TWO APPROACHES TO SUPPORTING NATIVE POLLINATORS: FIELD ESTABLISHMENT OF BUTTERFLY WEED AND A GARDEN FOR CONSERVATION EDUCATION

by

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(Under the Direction of James Affolter)

ABSTRACT

Pollinator conservation often involves two components: habitat restoration and educational outreach. In an experimental out planting of year-old Butterfly Weed (*Asclepias tuberosa*) plants we tested the effects of fertilizer application and spring mowing on plant growth, flowering, and fruiting. Plants performed similarly under all treatment methods suggesting that a dormant-season planting without site treatments is an effective establishment method. We recommend focusing on growing healthy potted plants to ensure the successful establishment in grassland ecosystems in the Georgia Piedmont.

Urban green spaces are known refuges for pollinators while also serving as places where conservation education can reach diverse audiences. We studied the efficacy of a college campus native plant garden to teach pollinator conservation topics to undergraduates using the garden as an outdoor classroom. This was an effective teaching method for both science and non-science majors and a majority of the students also supported the garden and interpretive signage as a framework for discussing topics on pollinator conservation and plant insect interactions.

INDEX WORDS: Conservation Education, Narrative Landscape, *Asclepias tuberosa*, Transplant Establishment, Georgia Piedmont Grassland

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

As urbanization and habitat fragmentation are increasingly destroying or degrading natural habitats on a global scale, biodiversity is under increasing pressure from humans. Much of this urbanization in the United States is concentrated in the southeast region and Georgia is currently the fourth fastest growing state (2010). As researchers study the effects of urban expansion on natural areas, it appears that homogenization is occurring biologically and also environmentally (Mckinney, 2006). Human activities and expansion of our cities result in environmental disturbance that results in an increase of exotic plant species (D'antonio & Meyerson, 2002) and the extirpation of native plants (Byers, 2002). At the same time, insect pollinators may also be declining globally, although more coordinated research efforts are necessary to improve monitoring and understanding of this phenomenon (Potts et al., 2010).

Conservation strategies should include the protection and restoration of remaining natural areas, but also emphasizing ecologically functional landscapes in urban areas that serve as educational resources for local communities. Restoring early successional habitats such as grasslands and prairies can be an excellent conservation measure due to the abundance of floral resources found in these habitats, providing forage for insect pollinators (Delaney et al., 2015). A common objective of grassland restoration involves increasing plant diversity. It has been shown that plant species richness can be an indicator of grasslands' ability to support insect and animal biodiversity (Peters et al., 2016). In urban settings, areas of high floristic diversity can also support a diverse suite of insect pollinators (Hall et al., 2017; Lowenstein et al., 2014; Shwartz et al., 2014). While people generally support conserving diversity, they are often not able to recognize what a more diverse landscape looks like (Shwartz et al., 2014), indicating a need for conservation education and to provide opportunities to connect with nature in our urban green spaces. Ultimately, the solution to global declines in biodiversity is not straightforward. Efforts should be focused on protecting and restoring natural areas while also increasing public awareness and appreciation for healthy ecosystems.

This research addresses the need for pollinator conservation from two different approaches: restoring natural areas for pollinator habitat and outreach to teach topics on pollinator conservation. The two elements of this thesis can collectively impact insect pollinator conservation in a positive way. Chapter two focuses on environmental education using an urban native pollinator garden as an outdoor classroom to discuss the role our urban landscapes in conservation. We looked at the impact of this garden-based lecture to see whether or not undergraduate students were able to recall information from the lecture and if they accepted the teaching style. Chapter three evaluates the effects of site treatments, spring mowing and fertilizer application, on the establishment of Butterfly Weed (*Asclepias tuberosa* L.) in a Georgia Piedmont grassland. It is essential that we both improve the quality and amount of suitable habitat in natural areas for insect pollinators but also increase educational outreach. Together, these two chapters address these components of pollinator conservation.

Declining Biodiversity and Habitat Loss in Georgia

An increasing body of research documents an alarming pattern of declining biodiversity on a global level. IUCN's Global Species Assessment (Baillie et al., 2004) indicates that extinction rates continue to rise and threatened species tend to be concentrated in areas of high population growth. The UN projects a global increase in population from 9.6 to 12.3 billion by the year 2100 (Desa, 2013). Forces such as habitat loss and degradation, exotic invasive species, disease pressure and climate change will all negatively impact both plant and animal species. These threats to biodiversity rarely effect ecosystems or species in a solitary manner and interactions between internal and external threats further add to the complexity of the issue. Habitat loss and fragmentation associated with anthropogenic activities, however, are often cited as the principal drivers behind declines in biodiversity.

Much of the growth in the United States is concentrated in the Southeast with the state of Georgia ranked as the fourth most rapidly growing state in the nation. Georgia's population is projected to increase by 46% by the year 2030, with the highest density of growth occurring in the Piedmont region (2010). Rapid urbanization in the Southeast can be attributed to a number of socioeconomic factors such as increased property values, high opportunity costs for maintaining forested land, and improved infrastructure (Nagy & Lockaby, 2011). The mild climate and arable land also make the Southeast appealing for increased development. Not only are urban areas expanding in Georgia, but living in non-metropolitan areas is increasingly appealing to many Americans (Brown et al., 1997; Johnson & Beale, 1994). As Georgia's population rapidly expands, human activities are increasingly fragmenting natural lands in the Piedmont region (Edwards et al., 2013).

Habitat fragmentation is defined by Wilcox and Murphy (1985) as destruction, reduction, or subdivision of demographic units resulting in isolated patches of vegetation. This phenomenon is the focus of a large body of conservation biology research and fragmentation is considered by many to be the greatest threat to biodiversity (Haila, 2002; Jonathan A. Foley et al., 2005). Initially described in by Macarthur and Wilson (1967), habitat fragments were thought to function similar to islands. Haila (2002) challenges the island metaphor and suggests fragmentation is a much more complex issue and must be examined in a context-specific manner. Even as the concept of habitat fragmentation is re-defined, it is understood that this process results in a cascade of negative effects on natural ecosystems (Joern Fischer & David B. Lindenmayer, 2007). Fragmentation may be especially impactful in Georgia where five distinct geologic ecoregions produce a diverse range of natural communities.

Effects of human land use in Georgia not only create disjointed patches of habitat but also degrade their quality. Poor agricultural practices in the 17th-19th centuries led to severe erosion and the loss of much of the topsoil in the Piedmont. (Trimble, 2008). Timber production is another important industry in Georgia that by the mid-1900's, led to the logging of most old-growth forests (Brender, 1974). Urbanization and associated human impacts degrade surrounding ecosystem function and structure (Nagy & Lockaby, 2011). Strong evidence suggests that habitat destruction and fragmentation alter interactions between plants and pollinators (Hans-Peter & Bruno, 2010). This in turn disturbs both ecosystem function and structure (Alexandra-Maria et al., 2007; Olesen & Jain, 1968), however, these ecosystem responses to habitat fragmentation vary under different ecological conditions (Neame et al., 2013). Isolation of populations is the fundamental concept behind this anthropogenic phenomenon. Empirical evidence shows that decreased plant (Martin-Queller et al., 2017; Menz et al., 2011; William F. Laurance et al., 2001) and pollinator diversity (Gaston, 2000) accompany decreased habitat patch size. Loss of diversity is often highlighted as the most important response to habitat fragmentation but the issue is more complex; species composition may provide more insight than diversity alone (Neame et al., 2013).

The literature documents various ways that urbanization and habitat fragmentation threaten the survival of insect pollinators. Light pollution (Altermatt et al., 2016), excessive roadside mowing (Halbritter et al., 2015), exposure to pesticides (Hladik et al., 2016), and decreased floristic diversity (Frankie et al., 2009) are just a few of the ways that humans impact insect pollinators. As pollinators' habitat changes and areas of suitable habitat decrease, even the behavior of insects can change (Hans-Peter & Bruno, 2010). Long-term monitoring reveals declines in European honey bees (*Apis mellifera*) (Spleen et al., 2013; Vanengelsdorp et al., 2010; Vanengelsdorp et al., 2011), native bumble bees in Britain (*Bombus*)(Goulson et al., 2005), certain fly species in areas of Britain (J. C. Biesmeijer et al., 2006), and butterflies in California's Central Valley(Casner et al., 2014). In particular, declines in Lepidopteran species such as the Monarch Butterfly have been crucial to the recognition of insects' ecological importance. Even as the body of evidence grows documenting declines in insect populations, little is still known about the detailed causes and consequences of these declines.

Research has also demonstrated negative effects of habitat fragmentation on plant communities, however, plant responses vary based on time and size of the habitat fragment (Alofs et al., 2014). For example, it has been shown that as fragment decrease in size, so does plant species richness (Maltz et al., 2017). As these fragments are reduced in size they may ultimately become too small to sustain perennial plant populations. Conversely, annual plants may still maintain successful populations due to their generally smaller size and shorter life cycle (Martin-Queller et al., 2017). Reduced pollination and subsequent seed set have also been observed in fragmented habitats, likely due to pollinator scarcity (Marcelo A. Aizen & Peter Feinsinger, 1994). This demonstrates the interconnectedness of healthy plant and pollinator populations.

