STUDYING SCHOOL GARDENS AS HABITAT FOR URBAN BUTTERFLIES AND OUTCOMES OF INVOLVING ELEMENTARY SCHOOL STUDENTS IN DATA COLLECTION DURING A DC SUMMER PROGRAM

by

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A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at George Mason University

by

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Bachelor of Science
Virginia Tech, 2020

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Spring Semester 2023
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DEDICATION

I dedicate this work to my younger self and our planet Earth.

ACKNOWLEDGEMENTS

I wish to thank my advisor, Dr. Travis Gallo, for his guidance and support throughout this process. I also want to thank the members of my committee for their invaluable input and infinite patience: Dr. Divya Varier and Dr. Cynthia Smith. Finally, my work would not have been possible without the collaboration with FRESHFARM FoodPrints and the District of Columbia Public Schools.

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LIST OF ABBREVIATIONS AND/OR SYMBOLS

District of Columbia .... DC
District of Columbia Public Schools .... DCPS
kilometer .... km
Science, Technology, Engineering, Mathematics .... STEM
United States .... U.S.

ABSTRACT

STUDYING SCHOOL GARDENS AS HABITAT FOR URBAN BUTTERFLIES AND OUTCOMES OF INVOLVING ELEMENTARY SCHOOL STUDENTS IN DATA COLLECTION DURING A DC SUMMER PROGRAM

Katherine Pontarelli, M.S.

George Mason University, 2023

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Schoolyard gardens are increasing in cities to simultaneously provide students with experiential learning opportunities and local communities with increased food security. These gardens may also provide urban habitats for pollinators and opportunities for students to interact with urban wildlife. Here we assess how schoolyard gardens may provide habitat for large-bodied butterflies and discuss how they may be designed to support more butterfly diversity. Due to their charismatic nature and presence in urban spaces, butterflies can be a flagship species to reconnect urban residents with the natural environment. Therefore, we designed the project to be student-led and assessed students' participation in the data collection process. Three elementary schools with rising first and third-grade students observe and capture large-bodied butterflies in their gardens during the summer of 2022. The species richness and abundance at school gardens were compared to butterflies caught by researchers in a corresponding natural area near each school. An N-mixture model was used to estimate the correlation between tree canopy, site area, and impervious surface to eastern tiger swallowtail (*Papilio glaucus*) abundance. Results showed that swallowtail abundance was negatively related to the percent of impervious surface at a site regardless of the site's area and proportion of tree cover. Our results indicate that urban schools with limited green space can increase butterfly abundance by planting more vegetation around the garden and decreasing impervious cover. Student discussions provided program feedback and increased interest in butterfly ecology within urban environments. These results indicate that involving K-12 students in urban ecological research within their school grounds may increase their awareness of interactions with nature.

CHAPTER ONE: THE USE OF URBAN SCHOOL GARDENS BY LARGE-BODIED BUTTERFLIES IN DC

INTRODUCTION

Biodiversity is declining at an unprecedented rate, primarily due to human land-use changes like urbanization (Hooper et al, 2012; Rosenburg et al., 2019). Urbanization is one of the fastest-growing forms of land use change (Dadashpoor et al., 2019) and is one of the greatest causes of species extinction (Nature Insight Biodiversity, 2000; Pimm & Jenkins, 2010). Urban areas cover 55% of the globe, and by 2050 is expected to increase to 68% (United Nations, 2018). As of 2018, North America is the most urbanized region in the world with 82% of the population living in cities (United Nations, 2018). Urban areas are usually seen as voids of habitat for wildlife due to the large loss of natural space (Shochat et al., 2010). However, urban areas can still contain habitats for some species.

The field of urban wildlife ecology is still an emerging field of study (Collins et al., 2021). In the last decade, there has been an increase in the total number of urban wildlife publications by 0.02% per year, and a total of 532 urban wildlife publications added worldwide (Collins et al., 2021). However, urban wildlife research has historically focused on mammals and birds, creating a need to increase research on other taxa, like arthropods (Collins et al., 2021). Collins et al. (2021) found that arthropods were among the least studied taxa in urban habitats. Fenoglio et al. (2020) noted a few specific knowledge gaps in their meta-analysis on the negative effects of urbanization on arthropods - 1) It is still unclear how arthropods are responding to changing climates due to the diversity of the taxa; however, it is known that terrestrial arthropod communities have lower species richness and abundance in urban areas, especially Coleoptera (beetles) and Lepidoptera (butterflies and moths) and 2) urbanization appears to affect the abundance of only these two groups, whereas a decrease in species richness is common across all groups except Araneae (spiders; Fenoglio et al., 2020).

Making up about 80% of all animal species on the planet, insect biodiversity plays an important role in ecosystem functions and ecosystem services, such as pest control, prey for wildlife, and decomposition of waste (Sabrosky, 1952; Hooper et al., 2012). Global declines of insects are linked to agricultural intensification and urbanization, having the potential for 40% of species to go extinct in the next few decades (Sánchez-Bayo & Wyckhuys, 2019). Lepidoptera are one of the three most affected insect taxa due to urbanization in terrestrial systems, with Hymenoptera (ants, wasps, and bees) and Coleoptera representing the other two imperiled taxa (Sánchez-Bayo & Wyckhuys, 2019). Lepidoptera currently has 54% of species in global decline and an annual species decline of 1.8% (Sánchez-Bayo & Wyckhuys, 2019). Lepidoptera's sensitivities to urbanization may be explained by the loss of host plants for larvae, nectar and other nutrient sources for adults, and changes in local microclimates like urban heat island effect and increased solar radiation (Ramírez Restrepo & MacGregor Fors, 2017; Fenoglio et al., 2020; Clark et al., 2007; Dennis et al., 2017).

The literature on urban drivers of plant-pollinator interactions is increasing, though there is not much existing literature to date (Harrison & Winfree, 2015). Habitat loss and fragmentation are known to affect the visitation rates of flowers and pollination success, but not the preference of native or non-native flowering plants by pollinators (Harrison & Winfree, 2015). Tew et al. (2022) found that even if urban gardens are small, the quality, or nectar supply, in the garden is more important than the size of the garden in attracting butterflies and other pollinators. Pla-Narbona et al. (2022) found that highly connected public and private gardens in Barcelona City have higher butterfly diversity. Overall, urban habitats with nectar sources, higher plant diversity, and connectivity to other sources provide the best conservation strategies for butterflies (Harrison & Winfree, 2015; Barranco-León de las Nieves et al., 2016; Ramirez-Restrepo & MacGregor-Fors, 2017).

Efforts to supply habitat, especially in urban areas, are critical to supporting butterfly populations. Because most of the United States population is living in urbanized areas, endeavors to create habitats in these areas can support pollinator conservation efforts (Tew et al., 2022). The District of Columbia (DC) is an example of a city in the United States that has incorporated urban gardens into its urban planning process. DC is heavily urbanized, yet has made efforts to create urban gardens spaces through various projects like the Golden Triangle Business Improvement District (https://goldentriangledc.com), requiring all buildings built after 2020 to install rooftop gardens (Section 703.4 of the 2017 DC Green Construction Code, https://dob.dc.gov/page/dc-construction-codes), and school garden programs like FRESHFARM FoodPrints (https://www.freshfarm.org). The effects of school gardens specifically in butterfly conservation are, however, less studied (Kabisch et al., 2016; Ramirez-Restrepo & MacGregor-Fors, 2017; Levy & Connor, 2004).

School gardens in DC provide a unique opportunity to study butterfly diversity and abundance within the built urban environment. For this chapter, I conducted a mark-recapture study in urban school gardens to ask the following research question: How do school gardens contribute to butterfly habitats in urban areas? I hypothesized that each school garden may be unique in the abundance and species richness of butterflies depending on the maintenance of gardens and the number of available nectar resources in the garden area. This research compared the species richness between school gardens and corresponding parks and assessed environmental and socioeconomic factors associated with the abundance of a commonly sighted large-bodied species – the Eastern tiger swallowtail (*Papilio glaucus*). The findings of this project can help inform the design of school gardens to increase their effectiveness as conservation tools for Lepidoptera and other insects. Having students take part in conservation efforts in their gardens can also be an educational tool for learning about biodiversity protection and restoration (see Chapter 2).

METHODS

Site Locations

This study was conducted in the Washington District of Columbia (DC) (38º54’17” N, 77º00’59” W), the capital city of the United States of America. It has an estimated population of 670,050 residents (4355.5 residents/km^2) as of 2021 and consists of 61.13 sq mi of terrestrial land cover (U.S. Census Bureau, 2021). DC consists of 27 km^2 of National Park land and 3.64 km^2 of DC Government-owned parks (Sustainable DC, 2022). The Anacostia and Potomac tidal rivers are the two major waterways in DC. DC has a humid subtropical climate with cool to mild winters and lies within the Piedmont and Coastal Plain ecoregions (Kottek et al., 2008). The DC region lies on the ancestral lands of the Anacostan (or Nacotchtank), and Piscataway people (Spruce & Thrasher, 2008).

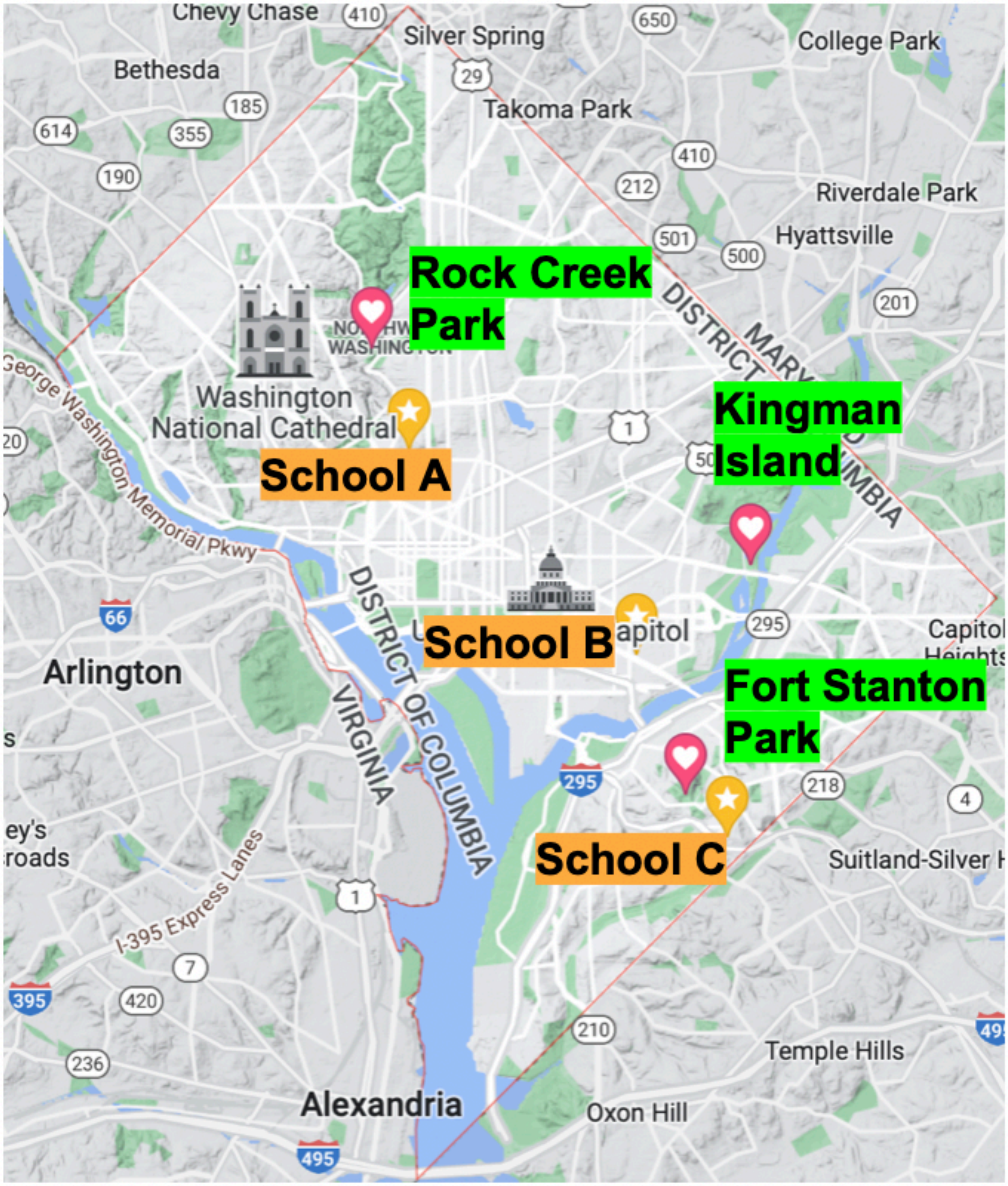


Figure 1. Map of schools and parks where butterflies were studied in Washington, DC.

