	White	open/cup	Y	Y	nectar, pollen	Small bees, mining bees, wasps, flies
Flowering	Zig zag goldenrod	*Solidago flexicaulis*	S - Sh	Dry - Med	1.5'	2	Aug - Sept	Yellow	composite	Y	Y	nectar, pollen, larval host (bilobed dichomeris, brown hooded owlet, twirler moth)	Mining bees*, sweat bees, yellow-faced bees, green sweat bees, bumble bees, thread-waisted wasp, carrot wasp, syrphid flies, soldier beetles
Flowering	Spring Symphony foamflower	*Tiarella cordifolia* 'Spring Symphony'	PSh - Sh	Med	0.5 - 0.75'	1'	Apr - June	Lt. Pink	tubular	Y	N	Early spring pollen and nectar source	Sweat bees, green sweat bees, syrphid flies, ants
Grass	Penn sedge	*Carex pensylvanica*	PSh - Sh	Dry - Med	1'	1.5'	Apr - May	Green	wind-pollinated	Y	Med	larval host (eyed brown, Appalachian brown, dion skipper, broad winged skipper, mulberry wing, dun skipper)	
Grass	Rosy sedge	*Carex rosea*	PSh - Sh	Dry - Wet	1'	1'	May	Green	wind-pollinated	Y	Y	Larval host for 36 species of caterpillars	
Shrub	Red-osier dogwood	*Cornus sericea*	S - Sh	Dry - Wet	3 - 9'	8 - 12'	June - Aug	White	pseudo-umbel	Y	N	Nectar, pollen, larval host	Mining bees*, small carpenter bees, metallic green sweat bees, small sweat bees
Shrub	Hazelnut	*Corylus americana*	S - PSh	Dry - Med	5 - 9'	12'	Mar - Apr	Yellow	wind-pollinated	N	Med	Larval host for 125 species of caterpillars	
Shrub	Witchhazel	*Hamamelis virginiana*	PSh - Sh	Dry - Med	20 - 30'	15'	Sept - Nov	Yellow	open/cup	Y	Med	Larval host for 62 species of caterpillars	Sweat bees, wasps, flies
Shrub	Ruby Slippers oakleaf hydrangea	*Hydrangea quercifolia* 'Ruby Slippers'	S - PSh	Med	3 - 4'	4 - 5'	June - July	White - Pink	tubular	Y	Y	Early summer pollen and nectar source	
Shrub	Spicebush	*Lindera benzoin*	PSh - Sh	Med - Wet	5 - 10'	6 - 12'	Apr - May	Yellow	open/cup	Y	Y	Larval host for spicebush swallowtail. Early spring pollen and nectar source.	Small bees, flies

Appendix C Sources:

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Appendix D Local and regional native plant nurseries.

Local native plant nurseries:

Name	Contact person	Contact information	Website
Ann Arbor Native Plant Nursery	Greg Vaclavek	P.O. Box 2292 Ann Arbor, MI 48106 (734) 677-3260	www.nativeplant.com
Feral Flora	Matt Demmon	Ann Arbor, MI 734-224-2080 info@Feral-Flora.com	www.feral-flora.com
Wildtype Nursery	Bill Schneider	900 N Every Rd. Mason, MI 48854 517-244-1140 info@wildtypeplants.com	www.wildtypeplants.com

Regional nurseries that offer both native and cultivated varieties of plants:

Name	Contact person	Contact information	Website
Hortech, Inc.	Tia Dumbrigue	14109 Cleveland St. Nunica, MI 49448 800-875-1392 tia@hortech.com	www.grownearthfriendly.com
Midwest Groundcovers	David Kieser	6N800 IL-25 St. Charles, IL 60174 (847) 742-1790 mginfo@midwestgroundcovers.com	www.midwestgroundcovers.com
North Creek Nurseries	n/a	388 North Creek Road Landenberg, PA 19350 (877) ECO-PLUG info@northcreeknurseries.com	www.northcreeknurseries.com

Appendix E SEAS Bees Website considerations from Katrina Folsom

SEAS Bees website planning

- Questions about governance of the SEAS Bees site:
    - Who will own and manage the website (manage user permissions, apply security fixes, troubleshoot, etc.)?
    - Who will continue paying for it?
    - Who will maintain the content?
- If governance is satisfactory, the best bet is for OCS and Grounds sites to link to the external site, treating it as the central source.
- If long-term (at least ~3 years) governance is not solid, I propose:
    - Create a new page (with up to a few sub-pages) on the OCS or Grounds website. Best fit depends on the focus of the site and who will generate the most updates.
        - If the focus is community awareness and engagement (events, maps, tips, etc.), OCS is best. If the focus is more about the on-the-ground aspects (e.g. plantings, landscape maintenance, etc.), Grounds might be a better fit because they'll generate more of the updates.
            - Caveat: I have not talked to F&O Information Services (FOIS) about their capacity to add to the Grounds site. For that matter, I'd need to confirm any plans to add to the OCS website, so this is all tentative depending on the nature of the SEAS Bees site.
        - The OCS website has a more exciting look and we can edit more often and more quickly than Grounds can. (Katrina and a few other OCS staff can make basic changes; for more complex stuff, we submit tickets to FOIS.)
    - Drawback, of course, is that the pretty site already designed wouldn't serve its purpose.
- Potential bridging approach: if another SEAS team will be taking over this project for 2021-22 and will actively maintain the draft site, use it for the next year and transition the content to pages on the OCS or Grounds sites for long-term ownership in spring 2022.
    - Funding TBD - how much are the website fees?
- Places to add links (feel free to list other potential places):
    - OCS website
    - Grounds website
    - SEAS Bees (static) project page

Sustainable Grounds spark story