Losses of biodiversity and the impact of fragmented degrading habitats are widespread problems. While effects of fragmentation are difficult to generalize, scientists still seek to interpret the differences between habitat loss and fragmentation and their different effects (Fahrig, 2003). Regardless, it is undeniable that we must address habitat loss and fragmentation and the potential implications on biodiversity and ecosystem health as a whole. Increasing urbanization is inevitable and efforts should be focused on preserving intact habitats (Fahrig, 2003). On the other hand, fragmented patches of habitat can also be restored or enhanced (Lindenmayer & Fischer, 2006) and even small habitat patches in urban areas can provide resources to pollinators (National Academies & National Research Council . Committee on the Status of Pollinators in North, 2007). It is also increasingly important to communicate implications of declining biodiversity through education and outreach. Preventative efforts to mitigate impacts may involve restoring habitat or informative outreach to educate the public. Involving and informing citizens is an important conservation practice as urban landscapes are increasingly thought of as potential refuges for insect pollinators and pollinator friendly landscaping becomes more popular (Hall et al., 2017).

Restoring grasslands for pollinators

Grasslands and prairies are among the most imperiled ecosystems in North America (Noss, 2013; Ricketts, 1999). Many butterflies are dependent on early successional habitats such as grasslands for nectar foraging (Smallidge & Leopold, 1997) and restoring grasslands can have a high conservation impact due to the extremely high levels of plant and insect biodiversity (Honnay et al., 2005). Climate and several disturbance factors are responsible for maintaining these early successional habitats (Roger, 2006). However, conversion of these habitats for agricultural use threatens the existence of these biologically rich ecosystems (Deák et al., 2016).

While the most important conservation strategy for grasslands involves protecting any remaining natural areas from further destruction, fragmentation, or development (Noss, 2013), habitat restoration is also a critical component of conserving imperiled habitats (Harmon-Threatt & Chin, 2016; Management & Society for Ecological Restoration International, 2004). There is no one standard protocol for grassland restoration and each project is site specific based on ultimate restoration goals, physical factors such as topography or soil properties, biological factors such as habitat features and current plant communities present, site ownership, management goals and legal concerns (Rieger, 2014). Ultimately, maintaining an early successional habitat and increasing plant diversity are two principal objectives for habitat restoration in grasslands.

Several management strategies such as burning and mowing are commonly used to clear undesirable exotic plants or to prevent woody encroachment (Harmon-Threatt & Chin, 2016). These methods simulate disturbance regimes that were responsible for shaping many grasslands in North America (Daniel I. Axelrod, 1985) and can alter community structure of the grassland matrix (Collins, 1987). The timing and type of disturbance are important components of grassland restoration in order to increase plant species richness (Fynn et al., 2004). Timing of mowing can have different implications for grassland restoration; mowing in the spring before flowering can increase plants reproductive success (Nakahama et al., 2016). Forbs showed increased growth of above and below ground biomass in mowed plots, likely due to increased light availability (Williams et al., 2007). Mowing may also increase species richness (Maron & Jefferies, 2001; Tälle et al., 2016). Another management strategy, burning, helps maintain an herbaceous dominated landscape, removes accumulated duff layer, and helps reduce the seed bank of exotic annual plants (Prober et al., 2005). Burning can also be an effective management strategy for transplant establishment (Smallbone et al., 2008)

Enhancing wildflower diversity is another key element of grassland restoration. Native plants are generally thought of as most appropriate for use in restoration (Ross et al., 2003). Locally sourced plant material doesn't always perform better but will prevent the spread of undesirable alien genotypes (Bischoff et al., 2010; Jones & Hayes, 1999). An assortment of methods are used to introduce or increase forb diversity into grasslands such as direct seeding, strip-seeding, plug planting, spreading seed-containing hay, and brush harvesting (Hedberg & Kotowski, 2010). These techniques may be necessary when nearby populations of wildflowers aren't present to serve as a seed source (Bullock et al., 1994). Utilizing a transplant method in grassland restoration can be more effective than direct seeding in established stands of grasses by addressing competitive disadvantage (Brown & Bugg, 2001). Additionally, larger transplants have been shown to have lower mortality rates than plugs. Transplanting season is another important component of restoration. Anecdotally, late season planting can be more effective than spring planting due to generally higher levels of precipitation. In addition, planting in the spring may not provide adequate time for roots to establish before summer droughts (Davies, 2003).

Urban pollinator gardens for conservation and education

Currently, over half the world's population resides in urban areas and these urban areas are expected to continue to increase (2014). Unfortunately residents in urban areas are less likely to experience elements of nature (Kaplan et al., 1998; Rosenzweig, 2003). While it is documented that urbanization can negatively impact biodiversity, people are beginning to rethink the way that urban green spaces can function. Parks and gardens in cities can have social, economic, and ecological value (Baycan-Levent et al., 2009). Green infrastructure's ability to provide ecosystem services helps us address global losses of biodiversity in urban environments where sustainability is increasingly a focus of urban planning and development (Thurstain-

Goodwin, 2001). Integrating ecologically-minded plantings with educational components can support insect pollinators while providing an opportunity to increase environmental education in urban spaces.

As we rethink the function of our urban green spaces, factoring in pollinator conservation has become increasingly common. Cities are no longer viewed as ecological deserts. Research shows that urban habitats can be an important refuge for a diverse assemblage of pollinators such as bees (Goulson et al., 2008; Hernandez et al., 2009; Jaffe et al., 2010; Matteson et al., 2008), butterflies (Koh & Sodhi, 2004), and hoverflies (Bates et al., 2011). By providing nectar for forage and nesting resources in small urban gardens, we can increase insect diversity in the urban landscape. (Shwartz et al., 2014). It appears that creating gardens with high floral diversity may be the best approach to supporting pollinators (Bates et al., 2011; Cariveau & Winfree, 2015; Partnershipbrings & Initiative; Salisbury et al., 2015). Urban pollinator enhancement is still an active area of research where scientists seek to better understand the effect of pollinator friendly practices on insect populations. These urban native plant gardens may serve as a resource to communicate the benefits of such gardens from an ecological perspective and can also provide opportunities for environmental stewardship (Barthel et al., 2010).

Green spaces such as community gardens or parks can serve as a narrative landscape that acts a place for relaxation or recreation but may also serve a greater purpose to alter behaviors and attitudes about our environment. Educational signage and citizen science programs are ways that urban gardens may engage the community. Signage is a beneficial addition to pollinator gardens in order to increase conservation awareness and understanding of the garden's function (Shwartz et al., 2014). As the functions of urban gardens are altered to enhance or support biodiversity, so too must our perceptions, and these perceptions are dependant on ecological literacy (Nassauer, 1993). People generally understand the benefit of creating biodiverse green spaces but aren't able to tell if gardens contain more species. This is known as the people-biodiversity paradox (Devine-Wright et al., 2007), and increasing garden species diversity alone may not be enough to increase conservation awareness (Shwartz et al., 2014). Engaging "city-dwellers" in conservation-based activities can improve knowledge of urban conservation efforts (Shwartz et al., 2012), and community gardens also act as a tool to engage communities in citizen science programs to gather data on urban pollinators (Birkin & Goulson, 2015; Oberhauser & Lebuhn, 2012). Ultimately, our urban parks and gardens are crucial not only for providing resources for declining pollinators but also to create opportunities for ecological exposure and learning opportunities.

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CHAPTER 2

CASE STUDY: CAMPUS POLLINATOR GARDEN EFFECTIVELY TEACHES CONSERVATION TOPICS TO UNDERGRADUATE STUDENTS[1]

[1] Muller, Lauren and J.M. Affolter. *To be submitted to North American Colleges and Teachers of Agriculture Journal*

Abstract

Insect pollinators are increasingly the focus of conservation efforts as local and national initiatives advocate for the protection of these important components of biodiversity on our planet. Pollinator conservation encompasses a variety of activities such as creation and restoration of natural areas and urban pollinator gardens, but also outreach and education-based programs. In this paper we examine the efficacy of using a university campus native pollinator garden as an outdoor classroom with interpretive signage to teach conservation topics to undergraduate students at the University of Georgia. We wanted to know if students would be able to retain information provided in a lecture given at the campus pollinator garden, did science or non-science majors differ in their ability to recall concepts from the lesson, and what elements of the lecture did the respondents remember most? We found that a majority of the students, regardless of whether they were science majors or not, were able to recall important concepts taught in the garden-based lecture. Students also reported that using the campus as a living laboratory is a helpful way to augment traditional classroom-based lectures and that a majority would also be likely to stop and learn from interpretive signage on campus.

Introduction

As urban areas continually expand, an enormous gap grows between society and the complex natural world that both surrounds and sustains us. Urbanization is a principal driver behind a global decline in pollinator populations and plant diversity (2007; Potts et al., 2010). In a highly urbanized world where people are surrounded by technology, directly connecting with nature in our daily life can be challenging. This may be especially true for college students balancing academics, social engagements, and responsibilities of paying for the rising cost of education. As declines in plant and insect biodiversity occur on a global level, separation of people from nature may have significant conservation implications. Many universities encourage sustainability initiatives on campus such as installation of native plant pollinator gardens to address losses in biodiversity (Lindstrom & Middlecamp, 2017). These green spaces on campus may also act as living laboratories to engage students in these conservation efforts while also providing an opportunity to connect with nature.