I worked with FRESHFARM Foodprints to conduct this study in three DC Public Elementary Schools that have schoolyard gardens managed by FoodPrints (Fig. 1). Three additional areas, one paired with each elementary school, were also sampled with the same mark-recapture methods described below. These sites include Montrose Park (38.9140º N, 77.0605º W) (paired with School A), Fort Stanton (38.8595º N, 76.9790º W) (paired with School B), and Kingman Island (38.8941º N, 76.9655º W) (paired with School C), which are all within 2 km of their respective elementary school (Fig. 1). For the sake of privacy, real school names are not used in this manuscript.

Data Collection

From July 11 – August 5, 2022, butterfly capturing occurred once per week at each school and park site with the help of Dr. Travis Gallo. The capture period was set to 30 minutes for each site while walking around the park or garden perimeters. School garden surveys took place each week between 13:00-15:00 and park surveys took place between 14:00 - 16:00, except for park surveys on August 5th which were conducted between 10:30-13:00. Butterflies were captured using aerial netting and gently handled for marking by smoothing out the net mesh and marking with a permanent marker through the net holes on the underside of the wing. Unmarked individuals were marked with a three-digit number code dotted with a permanent marker on the forewings of the butterflies (Fig. 2) following Ehrlich and Davidson (1960). At school-garden sites, captured and marked butterflies were momentarily placed in a designated capture container and released once the mark-recapture period was over for that day. The container was placed in the shade with a nectar source (sugar water or orange slices). The use of the container was to avoid capturing the individual butterfly again during the sampling period and enable students to observe the caught butterflies. At park sites, butterflies were released once marked by allowing them to fly out of the net. Marked individuals caught in subsequent sampling periods were not handled and only their unique identifier was collected before being released.

At each schoolyard garden sampling site, rising first and third-grade students participating in the FoodPrints summer school program were involved in the project to help gather butterfly data at their respective school gardens. Students and supervisors involved received training before the start of the program to increase the integrity of data collection. Students were also informed of the research project goals each week initially as an introduction to the program and a refresher thereafter for data collection objectives.

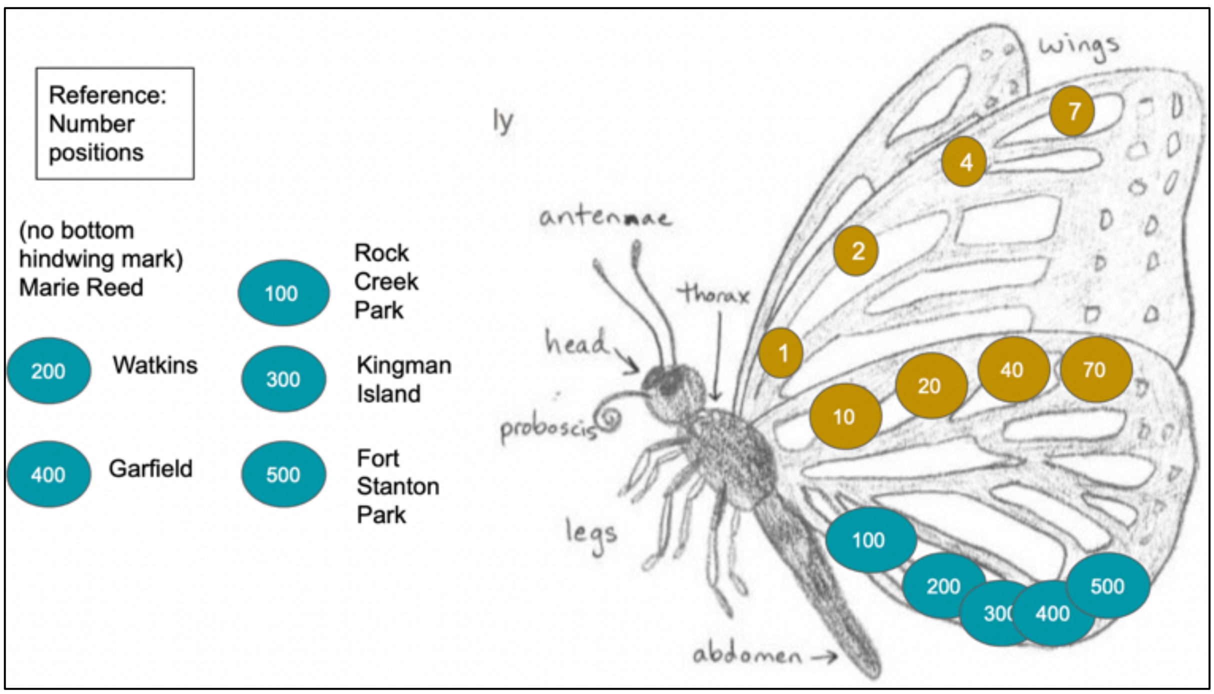


Figure 2. Three-digit number code for butterfly ID. Butterfly image was obtained by FoodPrints' and modified to demonstrate the method for making IDs.

For each butterfly captured, I and/or students recorded the species name, the date and time, the temperature when the individual was captured, the plant that it was captured on, and the unique identifier (Table 1). For this study, I was only focused on "large-bodied" butterflies.

Butterflies in DC were defined as “large-bodied” based on average wingspan using monarch butterflies as the baseline since they are commonly marked with Monarch Watch stickers as part of their eastern monarch butterfly study. Using iNaturalist to identify the most sighted butterfly species restricted to the DC area across all time, butterflies were included as large-bodied if their average wingspan range included three inches.

Table 1. Data sheet used by students and observers to collect data on each captured butterfly at each site.

Data	**Unit/Description**
Date	Date when data was collected.
Temperature	Temperature (ºF) when data was collected.
Time	Time butterfly was observed (hr:min)
Butterfly Species	Possible large-bodied butterflies in DC: Monarch Viceroy Red Admiral Red-Spotted Admiral Question Mark Mourning Cloak Great Spangled Fritillary Tiger Swallowtail Black Swallowtail Zebra Swallowtail Spicebush Swallowtail Pipevine Swallowtail
Plant	(flower/veggie/other)
Mark Identification	Codes Range from 1 to 999: 001-999
Recapture	Yes/No

Data Analysis

Species captured were not photographed or collected as part of the mark-recapture method. As a result, only male eastern tiger swallowtail butterflies (*Papilio glaucus*) and monarchs (*Danaus plexippus*) were confidently identified by observers. There was not enough data for the analysis of monarchs (n=5), therefore only eastern tiger swallowtail butterfly counts (n=17) were used for data analysis. I hypothesized that garden/park size, the income of the associated neighborhood, tree cover, and impervious cover would influence tiger swallowtail abundance. I fit n-mixture models (Royle, 2004) using the R ver. 4.2.2 (R Core Team, 2022) package *unmarked* (v1.2.5; Fiske & Chandler, 2011) to determine the influence each predictor variable had on the abundance of eastern tiger swallowtail butterflies. This model is used for estimating species abundance while taking into account imperfect detection (Royle, 2004).

Predictor variables. For neighborhood income (*income*), I extracted tract-level median household income from the five-year American Community Survey of 2015-2019 using the *tigris* and *tidycensus* packages in R (v2.0; Walker, 2022; v1.3.1; Walker & Herman, 2023; v4.2.2; R Core Team, 2022). Median household income was taken for the census tract that each school and park was located within. Rasters (30-m resolution) for 2019 impervious surface and 2016 tree canopy cover were obtained from the Multi-Resolution Land Characteristics (MRLC) raster layers (Dewitz & USGS, 2021). I then created a 100-m fixed radius buffer around each site. No literature exists for eastern tiger swallowtail butterfly territory sizes or individual ranges. Therefore, I used a 100-meter buffer to enable the buffer to capture the habitat characteristics of the school or park while being realistically large enough. The average percent of impervious surface (*impervious*) and canopy cover (*canopy*) within each buffer was extracted using the *terra* package, (v1.6-47; Hijmans, 2022) in R. Site area (*area*) was obtained by tracing the boundaries of each schoolyard garden and park with a polygon on Google Maps using the "Measure distance" feature. I also included an indicator variable for the park or school as a predictor variable (*site type*). For detection probability, I included the start time of the survey (*time*), the date of the survey (date), temperature (*temp*), and relative humidity (*humidity*). Upon checking for collinearity, the area of each site, canopy coverage, and impervious surface were colinear ($|r| > 0.7$). However, no correlated predictor variables were included in the same model.

Model fitting and model selection. Models were fit with the *unmarked* package in R. The best model for detection probability (ρ) was tested first by using the intercept only on abundance and fitting univariate models for each detection predictor variable. I also included an intercept-only model (.) (Table 2). Models were compared using AICc scores and the model with the lowest AIC value was considered the best-fit model (Burnham & Anderson, 2004). Once the best model for detection was determined, I then held the detection parameter constant with the respective parameter and fit univariate models for each abundance (λ) predictor variable. Again, I included an intercept-only model. Models were compared using AICc scores, and the model with the lowest AICc value was considered the best model (Table 2).

RESULTS

There was a total of 17 eastern tiger swallowtail butterflies captured or sighted, with 8 at Fort Stanton, and 9 at Montrose Park. There were also other species recorded, including cabbage whites (*Pieris rapae*), clouded sulfurs (*Colias philodice*), monarchs (*Danaus plexippus*), spice bush swallowtail (*Papilio troilus*), and a white-spotted skipper (*Epargyrius clarus*) that were not included in the data analyses, but visualized for students to compare previously collected data (Fig. 3). Figure 3 does not represent all data collected since it was created after the third week of data collection so students could observe it during their last week of the project.

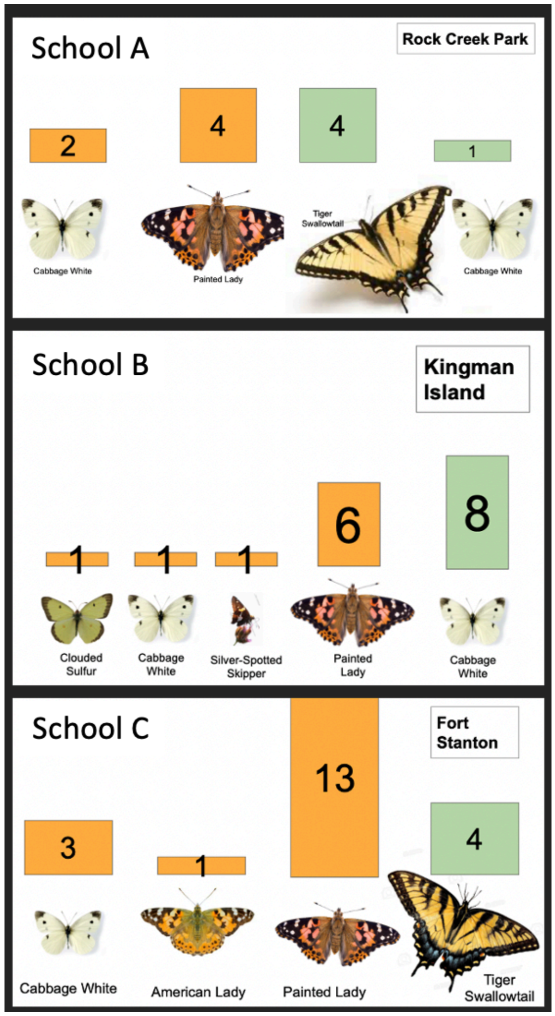


Figure 3. Visual comparison of species observed or captured from weeks 2-4 at each site for students to observe. Painted lady butterflies (*Vanessa cardui*) were reared by each class and released. They were not included in the data analyses. Bars in orange represent butterflies captured or observed at schoolyard gardens, and bars in green represent butterflies captured or observed at the associated park.

The best model for detection (ρ) was the null model (Table 2). Thus, I held the detection probability constant in our subsequent set of abundance (λ) models and found that the percent of impervious surface was the best predictor for tiger swallowtail abundance (Table 3). Within the top model, there was a significant negative relationship between the abundance of tiger swallowtails and the percent of impervious surfaces (β = -0.452, 95% confidence intervals = -0.88 - -0.05; Fig. 4).

Table 2 Detection models for tiger swallowtail butterflies

Model	Delta AICc	Estimate	SE	P-value
λ (.)ρ (.)	0.00	-0.172	0.476	0.718
λ (.)ρ (time)	7.69	0.00537	NaN	NaN
λ (.)ρ (temp)	9.48	0.0542	0.0771	0.482
λ (.)ρ (humidity)	9.56	-0.022	0.0335	0.511
λ (.)ρ (date)	9.94	-0.0126	0.0502	0.801

Table 3 Abundance models for tiger swallowtail butterflies with the detection probability constant.

Model	Delta AICc	Estimate	SE	P-value
λ (impervious) ρ (.)	0.00	-0.452	0.207	2.88e-02
λ (canopy) ρ (.)	3.90	0.0717	0.0215	8.57e-4
λ (site type) ρ (.)	8.13	9.14	31.3	0.770
λ (area) ρ (.)	21.67	-2.13e-16	0.00004	1.000
λ (income) ρ (.)	21.67	-3.72e-16	2.81e-05	1.000

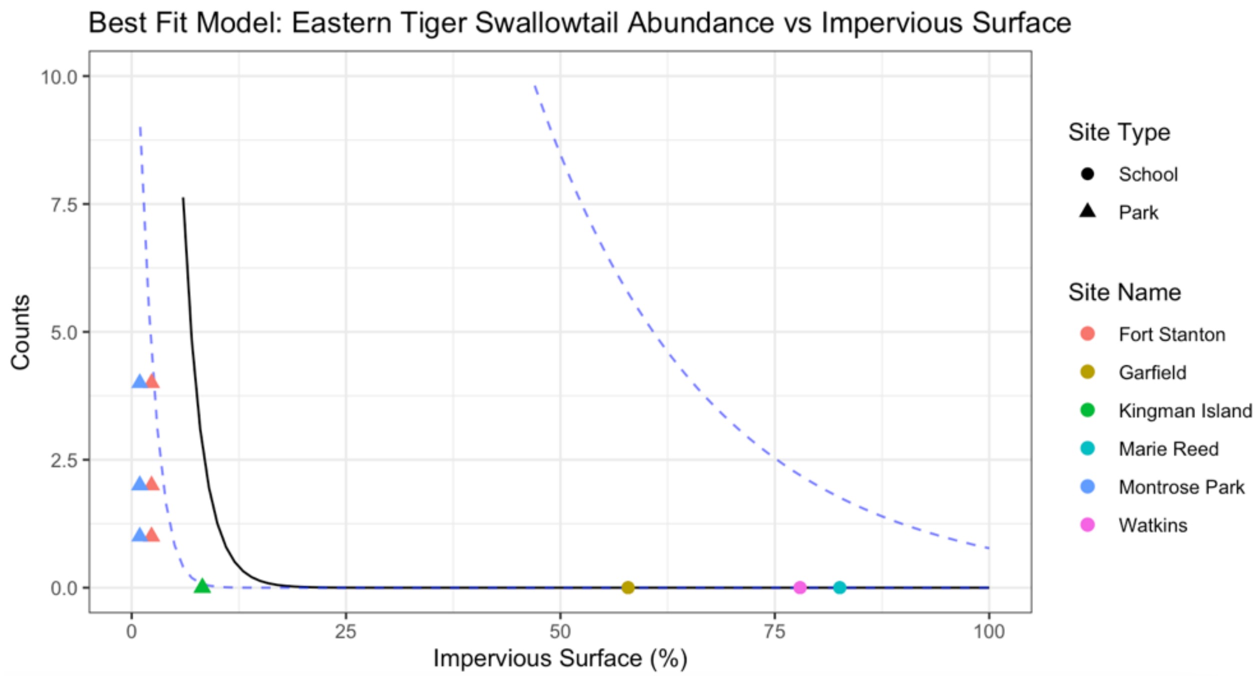


Figure 4. Predicted abundance of eastern swallowtails across a gradient of impervious cover using the top n-mixture model. The solid line represents the estimated values and blue dashed lines represent the 95% confidence interval. Shapes represent observed data. Site types are indicated by a circle for school sites and a triangle for park sites. Each color corresponds to the specific site.

DISCUSSION

In this study, I compared species richness and swallowtail abundance between school gardens and corresponding parks in Washington, D.C. I found that the percentage of impervious surface cover was negatively correlated with the abundance of tiger swallowtail butterflies. These findings can be applied to schoolyard gardens to increase their contribution to Lepidoptera conservation and improve educational programs about pollinators. School gardens can take part in pollinator conservation and teach students about how protecting and conserving biodiversity is essential.

Eastern tiger swallowtail abundance was negatively related to the proportion of impervious surface at a site regardless of whether the site was a schoolyard garden or a park.

Urban areas with higher percentages of impervious surfaces have less vegetation, thus fewer resources available for eastern tiger swallowtail butterflies and increased human traffic which increases the effort to avoid obstacles while flying (Laghude et al., 2020). Having less vegetative cover, makes for fewer resources including decreased availability of host plants for laying eggs, nectar sources, nutrient sources, and shelter to avoid predators and the elements. Less resources will often translate to lower diversity of butterflies in these areas.

It may be difficult, and in most cases even impossible, for urban schools to remove impervious surfaces such as concrete and buildings, but these surfaces can still be decreased by covering the surface with potted plants and garden beds that support butterfly habitats. For example, Kiers et al. (2022) found that pollinators prefer patches of plants with high levels of consistent food and that the density of plants was more important than the area of a site. Tew et al. (2022) also found that the habitat quality of garden space is more effective at attracting pollinators compared to garden size. This may be beneficial for urban schools that have limited green space and want to increase eastern tiger swallowtail abundance. Covering areas of impervious surface with container gardens that contain resources for pollinators can support butterfly populations even in small outdoor spaces.

There were limitations in our study that future studies should address. For example, I had a small sample size of school gardens and paired park spaces which did not cover a large range of impervious cover. Future studies should increase the number of school gardens that participate in the project and these locations should cover a greater variation of urbanization. Additionally, my study was conducted during the hottest month of the year for DC, though changing climate can alter when the abundance of butterflies is highest (Diamond et al., 2014). Based on iNaturalist observations in DC, the peak abundances of adult butterflies and eastern tiger swallowtail butterflies are in August, which was when my project ended (iNaturalist, 2023). I was restricted to the timing of the FoodPrints summer school program, but the temperature during data collection should be considered in future studies with different geographic locations.

Additionally, most adult Lepidoptera species do not solely get nutrients from nectar sources so future studies should consider the requirements of its other life stages, such as host plants and mud puddles. Finer-scale habitat covariates, such as species richness, plant diversity, and the presence of microhabitats should be included as covariates when studying butterfly abundance in school gardens.

While the number of studies on urban butterflies is increasing, there are still considerable gaps in understanding urban butterfly behavior, the effects of urban habitat management, and the monitoring of urban systems to integrate proper management for biodiversity conservation (Ramírez-Restrepo & MacGregor-Fors, 2017; Kabisch et al., 2016; Schwarz et al., 2017; Buchholz & Egerer, 2020). There also needs to be more of a focus on the relationship between these urban conservation actions and society, the impacts they have on the natural and social environment, and human perceptions of urban biodiversity (Kabisch et al., 2016; Schwarz et al., 2017). Working with students to address these gaps can be a great opportunity to include them in current ecological issues. Future research should assess student engagement in these programs to identify whether these experiences translate to increased stewardship of the natural environment. This is addressed in Chapter 2 of this thesis, where a pilot project was conducted with elementary students and their school gardens in DC.

Conclusion

This chapter identified a negative correlation between the percentage of impervious surfaces and eastern tiger swallowtail abundance in DC. Abundance was compared at three school gardens and corresponding park sites. Identifying that there is a negative correlation with impervious surfaces can guide action to be taken in school gardens to cover these surfaces with native plants that are beneficial to pollinators (without the removal of cement and buildings). Increasing vegetation generally will increase butterfly abundance, but my findings indicate that the addition of vegetation in areas of high impervious cover should be prioritized. I also demonstrated that students have the potential to contribute to these projects by collecting data on butterfly observations in their school gardens, which may lead to a better connection to current ecological issues and stewardship.

CHAPTER TWO: DC SCHOOL GARDEN BUTTERFLY PROJECT

INTRODUCTION

Creating and restoring urban green spaces are an example of providing "nature" back into cities, also known as Urban Reconciliation (Rosenzweig, 2003). Greenspaces can supply resources for butterflies such as food, habitat, shade, protection, and host plants for larvae. Butterflies (Lepidoptera) are generally well-studied in terms of their ecological roles in pollination, as prey, as pest control, and as environmental indicators (Ramírez-Restrepo & MacGregor-Fors, 2016). Additionally, Lepidoptera have the potential to reconnect urban populations with nature because of their public familiarity, charismatic nature, and intriguing metamorphic process (Sánchez-Bayo & Wyckhuys, 2019).