Treating the campus landscape as a living laboratory provides many opportunities for experiential learning. The concept of integrating campus sustainability practices with experiential learning was initially presented in the literature in 1998 as a new way to promote environmental stewardship at universities (Creighton, 1998). Early proponents of this practice argued that institutions of higher learning play an important role in sustainability development by creating student accountability for their campus and future communities (Leal Filho, 2000). A living laboratory approach utilizes existing university infrastructure as a tool to implement sustainability science from a multidisciplinary standpoint (Kates et al., 2001). It also creates an environment conducive for active learning and skill training as an alternative to more traditional lecture-based teaching (Barab et al., 2001).

Garden-based learning is an alternative to a lecture-based course that is often used to teach topics in the area of environmental education (Desmond et al., 2002). Desmond defines garden-based learning as "an instructional strategy that utilizes a garden as a teaching tool. The pedagogy is based on experiential education, which is applied in the living laboratory of the garden." An analysis of 48 studies showed that garden-based learning had a positive effect on students' knowledge and attitudes, especially for sciences (Dilafruz & Dixon, 2013).

The University of Georgia (UGA) is committed to responsible use and stewardship of natural resources. UGA's 2020 Strategic Plan (2012) identifies advancing campus sustainability as Strategic Direction VII and presents integrating sustainability into the student experience in and out of the classroom and enhancing coordination of sustainable activities as two strategic priorities. Green spaces on campus provide an opportunity for students to connect with nature and study ecological principals and sustainable practices on campus. There are already gardens present on campus such as the Trial Garden, Founder's Garden, and Latin American Ethnobotanical Garden that are used as outdoor classrooms by Horticulture and Anthropology undergraduate courses. A new campus garden that highlights Georgia native plants addresses the development of campus as a living laboratory while also enhancing the landscape's ecological value.

The objective of this study was to assess the efficacy of a native pollinator garden as a teaching tool for undergraduates to explore the role their campus green-spaces can play as solutions to declining pollinator populations. We tested the hypothesis that a garden-based lecture would be an effective way for students to learn about urban pollinator gardens, regardless of their program of study. Our research questions were:

1. Based on the respondents' abilities to recall information, was the lecture in the garden an effective way to teach about the contribution that campus landscapes and native plant pollinator gardens can make to conservation?
2. Did science or non-science majors differ in their ability to recall concepts from the lesson?
3. What elements of the lecture did the respondents remember most?

Methods

The study took place in the fall of 2017 at the University of Georgia (UGA). Approval for use of human subjects was received from the Institutional Review Board on August 21, 2017, prior to the initiation of student involvement. The 139 Study Participants were undergraduate students enrolled in the course *Herbs Spices and Medicinal Plants,* a 3-hour lecture course. Students enrolled in this course represented a spectrum of disciplines and colleges within the University. Ages ranged from 18-26; 41.0% of the students were male and 59.0% were female. Of the 139 respondents, 74 identified as non-science majors and 65 identified as science majors.

In the fall of 2017, staff and volunteers from the State Botanical Garden, a unit of Public Service and Outreach at UGA, planted a pollinator garden on D.W. Brooks Mall, a tract of green-space on UGA's South Campus within the urban Athens setting. Formerly a vehicular roadway, the space was transformed in 2003 into a pedestrian landscape and sanctuary for students with spacious grassy areas, shade trees, and seating areas. The greenspace is bordered by several science buildings, including Ecology, Plant Sciences, Forestry, and the Pharmacy School. Located in the heart of South campus in an area with high foot traffic, the pollinator garden is highly visible and reaches a broad audience. A primary objective of this garden is to support biodiversity in the Athens urban landscape, while also creating an opportunity for students to learn about native plants and their ecological significance. The garden contains over 20 species (Appendix A). of Georgia native grasses, wildflowers, and shrubs within a relatively small 200 sq ft bed. We chose the species to include plants that support larval stages of insects, provide seeds or protective areas for birds and small mammals, and nectar and pollen from spring until the late fall. At the time of the project, the garden was newly planted and many of the plants were beginning to go dormant. Few flowers were present. We explained to the students that this is a natural stage in development of a garden and that in the coming growing season the garden would mature and appear much fuller. We used laminated temporary signs to indicate plant species that we wanted to highlight as well as the insects that they supported. The signs were removed after the lectures were completed due to strict standards for signage on campus.

The treatment in this experiment involved inviting undergraduate students to the garden then engaging them in a discussion about supporting pollinator and plant diversity in urban landscapes. Small groups of 10-20 students met at the garden for a 30-minute lecture on threats to biodiversity and how planting native gardens can address these issues through education and increased awareness and by supporting insects, birds, and small mammals. The discussion incorporated stories highlighting specific ways that plants in the garden support insects or other animals. Another important topic in the lecture was the aesthetic and ecological design elements of the garden. It was important for us to emphasize how the design addresses the needs of pollinators and animals while also creating an attractive space on campus that inspires people to learn about the natural systems around us. The lectures were held over a period of one week. The weather was consistently warm and sunny with an average high temperature of 24° C (76° F) for all of the groups visiting the garden. After the presentation in the garden, the participants were emailed a link inviting them to complete a 17 question survey based on the experience and topics discussed in the lecture.

Prior to the meeting in the garden, the research project was introduced to the participants in a ten-minute presentation during the normal lecture periods. A brief description of the project was also available online. Each participant met on the UGA campus at the Connect to Protect native pollinator garden as part of a small group for a 30-minute lecture followed by the survey. All groups of students received the same information from the same presenter. The talk focused on the garden's design, six key plant species and supported wildlife, and the garden's ecological and aesthetic function. At the end of the lecture, each group was given the opportunity to ask questions in an informal discussion.

A link to the survey was provided to the undergraduate students a week after they participated in the meeting at the campus garden. The 17-item survey was designed and administered through the Qualtrics program and was completed online either on a computer or smartphone. The survey was predominately multiple choice with 3 short-answer questions. We estimated it would take no longer than 15 minutes to complete. Students were told that participation in this research survey was voluntary. To ensure anonymity, no personal identifiers were involved in the data collection. The students were given a 2-week period to complete the survey. After a week, if students had not completed the survey, a scheduled reminder email was sent through the Qualtrics program.

We analyzed data using Qualtrics and SPSS software. We used Qualtrics to code and categorize open-ended questions. SPSS allowed us to run t-tests to examine any differences in survey responses of science and non-science majors. The Likert scale allowed us to score student attitudes numerically. The t-tests used content-based questions and questions regarding student opinions on experiential garden-based learning.

Results

Survey results revealed that of the 137 respondents, 71% reported that they grew up in suburban areas, 11% grew up in urban areas, and 17% grew up in rural areas. 53% of students reported being non-science majors and 46% as science majors. Half of the respondents reported they spent 3 hours or less a week outside for recreation and 21% reported they spent over 6 hours.

A majority of the students were able to accurately recall important concepts from the lecture given in the garden when prompted in the post-lecture survey. T-tests did not indicate any significant differences between survey responses of science and non-science majors. 90% of the participants were able to specifically name a plant-insect interaction we discussed. 89% were able to remember an ecological concept used in the garden's design. 86% could name a specific resource that the garden's plants provide to insects or other wildlife. Figures 2.1, 2.2, and 2.3 show the student responses to each of these 3 content-based questions.

We also asked the participants to report their general attitudes on the importance of campus pollinator gardens and their usefulness as an educational tool using the Likert scale. 72% felt that it is very-extremely important to provide food or habitat for insects and animals in urban green spaces. Over half of the participants were extremely-moderately likely to stop and read interpretive signage on campus. 81% of the student participants felt that it was very-extremely important to combine lecture-based learning with hands-on experiential learning and 92% stated that using the campus garden as an educational tool was helpful. Figure 2.2 shows the complete breakdown of student responses to these survey questions.

Answers to the 3 qualitative questions were categorized to see what information the students were able to recall most frequently. Students were only directed to these 3 open-ended response questions in the survey if they answered "yes" to the previous question: "Are you able to remember __________ from the survey…?". Figures 2.1, 2.2, and 2.3 show the categories and frequencies of student responses to these 3 questions. The first question asked what plant-insect interaction they remembered from the lecture. A majority (64%) of students remembered that milkweed plants were the obligate host species to the monarch butterfly. The next most frequent responses were incorrect answers. 25% of students were not able to accurately remember a specific plant interaction even though they reported they did in the previous question. Many students simply wrote a general statement such as “pollination” or “caterpillars” rather than specifically citing a plant and insect species. This may indicate a need for better wording of the question in the survey or to reiterate these specific plant-insect interactions in the garden lecture.

The second qualitative question asked: “What concept can you recall about the design of this native plant garden?”. 47% of students mentioned that understanding site conditions such as soil characteristics, drainage, and sunlight were important. This was the most frequent response. Including plant species with overlapping bloom periods to provide nectar throughout the growing season was the second most frequent response at 17%. 14 students answered this question incorrectly. Understanding site conditions was the first area we discussed in the lecture and students appeared to pay attention to this topic more than the ecological components of garden design.

The final qualitative question asked students to list resources that native plants can provide to wildlife. 55% of the responses listed food, 49% listed shelter, and 17% listed breeding habitat. Overall, the respondents’ answers captured the full range of themes that we focused on in the lecture. Only a small percentage of the students replied with an incorrect response. In general, students were able to correctly cite important themes from the lecture in the 3 open-ended response questions.