As described in Chapter 1, school gardens can serve as greenspaces in heavily urbanized areas. The District of Columbia Healthy Schools Act 2020 Report recorded that currently 47% of schools in the District (110 out of 236 sites) have active school gardens, and an aim to increase the number of school gardens to 60% of DC public schools (DCPS) was set for the 2020-2021 school year (Office of the State Superintendent of Education, 2020, p.117). Of the schools surveyed, approximately 50% of school gardens have elements that support wildlife, pollinators, and native species of the DC area (Office of the State Superintendent of Education, 2020, p.25). School-garden programs, like in DC, are excellent immersive environments for students to learn about pollinators' ecology, connect with nature, and become self-sufficient by forming healthy habits (Klemmer et al., 2005).

The use of school gardens for environmental education in the United States first originated around the late 19th century from the Nature-Study Movement (Trelstad, 1997). This Movement was started by a group of educators to create more hands-on learning experiences for students while also “instilling in young people a love for the earth” through farm work in cities (Trelstad, 1997). At the start of World War I, the aspect of hands-on learning in the classroom and instilling a love for nature was replaced with food production for the war effort in a program called the US School Garden Army (Trelstad, 1997). However, this program disappeared once the First World War was over (Trelstad, 1997). In the 1980’s and 90’s, there was a resurgence of school and community gardens, which are part of the school gardens that exist today (Trelstad, 1997). Since the resurgence, there have been more programs to apply hands-on, nature-based learning, as was the original purpose of the Nature-Study Movement.

Outdoor environmental education and citizen science projects have been successful in inspiring curiosity and awareness of nature, but there are few studies specifically on urban habitats and young participants (Wake & Birdsall, 2016; Schönfelder & Bogner, 2017; Fisher-Maltese, 2016; Jaus, 1982; Blakcawton, 2011). Generally, citizen scientist projects have been intended for adults due to the need for accurate data collection, which is more difficult with younger participants, especially for elementary to middle school students (Kountoupes & Oberhauser, 2008; Saunders et al., 2018; Hiller & Kitsantas, 2014; Snäll et al., 2011). However, exposing young students to the ecological interactions in their local settings can “lead to transformative learning…that can result in resilient children who see themselves as future guardians of the Earth” (Fischer et al., 2017; Wake & Birdsall, 2016).

Citizen science projects in urban ecology are less abundant, but environmental education programs involving public schools have acted in the same way as citizen science projects and have simultaneously increased students’ interest in science, technology, engineering, and mathematics (STEM) careers (see Table 4 for review of literature).

There have been several studies implementing citizens science within school settings, such as Jaus (1982) including environmental education outdoors, Fisher-Maltese & Zimmerman (2015) and Fisher-Maltese's (2016) garden insect identification project for students to be environmental stewards, the Georgia Pollinator Census, and Blackawton's (2011) bee project involving 8 to 10-year-olds with the publication written by students in "kids speak" (Griffin & Braman, 2021). These studies have shown that outdoor involvement does enhance learning science curriculum and can increase curiosity about the environment (Schönfelder & Bogner, 2017; Fisher-Maltese, 2016; Jaus, 1982; Blakcawton, 2011). In addition, the National Science Foundation has noted that informal science learning settings, like citizen science projects, are essential for increasing the number of students entering STEM careers (Friedman, 2008).

Table 4. Examples of successful citizen science projects conducted with students in environmental education.

Paper	Project	Outcomes
Hiller & Kitsantas, 2014	• U.S., Middle schoolers • Horseshoe crab citizen science program	• Higher motivational beliefs in science • Higher levels of achievement of content knowledge vs classroom only students
Elser et al., 2003	• U.S., High schoolers • Ecology Explorers – Arizona State University's community education component • Urban bird identification	• Increased students' observational skills • Higher motivational levels for learning about the project and identified birds • Developed new awareness and appreciation of the ecosystem
Culin, 2002	• U.S., Grades 6-12 • Make butterfly gardens • South Carolina Butterfly Project - Citizen science project	• Curriculum for teachers and other agents
Saunders et al., 2018	• Australia, 7-12 year old students • Citizen science project with pollinator habitat	• Enhanced scientific literacy and skills
Mnisi et al., 2021	• Cape Town, South Africa • 8 schools	• Slightly increased species richness and abundance

	• Project running over 7 years to create and monitor gardens of bird-pollinated plants for bird conservation	• Potential to reconnect people with nature
Aivelo, 2020	• Finland • Secondary students • Combined formal education and citizen science on urban rats	• Students that originally had negative views toward rats changed to less negative perceptions after participating in the study

School gardens can be a resource for increasing student understanding of the natural world and for increasing positive attitudes and empathy towards nature. Previous studies have demonstrated this through academic curriculum or studying insects in school gardens, though not in the sense of urban ecology (Fisher-Maltese, 2016; Carrier, 2009; Fancovicova & Prokop, 2011; Farmer et al., 2007; Skelly & Zajicek, 1998; Waliczek & Zajicek 1999). Involving students in a school garden activity that incorporates actions toward more nature-inclusive cities can have an important impact on students' attitudes toward protecting the environment (Fisher-Maltese & Zimmerman, 2015). Thus, conducting scientific research in an urban school garden can open opportunities for future involvement in environmental inclusion and protection in urban areas that are not often afforded to urban youth (Kudryavtsev & Krasny, 2012).

There is a need to study the relationship between urban habitat solutions and society, the impacts the solutions have on the natural and social environment, and human perceptions of urban biodiversity (Kabisch et al., 2016; Schwarz et al., 2017). School gardens specifically have been increasingly used to enrich student learning and increase connections to nature, but few have addressed the impacts of student involvement in research (Schönfelder & Bogner, 2017; Wake & Birdsall, 2016; Fisher-Maltese, 2016; Jaus, 1982; Blackawton, 2011; Aivelo, 2020; Elser et al.,2003; Saunders et al., 2018; Culins, 2002). Here, I am interested most in how elementary student involvement will impact their appreciation, curiosity, and interaction with nature in urban areas, especially since elementary school is the time when children are discovering their interests based on lived experiences (Klemmer et al., 2005). Outdoor involvement and physical interaction with nature in urban areas can increase inquiry about careers in environmental science within these spaces as well (Kelley & Williams, 2013). This chapter aims to answer the research question, "To what extent does participating in data collection in their school gardens support or increase students' awareness of urban nature?"

METHODS

This research project termed the DC School Garden Butterfly Project, engaged students in scientific research using their school gardens as sites to collect data on urban butterflies. I collaborated with FRESHFARMS FoodPrints staff and three DCPS elementary schools (Fig. 1) during the summer of 2022 to develop a school garden project that allowed students to participate in ecological data collection. This project was approved by George Mason University's Institutional Review Board (1905363-1). Teachers and those supervising the program were trained in early June 2022 before the summer program started. Teacher training included an overview of the research project, capture and data collection methods of butterflies, and a program evaluation focused on student involvement in data collection. Two researchers, myself and Dr. Travis visited the schools for data collection one day each week for four weeks, from July 5 – August 5, 2022, starting the second week of the students' 5-week summer school program. The purpose of starting the second week was to let students and staff adjust to the program's classroom rules during the first week of the program. There was a total of 67 students participating throughout the summer program. There were 25 students at School A (rising third-graders), 27 at School B (rising third-graders), and 15 at School C (rising first-graders) that participated, although the number of students that participated each week varied.

Daily lessons and data collection started with brief lessons (~ 5 minutes) about urban ecology, methods for researching butterflies, and methods for catching and handling butterflies. Students then began the process of capturing butterflies and recording data from Table 1 which lasted ~ 20 minutes. Data was recorded whenever a butterfly was captured. Student observations about insects in their garden were recorded when there was not a butterfly present. If a butterfly was captured, students would bring them to a supervisor to be marked with a unique ID and record the ID code. While students were looking for butterflies, researchers engaged in one-on-one informal check-ins about students' experiences to record their thoughts while engaging in capture methods (~1 minute). A debriefing session with the students occurred at the end of the day where students were asked questions about their enjoyment and views of the project, and what they retained from that day's lesson on urban ecology (5-10 minutes). These methods are described in more detail below. Discussion sessions were recorded with the student's and parent's permission.

Student Safety & Privacy

All students (n = 67) participated in the above aspects of the program. The study involved students handling live butterflies outdoors in a school garden. Any risk to students was associated with being outdoors in a school setting. Handling butterflies pose no risk to participants, but students may experience anxiety. All students received training for the safe handling of the butterflies if they needed to be marked. If students did not want to participate in handling butterflies, they were engaged in another related activity, such as recording data. All questions are familiar and easy to understand for students in an education setting, so no psychological risk was anticipated.

Student responses were audio recorded during the debriefing sessions and one-one conversations. No identifying features were collected from students. A participant ID was assigned to keep student confidentiality. An information sheet (Appendix A) and parental waiver of a signature on the Informed Consent were included as part of FoodPrints' packet of program materials for the DCPS elementary summer acceleration program that was sent to parents before the start of the program. The digital/hard copy signed waiver consent forms were collected from the program. Only the PI (Travis Gallo) and I have access to this material. Recordings were deleted after being transcribed. These responses were the primary source of data collection for program evaluation.

Materials

Field Data Collection Materials. Materials included 3D-printed hinged butterflies used for the handling demonstration of live butterflies for the mark-recapture process. Students were able to take these models home with them. Metallic, non-toxic, permanent markers were used to mark butterflies due to the large butterflies of interest being generally darker in color or black. Nets for each student were provided as well as a capture container to store captured butterflies during the sampling period. Holding captured butterflies during sampling periods also allowed students more time to observe the butterflies visiting their gardens. Students had data sheets to record their observations during the mark-recapture process and observations if butterflies are resighted in between school sampling visits (Table 1). However, there were very few butterfly encounters in the garden during the program.

Butterfly Books. "Butterfly Books" were created and printed for students that included pre- and post-tests, exploratory questions, puzzles, and a butterfly guide of large-bodied butterflies in the DC area (Appendix B). The pages to be completed included writing answers, circling, drawing pictures, and numbering steps. The following are the questions asked in the Butterfly Book to investigate student knowledge and desires within urban ecology:

- Pre and Post-Tests:
    - 1. Pre: Do you think you will see butterflies? How many butterflies do you think you will see?
    - 1. Post: How many butterflies did you think you saw?
    - 2. Pre/Post: Where would you hold butterflies for mark-recapture?
- Where do you want to see more trees?
- Where do you want to see more butterflies?
- Draw a butterfly you saw in the garden.
- Where would a butterfly be in the garden?
- What flowers would butterflies like?
- In what order were the following steps done?

The end of the book included butterfly crossword puzzles and games for student enjoyment outside of the program and when time allowed at the end of the day. The butterfly field guide (Appendix B) included a picture of the butterfly and its common name, some fun facts, and tips for identifying the species. There were also a diagram of butterfly anatomy and an image of flower colors that butterflies were generally attracted to. While the book was meant to collect data on student experiences, it was also designed for students to use outside of the classroom for their own butterfly observations. A butterfly identification sheet was also provided to students to identify potential large-bodied butterflies that may be seen in the DC area. Students took this book home after completing the program.