Discussion

This study found that UGA’s new native plant pollinator garden was an effective way to teach undergraduates in both science and non-science programs about plant and pollinator conservation. Garden-based lecture was designed to demonstrate the design and function of native plant gardens in an urban landscape through the lens of pollinator conservation. We believe this display garden has the potential to benefit the University and the Athens community by connecting people to native plants and the pollinating insects that sustain us. Results of the post-lecture survey suggest that this can be a successful way to teach these topics to undergraduates, regardless of whether or not they are science majors. This garden on campus is a high impact feature that can reach a broad audience beyond just science majors. As universities increasingly emphasize the importance of campus as a living laboratory, this garden provides a mode for increasing environmental sustainability on campus while simultaneously providing an effective teaching tool.

Survey assessment of student perceptions indicated an overall approval of alternative teaching methods to augment the traditional lecture-based instruction style. A vast majority of the students also reported that they found this specific experience a helpful way to learn about preserving biodiversity in urban green spaces. Over half of the respondents claimed to be slightly-extremely likely to stop and read interpretive signage on campus. These results indicate a majority of the students from a wide range of disciplines supported garden and interpretive signage as framework for discussing plant and pollinator conservation.

The garden installation was a collaborative effort between the University of Georgia's State Botanical Garden, \ Grounds Department, and Campus Environs Committee. The University of Georgia initially had a number of concerns about the logistics of garden installation and maintenance, and several months of communication and meetings led up to the overall approval of this project. South Campus, where the garden is located, is a 15 year-old landscape on campus and there were apprehensions that the garden might not fit the overall aesthetic and current plant selection. This is a fairly common argument against these types of installations on college campuses. In order to address these concerns, a landscape designer with UGA was put in charge of the garden design. The State Botanical Garden of Georgia took responsibility for garden installation, irrigation, and long-term maintenance.

Strict policies are in place that limit the size and format of signs on campus which limited our ability to provide interpretive signage. The narrative and educational value of the garden would be greatly enhanced by the addition of more detailed interpretive labels.

In the future, lectures should emphasize the specific insects and plants found together in the garden. For this study, the lecture in the garden occurred in the fall season when many of the plant species were dormant. The garden was newly installed and the plants had not yet become established in the landscape. Repeating this experiment during the growing season when plants are in bloom and well established might yield different results. We believe this garden has great potential to serve as an outdoor class room for numerous disciplines including entomology, horticulture, plant biology, ecology, and environmental design. Future experiential lessons in the garden may include pollinator observations, plant identification, and studying native plant performance in the landscape.

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Table 2.1. Likert scale ranking of questions: “How important do you feel it is to provide food or habitat for insects and animals in urban green spaces?”

Table 2.2. Likert scale ranking of question: “How important is it to combine lecture-based learning with hands-on experiences?”

Table 2.3. Likert scale ranking of question: “How likely are you to stop and read interpretive or educational signage on campus?”

Table 2.4. Responses to question: “Was this landscape narrative a helpful way to learn about preserving biodiversity in urban green spaces?”

Figure 2.1. Frequency of student responses to survey question: *Name a specific plant-insect interaction*. (n=137)

Figure 2.2. Frequency of student responses to the question: *Please name design components of this native pollinator garden.* (n=137)

Figure 2.3. Frequency of student responses to survey question asking: *What resources can native plants provide to insects and wildlife?* (n=137)

	Not at all	Slightly	Moderately	Very	extremely
How important do you feel it is to provide food or habitat for insects and animals in urban green spaces?	0%	2.1%	21.5%	26.6%	49.6%

Table 2.1.

	Not at all	Slightly	Moderately	Very	extremely
How important is it to combine lecture-based learning with hands-on experiences?	0%	1. 4%	19.7%	34.3%	44.5%

Table 2.2.

	Extremely unlikely	Moderately unlikely	Slightly unlikely	Neither likely nor unlikely	Slightly likely	Moderately likely	Extremely likely
How likely are you to stop and read interpretive or educational signage on campus?	2.1%	1.4%	5.1%	4.3%	27.0%	43.8%	16.0%

Table 2.3.

	No	Maybe	Yes
Was this landscape narrative a helpful way to learn about preserving biodiversity in urban green spaces	0%	7.3%	92.7%

Table 2.4.

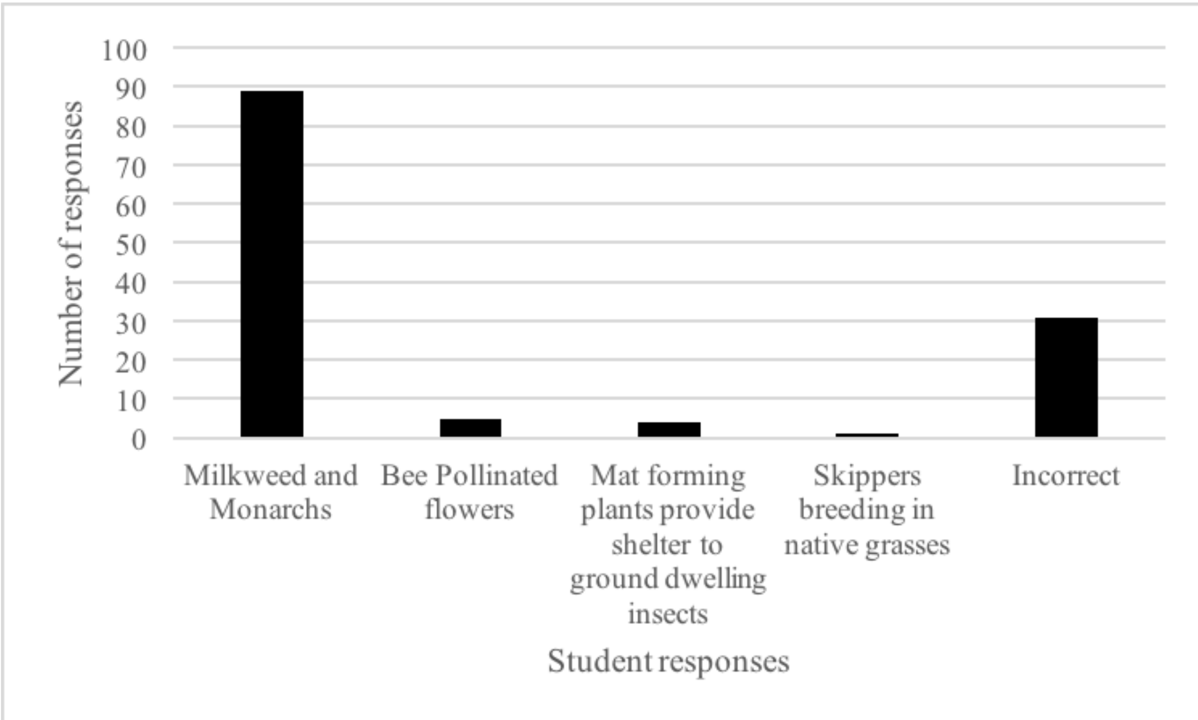
100
90
80
70
60
50
40
30
20
10
0
Number of responses
Milkweed and Monarchs
Bee Pollinated flowers
Mat forming plants provide shelter to ground dwelling insects
Skippers breeding in native grasses
Incorrect
Student responses

Figure 2.1.

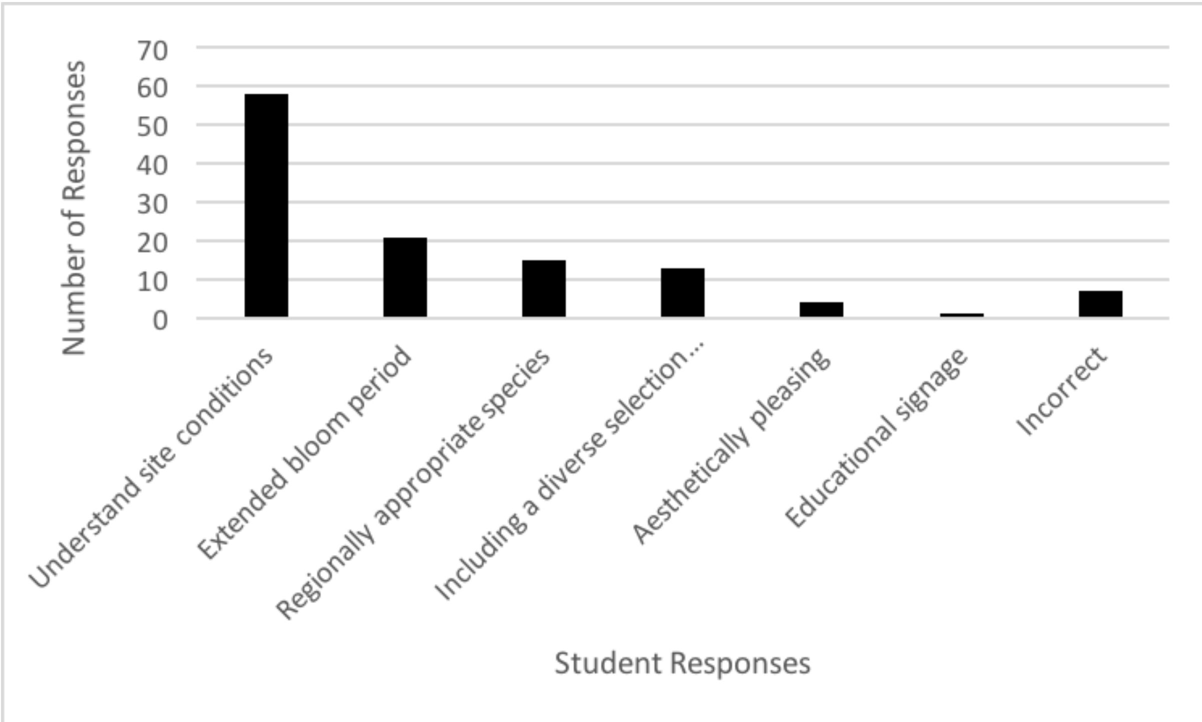
Number of Responses
70
60
50
40
30
20
10
0
Understand site conditions
Extended bloom period
Regionally appropriate species
Including a diverse selection…
Aesthetically pleasing
Educational signage
Incorrect
Student Responses

Figure 2.2.