Assessments and Evaluations

To assess students' participation and engagement in the project, a variety of techniques were used throughout the program. The timeline of when these activities were implemented is shown in Fig. 5.

Activities Timeline

	Week 1	Week 2	Week 3	Week 4	Week 5
Butterfly book activity	W1 activities - (pre-tests)	W2 activities	W3 activities	W4 activities	W5 activities (post-tests)
Movement Questions			X		
Sticker Board					X
Debriefings		W2 questions	W3 questions	W4 questions	W5 questions

Figure 5. Timeline of activities done during the summer program. Pages in the Butterfly Book were administered every week, with debriefings starting the second week, and Movement Questions being administered during the third week of the summer program. The Sticker Board activity was done at the end of the program. I administered the pre-test of the Butterfly Book during Week 2 since FoodPrints teachers did not yet have the materials to complete it during Week 1.

Movement Questions. Movement Questions (Fig. 6) were applied by using an object or line on the ground to divide space for students to enter if they answer ‘yes’ or ‘no’ to a question. Warm-up questions were asked first to teach students how the “game” worked and decouple students answers from their friends. Students were asked a set of questions (Fig. 6) and moved to the location that indicated their answer. The number of students in each space was then recorded.

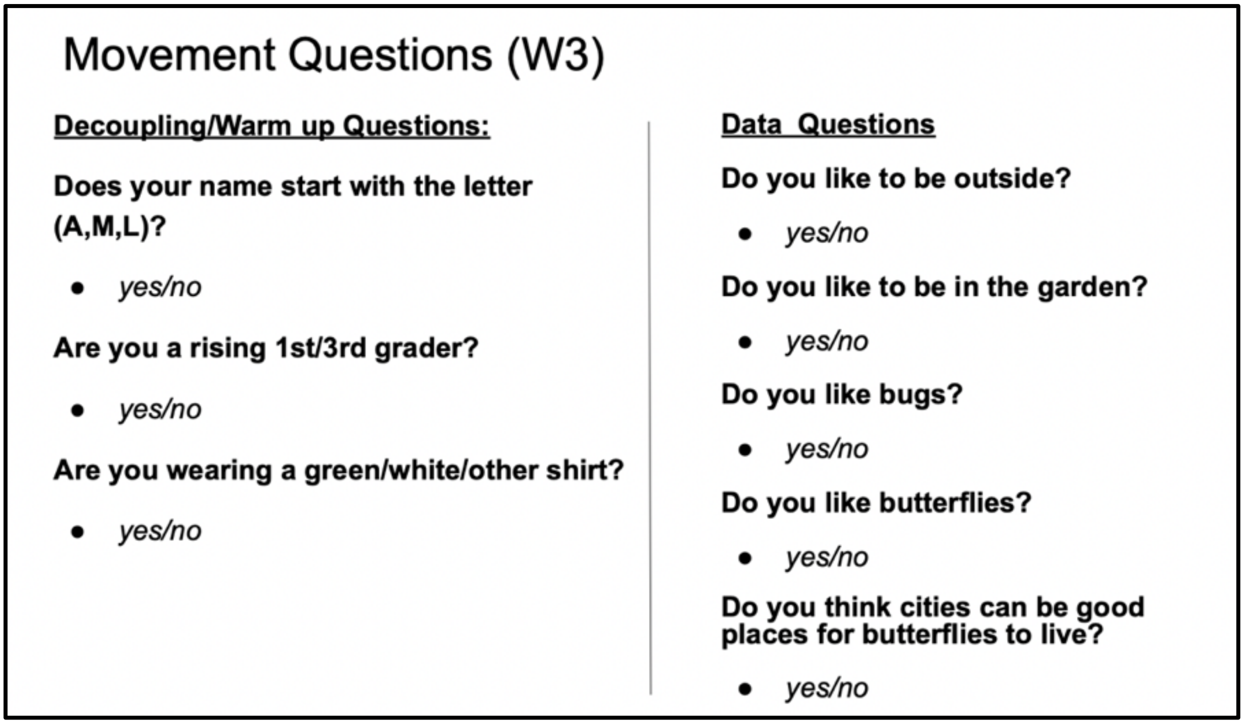


Figure 6. Movement Questions activity layout for researchers/instructors of warm-up and data questions to ask students.

Sticker Board. During the last week of the program, an activity called the Sticker Board was used to get feedback from students on the overall program. A board with six topics was presented to the students (Fig. 7). Students were asked if they liked or disliked each topic based on their experience in the program and answered ‘yes’ with a blue sticker and ‘no’ with a red sticker (Fig. 7).

Sticker Board: **What was your favorite part of the project?** (W5)

Instructions: blue stickers if they liked it, red if they didn't like it so much; students answer for each box

Learning about Urban Nature	Catching Butterflies	Holding Butterflies
Writing Information	Looking at Bugs	Being a Scientist

Figure 7. The layout of the Sticker Board administered during the last week of the program.

Debriefing Questions. To evaluate how the program affected the students participating, debriefing questions were asked in interviews throughout the entire program. Questions were asked to small groups, in debriefing sessions at the end of the day, and informally to individual students throughout the program that day (Fig. 8). Evaluation questions during the discussion sessions were based on three topics: urban areas as part of ecosystems, urban areas and habitat for butterflies, and gaining an intrinsic value of nature (Fig. 8). These questions aligned with goals outlined in specific DCPS learning standards and FRESHFARM FoodPrints curriculum in third and 4th grades. These included sections from Next Generation Science Standards 3-LS2-1, 3-LS4-3, 3-LS4-4, and ESS3.C *Human Impacts on Earth Systems* (NGSS, 2013).

Responses were analyzed by focusing on coding by word choice and expression of the students' responses. Analyses were based on the process done by Fisher-Maltese (2016) during the recorded interviews and student conversations by using multiple rounds of coding words and grouping them into themes.

Debriefing Questions

Consistent Questions Each Week:

- What behaviors did you see the butterflies do today?
- What was your favorite part about today? Part you liked the least?
- Do you have any questions for me? (about butterflies, the project, being a scientist…)

W2

- Who held a butterfly? What was it like?

W3

- What other things did you see in the garden?

W4

- What color butterflies did you see today?
- What butterfly names did you learn? (go through some names)

W5

- What was your favorite part of the project?
- Do you want to be a researcher? (of anything, butterflies..)
- Would you want to do this program again?

Figure 8. A list of debriefing questions to be asked each week at the end of the session. These questions were asked in addition to the three consistent questions asked every week.

Daily Butterfly Book Activities. Week 2 activities were the pre-tests shown in the previous Butterfly Book section, and where students would like to see more trees (Appendix B). Week 3 had students answer where they would like to see more butterflies. Week 4 activities included drawing a butterfly, drawing where a butterfly would be in a picture of a garden, and choosing plants that would attract butterflies based on flower color. While searching for butterflies and other insects in the school gardens, the students were often reminded of these different colors and would look in these areas first. During Week 5, the students completed the post-tests and ordered the steps their fieldwork in the garden was done.

VALIDITY OF FINDINGS

The trustworthiness of findings and interpretations was increased by including worksheets with students and consistent communication with FoodPrints teachers. Worksheets were created to be child-friendly and received feedback from teachers to be grade-appropriate. Questions were developed to target specific learning goals of students and investigate their reactions to novel interactions within the garden or conducting research. Activities in the butterfly book primarily used pictures where students had to circle, label, or draw their responses. Questions were made to be simple but still allow for open responses from students as part of the investigative study observing overall student connotations about insects and urban ecology. Foodprints staff and teachers were given the final product of questions to be used and offered feedback to make the questions more focused, such as removing additional pages and rephrasing questions to improve the material.

The analysis process of data was conducted with Dr. Varier along with regularly scheduled meetings to prepare materials and enhance the trustworthiness of data by creating reflections after each day of the program concluded. FoodPrints teachers also gave reviews of the outcome of the program and the results of the program were communicated back to them. The qualitative data collected was meant to be exploratory to assess what the common knowledge was for the students involved. Findings were also transparent and included an “audit trail” of conversations with students during debriefing sessions and the movement and sticker board activities (Shenton, 2004).

RESULTS

Reflection of Data Quality

Missing data appeared in the Butterfly Books, debriefing questions, and the Movement Game. Some students were picked up early during a project day or some students joined or left the summer program at different times resulting in missing responses for those IDs in the Butterfly Book activities. However, most students completed each week's Butterfly Book assignments (Week 2 – 61%, Week 3 – 64%, Week 4 – 72%, Week 5 – 56%). The presence and absence of students were beyond our control.

There were challenges associated with running the project simultaneously with two leaders. For example, School A had questions 3 and 4 missing when conducting the debriefing sessions, questions 1-4 were not repeated after week 2, and there was one week where questions and responses were not recorded. Questions that were repeated each week were only recorded for Week 2, with missing questions "what did you like the least about today" and "do you have any questions for me." Movement Game questions for Week 3 were asked to both groups at School A, though the second group was not asked "do you like to be outside" and "do you like to be in the garden." Tools to create more consistency among project leaders will help improve data quality in subsequent years. For example, printed out detailed activity checklist for each day would help leaders stay consistent among schools.

During Week 4 at School B, the class was combined, and debriefing questions were not able to be asked to any students. Students were hard to manage and remained distracted by their peers when combined into a larger classes even with multiple teachers. During this week only the Butterfly Book was able to be completed. During Week 3 at School B, the Movement Game questions were only able to be asked to Group 2. These missing sections were the result of balancing student enjoyment of the program and participation. Week 4 debriefing questions were cut for time and students' decreased attention span because of multiple distractions being with other students and teachers and being in a larger classroom size. If questions were asked, I would expect the quality of answers to be low or for there to be minimal participation. The Movement Game was cut from Group 1 to stay on schedule with the FoodPrints program to provide relief from the summer temperature. A simple review with teachers about the plan for each project day could solve this issue in the future when coordinating with leaders. Otherwise, multiple options for student activities can maintain flexibility for teachers.

Movement Questions

A total of 36 students participated in the Movement Question activity during Week 3. School C had a total of 11 (Group 1 = 5, Group 2 = 6), School B 10, and School A with 15 (Group 1 = 8, Group 2 = 7). Both School C and School A had a higher percentage of students responding 'yes' and 'no' likely due to some students answering 'maybe' at School B (Table 5). Percentages across answers do not all add up to 1.00 because of some students who were not participating.

Table 5. Movement questions asked to students during the movement question activity, my hypothesis for what students would answer, and the proportion of students that answered yes or no.

Question	Hypothesis	Percent of Student Answers
Are cities good for butterflies?	Majority 'no'	Yes – 19.4 No – 63.9 Maybe – 8.3
Do you like to be in the garden?	Majority 'yes'	Yes – 69.0 No – 17.2 Maybe – 3.45
Do you like to be outside?	Majority 'yes'	Yes – 44.8 No – 37.9 Maybe – 6.90
Do you like bugs?	Mixed 'yes'/'no'	Yes – 33.3 No – 44.4 Maybe – 11.1
Do you like butterflies?	Majority 'yes'	Yes – 80.6 No – 8.33 Maybe – 0.00

The most unexpected results for this activity were the responses to 'Do you like to be outside,' where the percent of answers for 'yes' and 'no' were very similar. This also occurred for 'Do you like bugs', with 'no' having the highest percent out of the other answers (44%). Not shown in the data are the comments made by students about why they chose their answers. For example, the number of responses and reasoning for if cities were good for butterflies often resulted in students discussing their answers with each other.