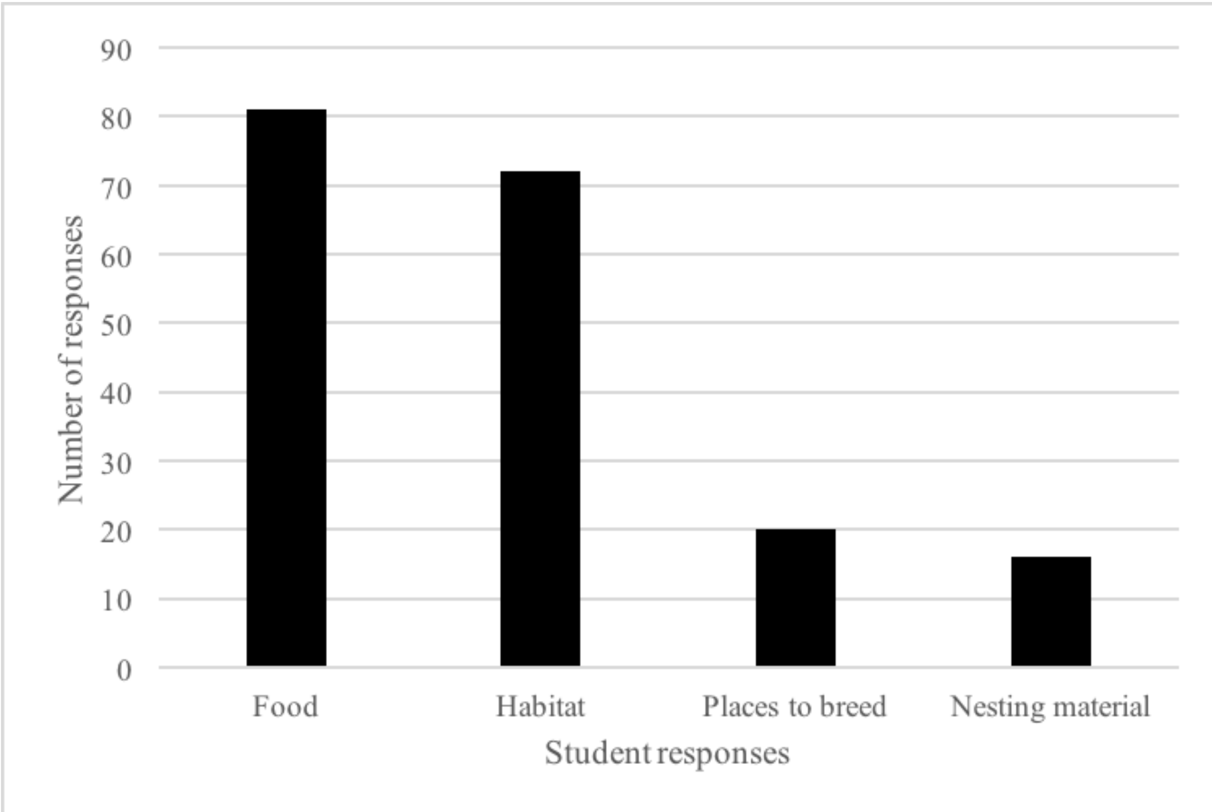
90
80
70
60
50
40
30
20
10
0
Number of responses
Food
Habitat
Places to breed
Nesting material
Student responses

Figure 2.3.

CHAPTER 3

ASCLEPIAS TUBEROSA CAN BE SUCCESSFULLY ESTABLISHED IN GEORGIA PIEDMONT GRASSLANDS THROUGH DIRECT INTERPLANTING[1]

[1] Muller, Lauren and J.M Affolter. *To be submitted to Native Plants Journal*

Abstract

This paper examines the effect of two early spring management options, fertilization and early spring mowing, on Butterfly Weed (*Asclepias tuberosa* L.) establishment in an existing warm-season grassland in the Georgia Piedmont. In December 2016, 180 greenhouse grown Butterfly Weed plants were established in experimental plots in a restored grassland at Panola Mountain State Park. We employed non-destructive harvest methods to gauge plant growth over a full growing season, measuring stem length, number of stems, number of leaves, and prevalence of flowering for each plant. We hypothesize that plants treated with early spring mowing will respond with increased growth and plants treated with fertilizer will not be effected. The planting was successful and survivorship of the out-planted Butterfly Weed was 93%; 30.5% of the plants flowered. Findings indicated no significant effect of either fertilizer application or spring mowing on leaf number, number of stems, or length of stems over the growing season. These findings show that Butterfly Weed can be successfully established in Georgia grasslands by directly transplanting greenhouse-grown plants in the dormant season without additional site treatments. Efforts should therefore be focused on growing healthy containerized plants for successful establishment.

Introduction

Asclepias tuberosa L., or Butterfly Weed is a tuberous wildflower found throughout the eastern and southern United States is an important species for pollinator conservation by providing nectar and supporting the Monarch Butterfly. A surge in interest in pollinator conservation has led many regional and national conservation efforts to shift their focus towards protecting pollinator diversity, an important component of healthy ecosystems (Potts et al., 2010; Winfree et al., 2008). National initiatives emphasize the importance of pollinators and call for restoration of habitats that support these insects (Vilsack & Mccarthy, 2015). A common theme of pollinator conservation initiatives is the importance of creating pollinator habitat by planting regionally appropriate species that act as host plants larval stages of insects and provide nectar for nectar feeding insects. Butterfly Weed is a high impact species to be included in pollinator conservation projects as it serves as both a host plant and nectar source.

An interconnected community of insects can be found on Butterfly Weed. Insects that are associated with Butterfly Weed inhabit different niches and may feed on nectar, foliage, or seeds of this plant. Fishbein (1996) found 79 species of insects representing a diverse assemblage of taxa, visiting Butterfly Weed, including *Coleoptera*, *Diptera*, *Hemiptera*, *Hymenoptera*, and *Lepidoptera*. Butterfly Weed flowers are long-lived and provide copious amounts of nectar that many of these insects feed on (Wyatt & Broyles, 1994). The imperiled Monarch butterfly (*Danaus plexippus*) requires milkweeds as a host plant for depositing its eggs (Ackery & Vane-Wright, 1984; Malcolm & Brower, 1986; Malcolm, 1994). Thus, Butterfly Weed is an important species for supporting Monarch butterflies and other insect pollinators (Borders, 2013).

Butterfly Weed can be found in early successional habitats along roadsides and power line rights-of-way, and in grasslands of the eastern and southern United States. These habitats are essential for providing habitat and floral resources to many insect pollinators (Feber et al., 1996; Harmon-Threatt & Hendrix, 2015). Grasslands in the Southeast are some of the most critically threatened habitats due to destruction and fragmentation (Noss, 2013). Increasing floral diversity through planting native species in grasslands can increase species richness and abundance of wild bees and butterflies (Hopwood, 2008; Ries et al., 2001). Higher floral diversity also has a positive effect on several ecosystem services such as nutrient cycling, erosion control, nitrogen retention, invasion resistance, and primary consumer diversity due to increased stability of ecosystem stability (Balvanera et al., 2006; Thompson & Kao-Kniffin, 2016). Enhancing plant diversity with species such as milkweed is a fundamental component of both grassland restoration and pollinator conservation.

Propagation methods for Butterfly Weed have been developed, however there is a need for understanding establishment methods in the Piedmont region of the southeastern United States in order to enhance and create habitat for native pollinators (Baskin & Baskin, 1977; Bir, 1986; Castillo, 2005; Ecker & Barzilay, 1993). A number of methods are used for species introduction into grasslands including direct seeding, plug planting, hay spreading, and seed drilling (Hedberg & Kotowski, 2010). Methods used by restoration practitioners depend on plant material availability and site conditions The direct seeding approach is commonly used in the Midwestern U.S, however, long growing seasons, clay soils, and intense weed pressure may reduce the efficacy of seeding in the Southeast. Additionally, Brown (2001) found that in the presence of established grasses, direct transplanting was more successful than seeding. Here we used mature plants due to local seed scarcity and issues with direct seeding in the Southeast.

We investigated two site treatments for establishing Butterfly Weed in the Georgia Piedmont region: spring mowing and application of slow release fertilizer. Mowing is a commonly used technique in grassland management and restoration and has been shown to have a positive effect on species richness and reducing exotic grasses (Maron & Jefferies, 2001; Tälle et al., 2015). Spring mowing may also improve early-season establishment of new plants by increasing light availability, an important limiting factor (Grime, 1973). Fertilizer applications have also been shown to increase size of perennials in the landscape (Yan et al., 2011). However it has also been shown that increased nutrient levels in grasslands can result in decreased plant diversity (Antonio & Aarssen, 1989; Borer et al., 2014; Gross et al., 2005; Suding et al., 2005) and reduced seedling survivorship (Jones & Hayes, 1999)

We examine the effect of two management options, fertilization and mowing, on Butterfly Weed establishment in an existing warm-season grassland in the Georgia Piedmont. Our objective was to develop a better understanding, maximizing success of Butterfly Weed establishment to guide future plantings by landowners and habitat restoration practitioners. We hypothesize that plants treated with early spring mowing will respond with increased growth expressed as stem length, stem number, or number of leaves. We predict that plants treated with fertilizer will not respond with increased growth.

Materials and Methods

Study Site and Plant Material Propagation

All *Asclepias tuberosa* plants were grown from seed obtained from a wild population at the Chattahoochee Nature Center in Roswell, Georgia. The seed-source at Chattahoochee Nature Center and the study site at Panola Mountain State Park where the experiment was conducted are both located within the Piedmont region of Georgia. The two sites are approximately 35 miles from one another. These plants were therefore considered to be local ecotypes adapted to the general environmental conditions of the study site. The seeds were collected on September 3, 2015 and stored dry and indoors at room temperature. We stratified the seeds at the State Botanical Garden of Georgia for 4 wk to break seed dormancy. We filled 7 petri dishes with moist vermiculite and placed approximately 75 seeds on the surface of the moistened media. The plates were then covered and enclosed in plastic bags to maintain humid conditions, then placed in a walk-in cooler maintained at 7°C [44.6°F].

After a 4 week stratification period, the petri dishes were removed from the cooler and the plastic bags, covered with a clear plastic humidity dome, and placed under Sylvania 34 W white fluorescent lights for 2 week under continuous 24 hour lighting. Upon germination, seedlings with cotyledons present were removed from the vermiculite using tweezers and planted individually into 6-celled trays measuring 3.81 cm square and 6.35 cm deep filled with Sungro 3B soilless media. Filled trays were then placed on greenhouse benches at the University of Georgia South Milledge greenhouses. In May, the small plants were moved to larger quart-sized black plastic pots filled with Sungro 3B soilless media and watered with a single application of 200 ppm Jack's 20-10-20 water-soluble fertilizer. In August, the plants were moved from the greenhouse to the UGA Riverbend Horticulture hoop houses and placed on metal mesh benches. We applied minimal water from August until December to avoid root rot, which commonly affects this species in cultivation. Stems and leaves turned yellow and withered away as the plants went quiescent in October.

Plants grown at the University of Georgia were planted on December 16 2016 at Panola Mountain State Park (33°38'21.3"N, 84°09'17.5" W). The plots were established at the park within the "Power of Flight" restored grassland bordering the South River. Since 2005, exotic Burmuda Grass (*Cynodon dactylon* L. [Poaceae]) and Johnson Grass (*Sorghum halepense* (L.) Pers. [Poaceae]) had been removed using herbicide and the grassland had been restored with native grasses such as Indian Grass (*Sorghastrum nutans* (L.) Nash. [Poaceae]), Gama Grass (*Tripsacum dactyloides* (L.) L. [Poaceae]), and Little Bluestem (*Schizachyrium scoparium* (Michx.) Nash. [Poaceae]). The grassland is divided into 2 subunits which are each burned in the spring once every other year. The study plot had been burned the previous spring. The site was dominated by grasses with interspersed forbs. Within the grassland, we installed our plots in a nearly flat area to maximize topographic homogeneity. Fall of 2016 was extremely dry and the soil was almost impenetrable. However, in December at the time of planting the soil was moist and friable from recent rains. All plants were dormant when we planted in December 2016. The root balls included a thick main taproot and smaller fibrous roots filling most of the quart-sized pots. No growing media was removed from the root balls before planting. Each hole was dug approximately the same size, one foot deep and 1 foot wide, and was large enough to accommodate the root ball. No surrounding soil was disturbed and we planted amongst the existing vegetation. We took care not to bury the crown of each plant and labeled each plant with a small metal tag and identification number. We visited the site weekly starting in January 2017 to check for emergence.

Experimental Design

The experiment was laid out in a complete randomized block design with 3 blocks, each block comprised of 4 experimental units. Blocks measured 3 m x 20 m and ran perpendicular to the site's gentle slope and parallel to the gravel road that transects the grassland. Each experimental unit consisted of a 3 m x 5 m plot containing 15 plants spaced evenly about 1 m apart. In total, there were 180 plants for the entire experimental field. Treatments were assigned using a 2-factor factorial design, with factor A being the presence or absence of spring mowing and factor B being the spring application of slow release fertilizer or no fertilizer. This design gave us 4 potential treatment combinations. Blocks were divided into 4 sections to which one of the 4 treatments were applied on April 25, 2017. Plants that received the fertilizer treatment had 5 g of Osmocote slow release fertilizer (14-14-14) applied to the base of each plant. The mowing treatment was applied using a weed wacker to cut back vegetation to ground level.

Data Collection

Data collection began when plants emerged from dormancy in April 2017. Using a standard metric ruler, we measured the height of the longest stem on each plant. We also counted the number of stems and number of leaves. The data collection process continued until the end of the growing season. Additionally, throughout the growing season we recorded how many plants were in flower and fruit at each recording date. Data collection was carried out every two weeks until July when we began collecting only once a month.

Results

We used two models, logistic regression and Kaplan-Meier estimator, to confirm that any lack of emergence was not due to application of fertilizer or the early spring mowing but was probably due to plant quality. This allowed us to justify removing the plants that never emerged from analysis rather than treating them as zeroes. The response variable for the logistic model is emergence at the last time point of the study (08/30/17), and the explanatory variables are application of fertilizer and early spring mowing. The resulting P-values for both explanatory variables are 0.084, which is not significant at a 0.05 level. The second model, a Kaplan-Meier estimator, reported log-rank tests for the survival function between fertilizer and between mowing. For the purposes of this analysis, the censor variable is ‘0’ if a plant emerged at any point during the study and ‘1’ if it does not. P-values for the two tests were 0.336 and 0.242 respectively, which indicates no significance at a 0.05 level between the two groups for each variable (fertilizer vs no fertilizer, mowing vs no mowing).

We employed a linear regression and Poisson regression model to analyze plant characteristics: length of stems, number of stems, and number of leaves. There are 7 time-points and thus we have 7 * 3 = 21 models total. We fit a linear regression model to investigate the relationship between stem length and the two explanatory variables, fertilizer and mowing, for each of the 7 time-points. The model is expressed as $Length_{Stem} = \beta_0 + \beta_1 \text{x} I\ (Fertilizer) + \beta_2 \text{x} I\ (Mowing) + \varepsilon$ for each of the 7 time-points. We fit a Poisson regression model to investigate the relationship between the response variable, number of leaves, and the explanatory variables, fertilizer and mowing for each of the 7 time-points. This model is expressed as $ln(\mu) = \beta_0 + \beta_1 \text{x} I\ (Fertilizer) + \beta_2 \text{x} I\ (Mowing)$ where we assume the response Number of stems has a Poisson distribution that is $Number_{Stems} \sim Poisson(\mu_i)$, for i= 1, …, N , and $E\ (Number_{Stems}) = \mu$. We fit a linear regression model to explore the relationship between response variable, number of leaves, and explanatory variables, application of fertilizer and mowing. The variable, number of leaves, was slightly skewed so we used a square-root transformation to make the error distribution more symmetric. This model is expressed as $\sqrt{\text{Number}_{\text{Leaves}}} = \beta_0 + \beta_1 \text{x} I\ .(Fertilizer) + \beta_2 \text{x} I\ (Mowing) + \varepsilon.$

Survivorship of the transplanted Butterfly Weed was high. Plants began to emerge in April and continued to emerge until June after which the above ground growth began to decline. Total emergence of the plants was 93.33% over the 4-month period of data collection. 30.5% of the plants flowered, however, none of the plants produced fruit. Overall, the 3 linear regression models showed no significant relationships between treatments and plant growth. There was no significant effect of either fertilizer application or spring mowing on measured leaf number, number of stems, or length of stem. However, there is marginally significant evidence that indicates the two factors, fertilizer and mowing, have positive contributions to stem length at the time-point 6 (July 18). We also observe significance at the initial time-point where mowing has a slightly positive effect on number of stems. July was the peak month of growth where expected stem length was approximately 31 cm, number of leaves was 134, and number of stems was 4.55.

The plants did not receive any additional water once planted in the field and the average monthly rainfall was 13 cm. In February, we observed that 40 plants had been damaged by animals feeding on the taproot. We spoke with Phil Delesterez, the Northern Resource Manager for GA State Parks, about this issue. He had been involved with wildflower plantings in the Power of Flight grassland and ran into similar issues. We determined that the damage was likely due to rodents, probably rats, feeding on the roots. 37 of the 40 damaged plants emerged in the spring and the damage didn't appear to have a significant effect on the ultimate survival of the Butterfly Weed. We also observed occasional deer browsing that appeared to result in vigorous regrowth of multiple shoots. By September, all plants were dormant with no above ground plant material present. We witnessed female monarchs ovipositing on the Butterfly Weed in April and counted 65 eggs on the foliage. The eggs were generally found on the undersides of the leaves. The following month we counted 13 monarch larvae on the plants.

Discussion

These findings show that Butterfly Weed can be successfully established in Georgia grasslands by directly transplanting greenhouse-grown plants in the dormant season without additional site treatments. Neither mowing nor fertilizer application had a significant effect over the growing season on the proxies we used to measure plant growth: stem length, number of stems, and number of leaves. Restoration practitioners can therefore plant container grown plants with no site treatments minimizing labor costs and time associated with planting. Planting in the dormant season may have reduced the challenge of planting in a grassland setting as the soil was friable, the presence of aboveground vegetation was reduced, and root systems of Butterfly Weed may have had more time to establish before warm-season grasses began to emerge. Efforts should then be focused on growing healthy containerized plants for successful establishment in natural areas.