Sticker Board

A total of 43 students participated in the sticker board activity across all three schools. Overall, more students answered 'yes' than 'no' for each choice on the sticker board except for writing information (Fig. 9). School C students were not asked to respond to this section since they did not write down any data, but for the other schools, this section was interpreted as using the butterfly books for daily activities. Students appeared to like holding butterflies the most (63%) with 'catching butterflies' and 'looking at bugs' tied for second (56%). The part of the project that was disliked the most was writing information or completing the butterfly book (50%). Students that answered 'maybe' were only for the nature and wildlife aspects of the project.

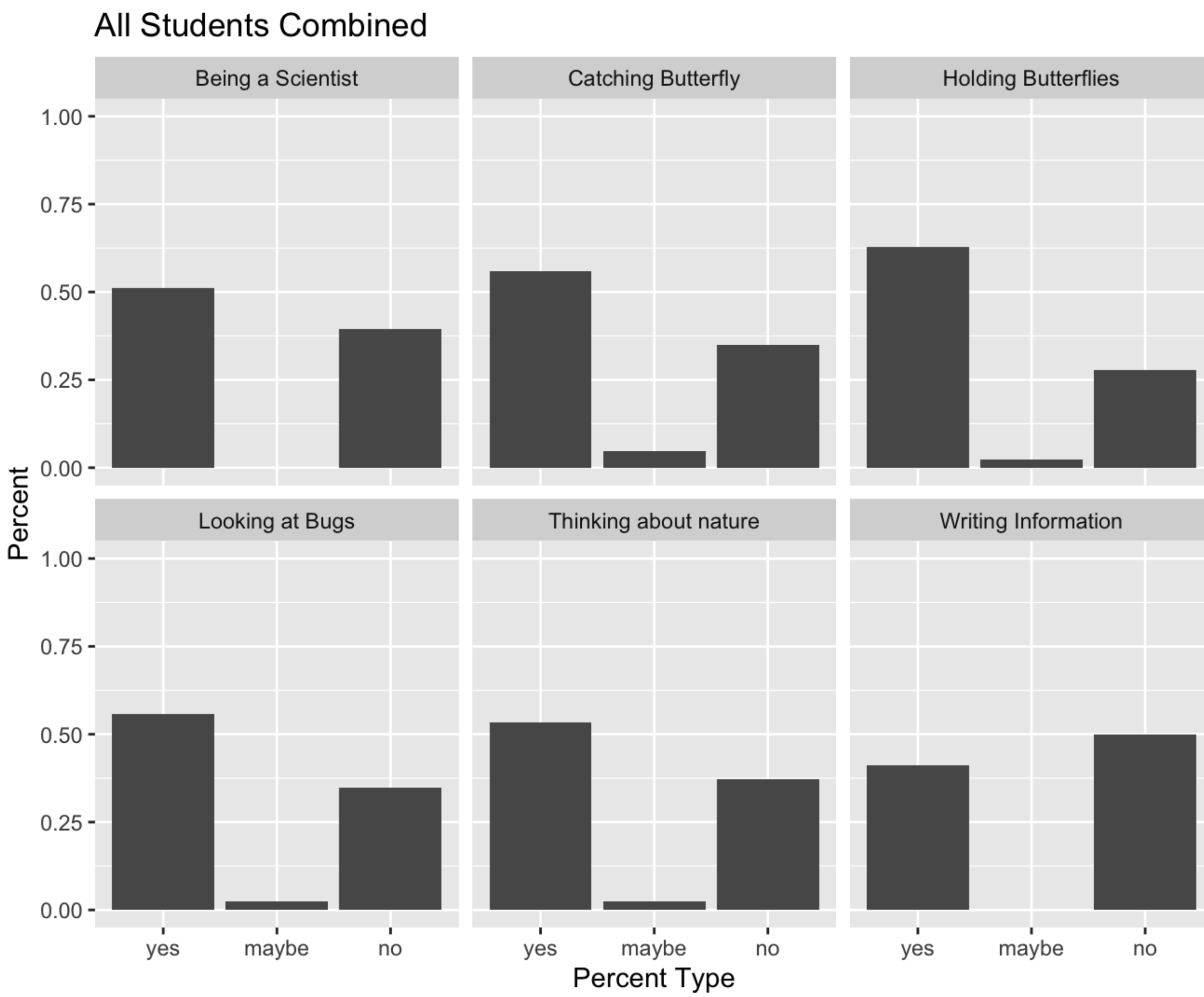


Figure 9. Sticker Board answers from all rising first and third-grade students combined during the school garden program.

Student Answers by Group. Contrary to my hypothesis that answers between groups would be relatively similar, the second group at School B had opposite responses compared to the first group when answering the sticker board (Fig. 10). At School B, students in Group 1 had more students answering ‘yes’ on the sticker board compared to Group 2. Group 2 had a higher percentage of students answering ‘no’ and less participation of students engaging in the activity. Only Group 1 had students answer ‘maybe.’ These differences were not observed in School A where students clearly indicated ‘yes’ or ‘no’.

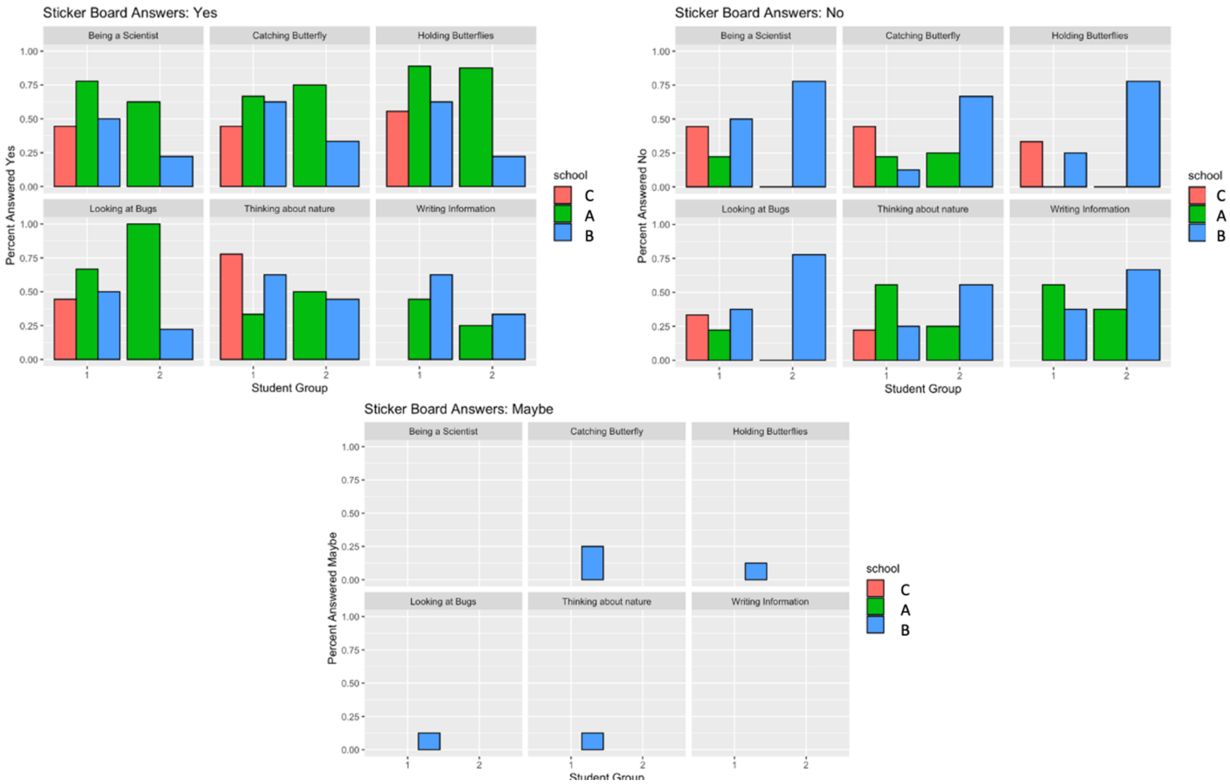
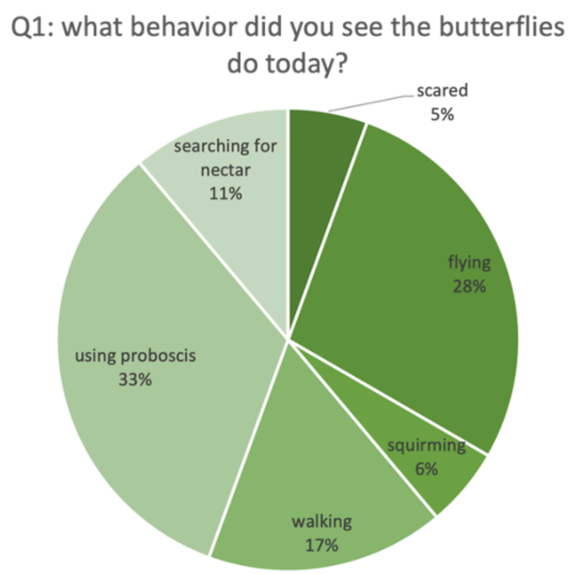


Figure 10. Student Sticker Board answers by groups for answers 'yes', 'no', and 'maybe.' School C is listed first to compare rising first to rising third-grade answers.

Debriefing Questions

Responses for each debriefing question averaged about 21 responses, with the most responses (39) given for what students liked the most about the program. Not seeing butterflies was most students' least favorite part of the program, however, they did enjoy being outside, seeing different bugs, and practicing with their nets (Fig. 12). Each class also raised painted lady butterflies (*Vanessa cardui*) from larvae and released them after eclosion. Students asked interesting questions, such as about the marking process of the butterflies, butterfly life cycles, and if caterpillars have a bed. Some students wanted to study animals in the future, or a different field still related to animals such as a "veterinarian artist," "teacher," or "doctor." Students also gave suggestions for the project such as doing it during a different time of the year like spring or incorporating looking for butterflies around their home instead of the school gardens.

Question 1: What behaviors did you see the butterflies do today? Overall, the majority of comments were about how butterflies used their proboscis (Fig. 11). School A only had one student respond about how the butterfly was flying. At School B, students saw butterfly behaviors such as butterflies intentionally flying away from the students, moth larvae doing inch-worm movements, and how the sulfur butterfly I captured during Week 2 never landed on the orange slices in the cage. They also saw the sulfur butterfly crawling and flapping its wings while in the cage. At School C, students were able to observe behaviors of newly emerged painted lady butterflies such as the unraveling of the proboscis and the use of their newly developed wings.



Categories	Comments
Scared	Scared
Flying	Butterflies flying Flapping wings Flying (x2) It was flying
Squirming	It went squirmy squirm (a caterpillar)
Walking	Walking (x2) crawling
Using proboscis	Using its tongue (x3) Licking flower Drinking nectar Using straw tongue
Searching for nectar	On orange flower On flowers

Figure 11. Debriefing question 1 student responses from the school garden program.

Questions 2 & 3: What was your favorite part about today? What did you like the least? Overall, there were more positive than negative comments from all students during the debriefing questions (Fig. 12). Comments were grouped based on common categories as shown in Figure 12. Not seeing butterflies was most students' least favorite part of the program (71%), however, they did enjoy being outside (3%), seeing different bugs (20%), and practicing with their nets (Fig. 12). Seeing different bugs was comprised of the categories “insect biodiversity,” “bees,” and “plant-insect interactions.” Students’ favorite part was catching butterflies (33%) and learning about or observing butterflies (23%). What School A students enjoyed the most was trying to catch butterflies, even if this included just practicing with their 3D-printed butterfly models (n = 6). Responses for what they did not like were not recorded for this school. Each day that a butterfly was caught, catching butterflies was the most common answer.

At School B, there were more positive comments than negative ones over the program (n = 15, n = 12 respectively). The students enjoyed seeing the different bugs the most since that section had the most comments. This included seeing different types of bees like honeybees and learning about solitary bees, seeing a monarch butterfly during the last week of the program, and interacting with a moth caterpillar. The students liked to comment on and imitate the movement of the caterpillar inching on their fingers and noted how it had different textures (smooth and prickly). One student commented how it was “so cute.” While in the garden students also like to pick produce while waiting for butterflies, like tomatoes, and note the color of the flowers that bees were on. They even enjoyed the process of trying to catch butterflies by being sneaky around the garden and using their nets. One student commented that they liked being able to meet me, which could mean that they enjoyed meeting a scientist or just the enthusiasm for insects in their garden. The main complaint for the program was not finding butterflies in their school garden, or at least when they were in the garden. This also included the time spent looking, which was set at 30 minutes at the beginning of the program and was adjusted to 5-10 minutes after the first day of the program. This was probably made worse by the hot, July temperature making students more irritable and tired.

The rising first-graders at School C had overall more positive than negative comments to say about the program (n = 18, n = 11 respectively). What they enjoyed the most was catching bugs in their gardens, whether it was a moth or butterfly, and doing the puzzles at the end of the Butterfly Book. The puzzle activities included a maze, butterfly symmetry, and crossword puzzles, and were just meant for students to do in their own time. The most common thing they disliked was when there weren't any butterflies in the garden to catch and being patient waiting and looking for butterflies in their garden. Some students also expressed their fear of bees. Students also complained about the hot temperature.

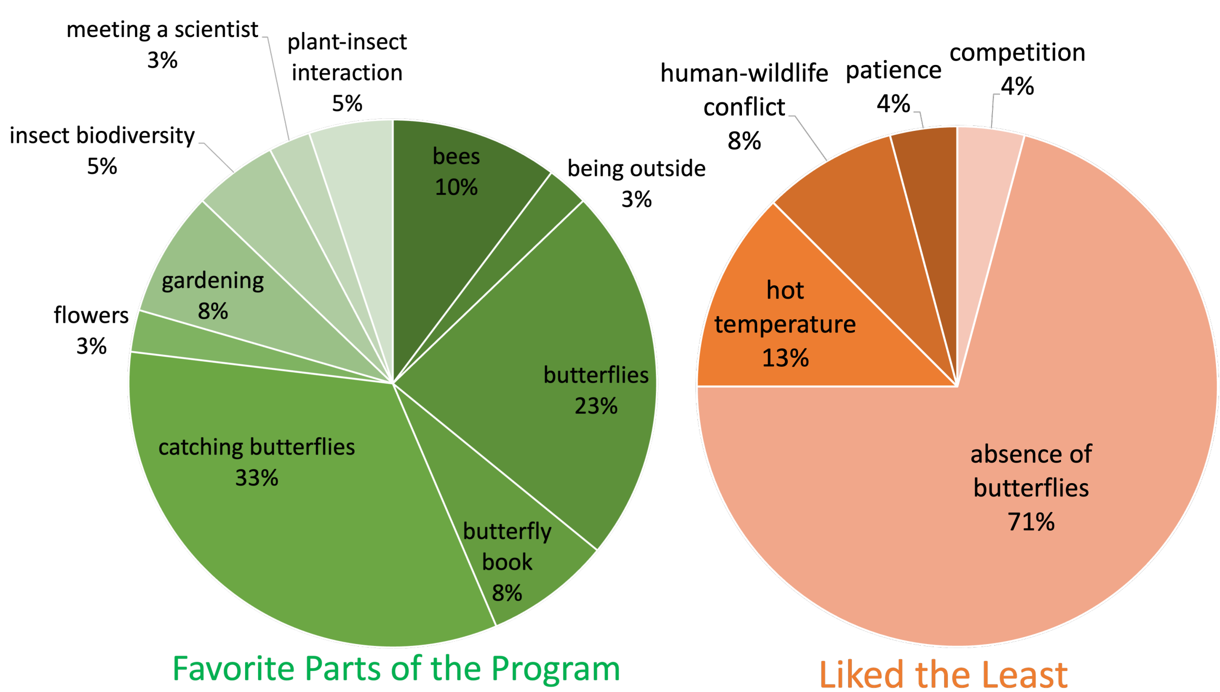
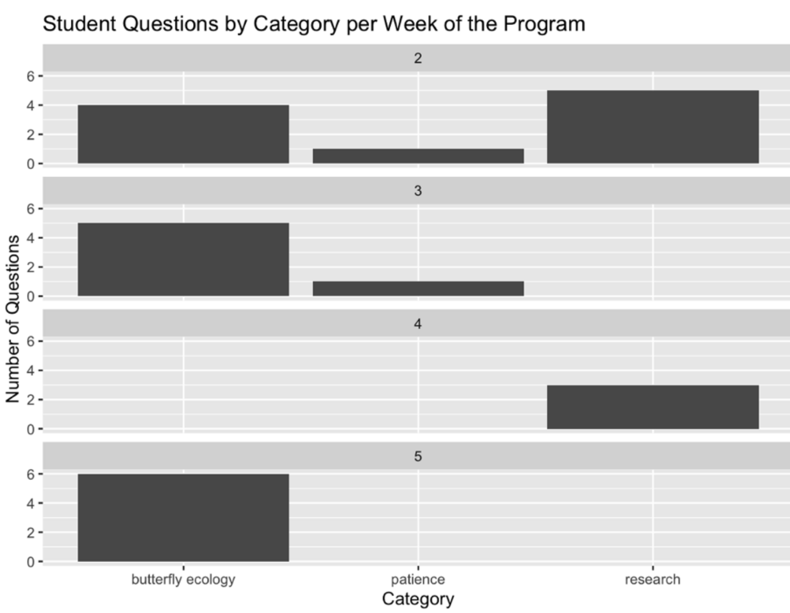


Figure 12. Student responses for debriefing questions 2 and 3. Question 2 responses are shown on the left in green, and Question 3 responses are on the right in orange.

Question 4: Do you have any questions for me? Students asked interesting questions, such as about the marking process of the butterflies, butterfly life cycles, and if caterpillars have a bed (Fig. 13). Questions were grouped into three categories: butterfly ecology, patience, and research. The first two weeks had the most questions from students that fit into the 'patience' category, such as how they were frustrated that a butterfly wasn't appearing and asking when a butterfly would appear. Questions about butterfly ecology were the highest except during week three where each class released their painted lady butterflies and many questions were asked about the mark-recapture process since some butterflies were marked as demonstrations for students. School A students were not asked the question about if students had any questions for the researchers.

There were much more questions asked by School B students than by the rising first-grade class (School C) and the questions were asked in a way that students could compare to their lifestyle as a human. Questions from the students were mainly about butterfly behavior but also included a question about how seeds are made, materials for the program, and how to catch butterflies. The questions about butterfly behavior included how they are created, how they mate, how to tell the sex of the butterfly, what they eat, and how the young live. Most students were surprised how most butterflies do not care for their young after laying an egg on a suitable leaf. One interesting question was "Is there such thing as a butterfly nest, like a birds nest?" and "Do caterpillars sleep inside something?", which I responded that I wasn't sure about the butterfly nest, but some caterpillars do sleep inside leaves or make a sleeping bag like the bagworm moth. One student asked many questions about my experience catching butterflies, such as how long I have done this job, how often I do it, and if I have a butterfly collection.

Questions from School C students were relevant and asked about the presence and behavior of butterflies in their garden. These included, “Why aren’t there butterflies out here?” and, “Do butterflies come around people?” to try to understand how they could see butterflies in their garden. This led to discussions about what butterflies like (flower colors, nectar) and what we were trying to learn as scientists in the garden. When the reared painted lady butterflies were ready to be released, one student asked many follow-up questions about the mark-recapture method. This included, “How come you put 5 dots on my butterfly?”, “How can you tell the number of dots on the butterfly?”, and “What if there’s 0 dots?”, which resulted in discussing how this will let you know if a butterfly visited before or not to try to guess how many butterflies are using your garden.



Category	Questions
Butterfly ecology	How do seeds get made? How do butterflies get made? How do you know if a butterfly is a boy or girl? How do they (butterflies) mate? What’s their favorite food? They drink sugar water? Do butterflies lay baby caterpillars? Is there such thing as a butterfly nest, like a birdnest? Do they (the caterpillars) sleep inside something? As soon as the baby’s born, they (butterflies) leave? *Are we going to look at the book when we catch the butterflies to find out what kind it is? If the butterfly lays an egg, then that’s their kid? *Why aren’t there butterflies out here? *Do butterflies come around people
Patience	*Are we ever going to find butterflies? *Why aren’t there butterflies out here?
Research	*Are we going to look at the book when we catch the butterflies to find out what kind it is? Do you catch butterflies a lot? Do you have a long collection of butterflies in your house? When you leave to go home do you catch butterflies? How did you catch that one (the butterfly)? How come you put 5 dots on my butterfly? How can you tell the number of dots on the butterfly? What if there’s 0 dots?

Figure 13. Types of questions students had for leaders during each week of the program. The table on the right shows all questions and how they were categorized. Questions with asterisks (*) indicate a question that could be counted for more than one category.

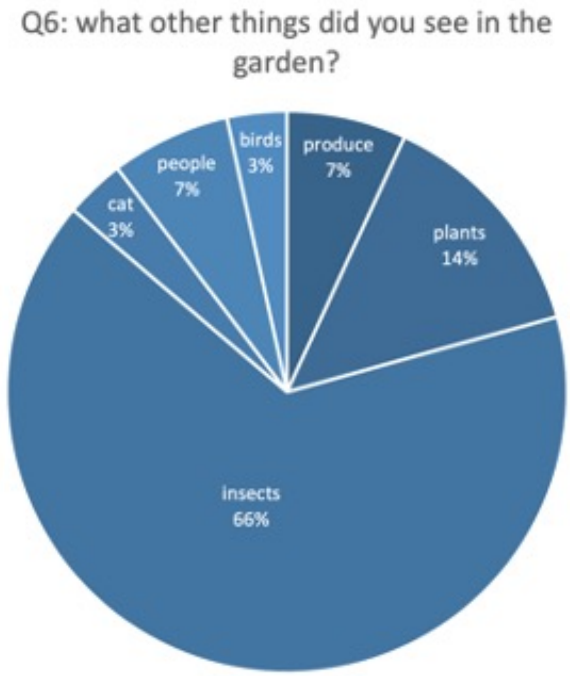
Question 5: Who got to hold a butterfly and what was it like? Question 5 asked about student experiences holding butterflies but was not asked because students had not had this experience and were not needed when marking butterflies. The marking method was adapted to reduce the handling of butterflies by marking the captured butterflies through the holes of the butterfly net they were captured in.