We found significant effects of mowing and mowing and fertilizer on stem length and number of stems respectively, but only at discreet time-points. On April 1 mowing had a positive contribution to the number of leaves. This effect was slight and we don't believe that this observation has any practical implications. Similarly, on July 18 the application of slow release fertilizer and mowing had positive contributions to the number of stems. If these treatments truly had a positive effect on the growth of Butterfly Weed, we would have expected to see these effects over a longer period of time.

After 8 months in the field, only a third of the plants produced flowers. This contrasted with our observations from the previous year where 100% of the plants flowered in the greenhouse. This finding is supported by research that has shown that reproductive performance can be inhibited by both limited light availability in dense vegetation (Cid-Benevento, 1987) as well as below-ground competition and limited rooting space that are characteristic of grasslands (Mcconnaughay & Bazzaz, 1991). By July, the grasses had exceeded five feet in height, ultimately shading out all the Butterfly Weed below. It is likely that the thick clumps of established perennial grasses limited the amount of resources that are critical for producing energy expensive flowers and subsequent fruit.

We observed multiple incidences of herbivory on the field grown plant by deer, rodents, and insects. Biotic stresses such as these can be detrimental to the success of habitat restoration projects. Research findings have shown the negative impact deer herbivory can on many habitats such as riparian corridors, grasslands, and bottomlands (Dorner, 2002; Opperman & Merenlender, 2000; Ruzicka et al., 2010). It has also been shown that small-rodents preferentially feed on dicots and can alter the vegetation structure of grasslands (Howe & Brown, 1999) and reduce plant biomass (Hulme, 1996). We found evidence of deer feeding on flowers and foliage during the summer and small rodents feeding on the tuberous roots in the dormant season. It appeared that the deer were not targeting the Butterfly Weed and browsing was random and herbivory from rodents and deer did not result in catastrophic damage to the overall health of the out planting.

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Figure 3.1. Total emergence of planted Asclepias tuberosa over time in 2017. Treatment regimes were: *A*, application of slow-release fertilizer with no mowing; *B*, no slow-release fertilizer and spring mowing; *C* no application of slow release fertilizer and no mowing; *D*, application of slow-release fertilizer and spring mowing.

Table 3.1. The averages (± SD) of length of the longest plant stem (cm) per plant of Asclepias tuberosa planted in December 2016 under 3 treatments: *A*, application of slow-release fertilizer with no mowing; *B*, no slow-release fertilizer and spring mowing; *C* no application of slow release fertilizer and no mowing; *D*, application of slow-release fertilizer and spring mowing.

Table 3.2. The averages (± SD) of the number of leaves per plant of Asclepias tuberosa planted in December 2016 under 3 treatments: *A*, application of slow-release fertilizer with no mowing; *B*, no slow-release fertilizer and spring mowing; *C* no application of slow release fertilizer and no mowing; *D*, application of slow-release fertilizer and spring mowing.

Table 3.3. The averages (± SD) of the number of stems per plant of Asclepias tuberosa planted in December 2016 under 3 treatments: *A*, application of slow-release fertilizer with no mowing; *B*, no slow-release fertilizer and spring mowing; *C* no application of slow release fertilizer and no mowing; *D*, application of slow-release fertilizer and spring mowing.

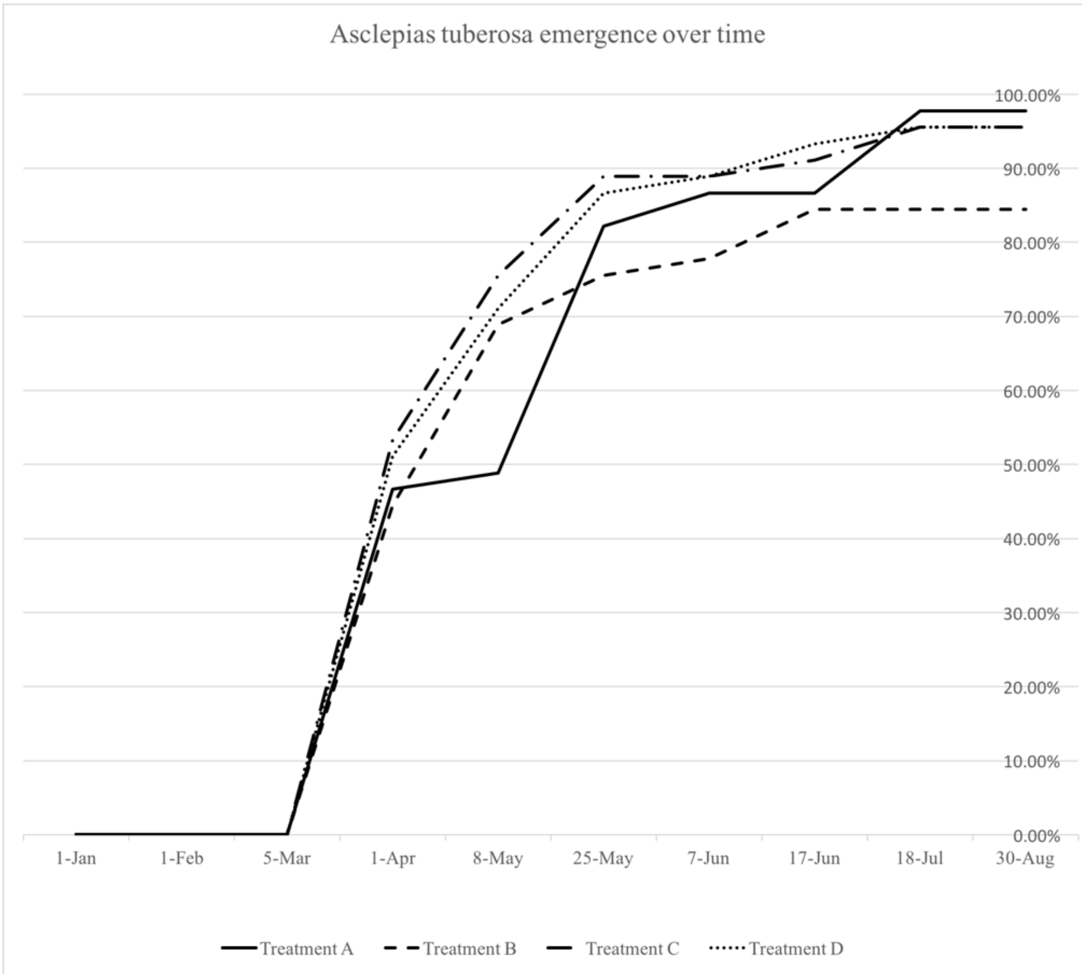
Asclepias tuberosa emergence over time
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
1-Jan
1-Feb
5-Mar
1-Apr
8-May
25-May
7-Jun
17-Jun
18-Jul
30-Aug
Treatment A
Treatment B
Treatment C
Treatment D

Figure 3.1.

Treatment							
Date	1 Apr 17	8 May 17	25 May 17	7 Jun 17	17 Jun 17	18 Jul 17	30 Aug 17
A	5.2 ± 7.6	14.2 ± 12.4	19.5 ± 12.8	24.4 ± 12.7	25.4 ± 13.6	29.6 ± 12.2	18.3 ± 14.5
B	6.7 ± 9.2	14.1 ± 13.0	16.5 ± 14.0	21.0 ± 14.4	23.6 ± 14.2	28.1 ± 14.0	15.2 ± 14.4
C	8.8 ± 11.4	15.8 ± 15.3	20.7 ± 14.6	21.0 ± 14.4	22.9 ± 15.2	26.0 ± 12.8	11.9 ± 13.8
D	8.5 ± 10.7	15.0 ± 13.8	20.6 ± 13.5	26.5 ± 13.0	29.1 ± 12.3	34.7 ± 12.8	21.1 ± 16.8

Table 3.1.

Treatment

Date	1 Apr 17	8 May 17	25 May 17	7 Jun 17	17 Jun 17	18 Jul 17	30 Aug 17
A	11.5 ± 18.2	30.3 ± 33.2	57.0 ± 53.8	72.2 ±55.2	99.2 ± 64.6	142.4 ±81.5	65.5 ±77.9
B	18.8 ± 32.6	35.4 ±39.1	48.2 ± 48.3	70.4 ± 61.5	103.6 ± 75.0	135.8 ± 88.0	66.8 ±83.1
C	16.2 ± 20.1	31.1 ± 32.6	63.5 ± 52.1	73.6 ± 49.6	93.3 ± 69.8	113.7 ±81.2	40.7 ±61.4
D	21.2 ± 30.5	35.7 ± 38.3	57.6 ± 45.7	91.5 ± 68.1	116.4 ± 71.1	176.5 ± 112.1	66.6 ± 77.0

Table 3.2.

Treatment Date	1 Apr 17	8 May 17	25 May 17	7 Jun 17	17 Jun 17	18 Jul 17	30 Aug 17
A	1.3 ± 1.7	2.4 ± 2.2	2.7 ± 2.4	3.6 ± 2.9	3.5 ± 2.7	4.1 ± 2.9	2.4 ± 2.4
B	1.6 ± 2.1	2.3 ± 2.3	2.3 ± 2.3	2.9 ± 2.4	3.5 ± 2.9	4.4 ± 4.1	2.5 ±3.2
C	1.4 ±1.6	2.4 ± 2.3	3.0 ± 2.1	3.5 ± 2.8	3.5 ± 2.9	4.3 ± 2.8	1.9 ± 2.4
D	1.7 ± 2.0	2.4 ± 2.0	3.0 ± 1.9	3.9 ± 3.0	4.1 ± 2.6	4.4± 2.7	2.2 ± 2.6

Table 3.3.

CHAPTER 4

CONCLUSIONS

In response to President Barak Obama's memorandum "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators", the Pollinator Health Task Force released the Pollinator Partnership Action Plan. This document emphasizes the need for conserving both public and private lands as well as the important role that outreach and education play in pollinator conservation as a whole. The objectives of this thesis are aligned with Focus Area 2: Monarch Butterfly Conservation and Focus Area 3: Pollinator Habitat: Land Conservation, Restoration, and Enhancement in this Action Plan as well as other global, national, and local pollinator conservation initiatives.

Our first study revealed that using a campus pollinator garden for a garden-based lecture on plant and pollinator conservation can be successful. This method of teaching topics related to conservation in urban areas in a pollinator garden setting was effective for students regardless of whether they were science or non-science majors and students were able to recall specific information we discussed in the lecture. A majority of the students reported that this exercise was helpful for discussing conservation topics and they would also be likely to stop and look at interpretive signage on campus. Garden installations such as this fit in with the growing focus of creating sustainable college campuses while also providing opportunities for experiential learning. We suggest expanding the study to use a pre- and post-survey method and to schedule the site visit during the growing season when plants would be in bloom. We believe this garden has the potential to serve as a narrative landscape and outdoor classroom for plant, insect, or ecosystem focused courses in the future.

The second study we conducted on Butterfly Weed establishment in the Georgia Piedmont region addressed three key priorities: grassland restoration in the Southeast, pollinator habitat enhancement, and Monarch Butterfly conservation. The results of this experiment suggest that Butterfly Weed can be successfully established through dormant season planting of year-old healthy potted plants in Georgia Piedmont grasslands. Butterfly Weed root balls can simply be interplanted amongst existing clumps of grasses. Site preparations such as spring mowing or additional fertilizer were not needed. We found that first year plantings of Butterfly Weed are also able to support monarch butterflies. Additional years of monitoring are recommended to further observe survival, flowering, and fruiting of the established plants.

APPENDIX A

CAMPUS POLLINATOR GARDEN PLANT SPECIES LIST

GRAMINOIDS

Carex glaucescens	Southern Waxy Sedge
Carex lurida	Shallow Sedge
Schizachyrium scoparium	Little Bluestem

HERBS

Asclepias tuberosa	Butterfly Weed
Asclepias incarnata	Swamp Milkweed
Eutrochium purpureum	Sweet Joe-Pye weed
Helenium autumnale	Autumn Sneezeweed
Hibiscus coccineus	Scarlet Rosemallow
Hibiscus moscheutos	Crimsoneyed Rosemallow
Iris virginica	Virginia Iris
Kosteletskya virginica	Seashore Mallow
Liatris spicata	Dense Blazingstar
Lobelia cardinalis	Cardinal Flower
Lobelia silphilitica	Great Blue Lobelia
Osmundastrum cinnamomeum	Cinnamon Fern
Physostegia virginiana	Obedient Plant
Rhexia nashii	Maid Marian

Saururus cernuus	Lizard's Tail
Solidago rugosa	Wrinkleleaf Goldenrod
Symphyotrichum georgianum	Georgia Aster

<u>WOODY SHRUBS AND TREES</u>

Aronia arbutifolia	Red Chokeberry
Cephalanthus occidentalis	Buttonbush
Clethra alnifolia	Sweetshrub
Cornus amomum	Silky Dogwood

APPENDIX B

GARDEN-BASED LECTURE TOPICS

1. Environmental issues we address with this garden

a) Loss of biodiversity

b) Habitat loss

c) Invasive species

d) People's disconnect from nature

2) Components of the garden's design

a) Intentional design with repeated patterns to avoid looking unkempt.

b) Species selection to extend bloom period to provide nectar from spring to fall.

c) Host species support larval stages of specialist insects.

d) Protective niches formed by mat forming plants, trees, and shrubs.

e) Understanding the site conditions such as soil texture, moisture, and sunlight availability to choose the appropriate natives for the site.

3) Plants in the Garden and the insects or wildlife they support

a) Cephalanthus occidentalis

a) Buttonbush mite: hairy leaf galls

b) Buttonbush leaf beetle

c) Buttonbush Gall midge

d) Ruby throated hummingbird

b) Osmunda cinnamomea

a) Birds use fiddleheads for nesting material

c) Saururus cernuus

a) Buffalo moth feeds on the roots

b) Dense stands provided ground cover for small animals

d) Clethra alnifolia

a) Hummingbirds

b) Mammals and birds eat the fruit

e) Asclepias incarnata

a) Hosts Queen & Monarch butterflies

b) Birds use coma (floss) for nesting materials

APPENDIX C

SURVEY CONTENT

Start of Block: Consent

Q1 **Consent Form** You are being invited to participate in a research study entitled Evaluating students' perceptions of the effectiveness of the Connect to Protect native wildlife garden as an outdoor classroom. This research hopes to assess student perceptions of using this campus garden as an informal learning environment and determine if students are able to recall information given to them on a field trip to the garden. Your participation will involve allowing the researchers to use the information/data that were collected through your participation in the Qualtrics survey following the fieldtrip to be included in their research. The one-time survey is the only data collection period. You don't have to do anything else.

Your participation, of course, is voluntary but would be greatly appreciated. You may choose not to participate or to withdraw your consent at any time without penalty or loss of benefits to which you are otherwise entitled. If you agree to the use of your information/data for this research project, please simply sign on the line below; if you don't agree, none of your data will be included in the research and you can still participate in the program. The investigator intends to honor a research subject's request that the investigator destroy the subject's data or that the investigator exclude the subject's data from any analysis. If you decide to withdraw from the study, the information that can be identified as yours will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information.] The results of the research study may be published, but your name or any identifying information will not be used. In fact, the published results will be presented in summary form. Only the two investigators, Lauren Muller and Dr. James Affolter will have access to the data collected in the survey. There are no known risks associated with this research The findings from this project may help us improve future Connect to Protect garden installations. The information may show that students regard this green space as beneficial for learning as well as for biodiversity in our urban landscape.

The researchers conducting this study are: Lauren Muller and Dr. James Affolter. You may ask any questions you have now. If you have questions later, you are encouraged to contact them at the State Botanical Garden of Georgia, 706) 542-1244 , Affolter@uga.edu.

Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Q2 Do you consent?

○ Yes (1)

○ No (2)

Skip To: End of Survey If Do you consent? = No

End of Block: Consent

Start of Block: Background Information

Q3 Age

____

Q4 Gender

▼ Male (1) ... Female (2)

Q5 What is your Major at UGA?

____

Q6 How would you describe the environment where you grew up?

◯ Urban (1)

◯ Suburban (2)

◯ Rural (3)

Q7 On average, how many hours a week do you spend outside for recreation

- ◯ Rarely (1)
- ◯ 1-3 hours (2)
- ◯ 3-6 hours (3)
- ◯ More than 6 (4)

End of Block: Background Information

Start of Block: Recalling Information from lecture in the garden

Q8 How important do you feel it is to provide food or habitat for insects and animals in urban green spaces?

- ◯ Extremely important (1)
- ◯ Very important (2)
- ◯ Moderately important (3)
- ◯ Slightly important (4)
- ◯ Not at all important (5)

Q9 Can you name a plant-insect interaction that was mentioned in the lecture?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Can you name a plant-insect interaction that was mentioned in the lecture? = Yes

Q10 What specific plant-insect interaction can you recall?

____

Q11 Can you recall an important concept to consider when designing a native plant garden to support wildlife?

- Yes (1)
- No (2)

Display This Question:

If Can you recall an important concept to consider when designing a native plant garden to support w... = Yes

Q12 What concept can you recall when designing a native plant garden to support wildlife?

____

Q13 Can you recall examples of resources that native plants can provide to insects or other wildlife?

◯ Yes (1)

◯ No (2)

Display This Question:

If Can you recall examples of resources that native plants can provide to insects or other wildlife? = Yes

Q14 Please list resources that native plants can provide to wildlife.

____

End of Block: Recalling Information from lecture in the garden

---

Start of Block: Assessing outdoor learning experience

Q15 How important is it to you to combine lecture-based learning with relevant hands-on experiences?

◯ Extremely important (1)

◯ Very important (2)

◯ Moderately important (3)

◯ Slightly important (4)

◯ Not at all important (5)

Q16 How likely are you to stop and read interpretive or educational signage on campus?

- ◯ Extremely likely (1)
- ◯ Moderately likely (2)
- ◯ Slightly likely (3)
- ◯ Neither likely nor unlikely (4)
- ◯ Slightly unlikely (5)
- ◯ Moderately unlikely (6)
- ◯ Extremely unlikely (7)

Q17 Was this landscape narrative a helpful way to learn about preserving biodiversity in urban green spaces?

- ◯ Yes (1)
- ◯ Maybe (2)
- ◯ No (3)

End of Block: Assessing outdoor learning experience