Question 6: What other things did you see in the garden? Things students saw in the garden included bugs, and produce they were growing. Students were able to name and observe many different types of insects in their school garden (Fig. 14). They were also able to see other taxa such as birds and the presence of one black cat.

In their garden at School A, students were able to make many observations of animals coexisting besides butterflies. These animals were mainly insects, but some students also noted that humans were there too. Insect taxa that students named were bees, ants, flies, roly-polies, mosquitos, and an unidentified insect one student had never seen before.

At School B, insects observed were generally bees, specifically, solitary bees and honeybees. They also got to see aphid infestations on milkweed plants. Students also noted how they saw eggplants and cucumbers growing in their gardens.

Observations that students made at School C saw in the garden included the plants (flowers, sunflowers, leaves), insects (bugs, butterflies, bees, beetles, some sort of larva by their compost bin), and other visitors crossing by in their parking lot, such as a black cat that made two appearances over the course of the program.



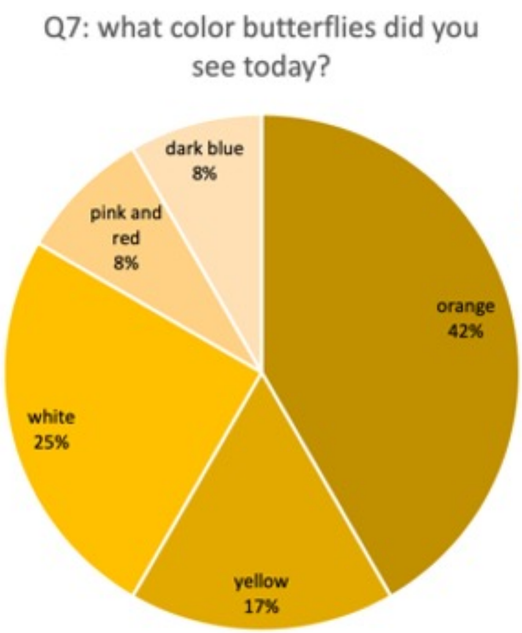
Categories	Comments
Produce	Eggplants cucumbers
Plants	Sunflower Flowers Leaf Leaves
Cat	Saw a black cat
People	Humans (x2)
Birds	birds
Insects	Solitary bees, they were tiny Lots of bees Aphids Bugs Butterfly Bee Beetle Larvae by compost bin Bees Ants and flies Rolly polly (x2) Mosquito and bee (x2) Mosquito and weird insect (x2)

Figure 14. Debriefing question 6 student responses. Answers with (x2) meant that this answer was given by two different students.

Question 7: What color butterflies did you see today? Students mainly described the colors of their painted lady butterflies and cabbage whites seen in the garden. Orange was a prominent color they remembered seeing (Fig. 15). School B did not have any student responses to this question.

At School A, the most common answers were white and a mix of orange, pink, and red, corresponding to the cabbage whites and painted lady butterflies that were caught or released in their garden. One student noted a dark blue butterfly on the playground that they saw at a different time, not during the program, and another used the guide in the beginning of the Butterfly Book to identify a "spotted red admiral" that was seen on the playground but not during the program.

School C students also enjoyed describing the colors of butterfly wings of their painted lady butterflies, which they described as orange and black, orange and silver, and yellow. At School A, the most common answers were white and a mix of orange, pink, and red, corresponding to the cabbage whites and painted lady butterflies that were caught or released in their garden. One student noted a dark blue butterfly on the playground that they saw at a different time, not during the program, and another used the guide at the beginning of the Butterfly Book to identify a "spotted red admiral" that was seen on the playground but not during the program.



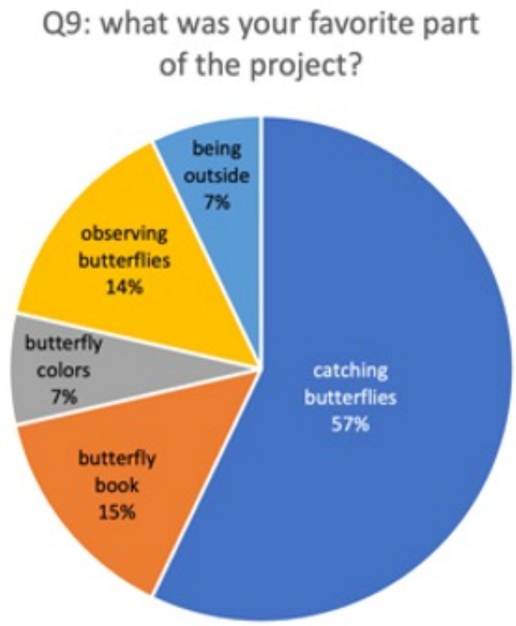
Categories	Comments
Orange	Orange and black Orange and silver Orange and a dark blue one
Yellow	Yellow Little bit yellow
White	White butterflies White (x2)
Pink and red	Pink and red
Dark blue	Orange and a dark blue one

Figure 15. Debriefing question 7 student responses. "orange and a dark blue one" was counted for two different categories.

Question 8: What butterfly names did you learn? Only School A students recalled names of butterflies they saw in the school garden and from the Butterfly Book. Students also recalled many common names of butterflies seen and butterflies in their guide. The butterflies they recalled were cabbage whites (“white cabbage”), painted ladies, zebra swallowtails, monarchs, and viceroys.

Question 9: What was your favorite part of the project? Overall catching and observing butterflies was the highlight of the program (Fig. 16). The favorite part of the project for School A students was seeing the butterflies. Some students saw them on their playground not during the program session and on one of their field trips. They had fun being outside looking for butterflies, as well as catching them or trying to catch them. One student remarked how they liked the activities they did inside with butterflies, which may refer to the FRESHFARM FoodPrints activities or their Butterfly Book.

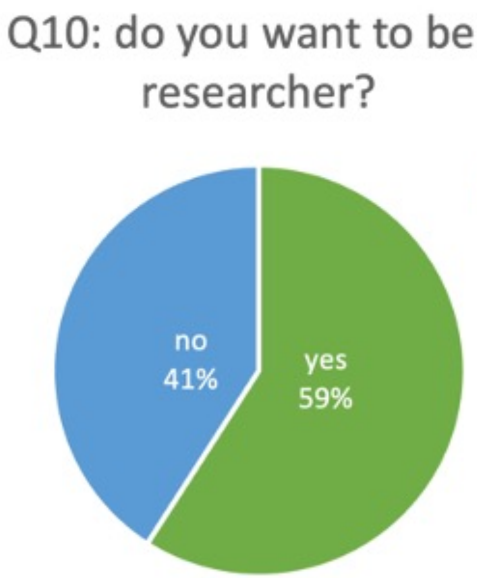
At School B, students’ favorite part of the project was catching butterflies, which was also School C’s favorite, and playing with nets. School C students said their favorite part of the project was catching butterflies and using the butterfly nets, which were given to the students on the last day. Coming in second and third were completing the butterfly books and looking at the butterfly colors and designs, respectively.



Categories	Comments
catching butterflies	Catching butterflies (x3) Playing with netes Trying to catch butterflies Catching all the butterflies Catching a butterfly (majority wanted to have their own net and keep catching butterflies)
butterfly book	Working on book puzzles Doing the butterfly things inside
butterfly colors	Different colors on butterfly wings
observing butterflies	Seeing butterflies on the playground Seeing butterflies on the field trip
being outside	Yes (had fun being outside looking for butterflies)

Figure 16. Debriefing question 9 student responses. Student answers are shown in each category on the right. (x3) refers to three different students having this answer.

Question 10: Do you want to be a researcher? At the end of the program Question 10 was asked and the majority of students were interested in being a researcher and even gave some examples of what they wanted to pursue (Fig. 17). Many students at School A shared what they wanted to be when they grew up, and the majority that responded did want to study animals. Some students stated what animal they wanted to study (“bears”, “tigers”), and some just stated that they liked animals and did want to be a researcher. Those who responded “no” explained that they wanted to be a doctor, a teacher, or an artist. Some students responded that they wanted to be a “veterinarian artist,” drawing pictures of animals. At School B, a mix of students said that they would and would not want to be a researcher, but the first group had more “yes” responses than “no.” About half of the School C students present on the last day said they would like to be a scientist when they grow up.



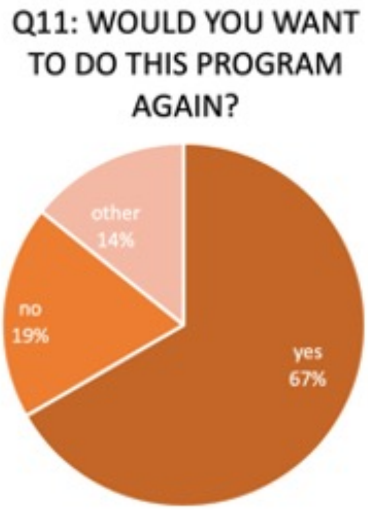
Categories	Comments
yes	Yes (x6) To study animals (x3) Study bears Study tigers Yes, I like animals researcher
no	I want to be a doctor I'm gonna be a teacher Painter and drawer Veterinarian artist

Figure 17. Debriefing question 10 student responses and student comments by category.

Question 11: Would you want to do this program again? Most students responded that they would like to do this program again and some students offered suggestions for changes as well (Fig. 18).

Students at School C had six out of a total of eight students who responded that they would like to do this program again (~75%). At School B, there were at least three students that wanted to do this project again from both groups combined, and some suggested doing it at home. Another student commented that they wanted to do it now since they had nets.

School A had mixed responses when students were asked if they wanted to do this program again, but generally, there were about five distinct answers for "yes" and a couple for "no." One student gave a recommendation for the project about choosing a different season, like spring, to try to see more butterflies. Teachers responded to this suggestion by saying that maybe more flowers could be planted or included types of plants that would attract the most butterflies.



Categories	Comments
yes	Yes (x14)
no	No (x4)
other	Want to do it at home Want to do it right now because I have a net Maybe we should try to do it earlier like the spring

Figure 18. Debriefing question 11 student responses during the last week of the school garden program. The numbers next to each answer in the table correspond to the number of students giving those comments. The "other" category includes suggestions and other comments from students about doing the program again.

Butterfly Book

Activities in the Butterfly Book, including two pre and post-tests, were scheduled to be completed during Weeks 2 and 5 of the program. Because students were not consistently in the program, sample sizes of students completing each section varied.

Pre and Post Tests (Weeks 2 & 5). The first pre-test had 48 students who gave at least one response. For the question "Do you think you will see butterflies in the garden", 85% said 'yes', and 4% (two students) said 'yes and maybe' (Table 6). A wide range of responses was given for the number of butterflies students thought they might see ranging from zero to 10^{23}. Most student answers were in the 1-25 category (n = 26; Fig. 19).

Between schools, there was a wider range of answers in rising third-grade classes than rising first for estimating the number of butterflies seen in their school gardens. Rising first-graders only entered single numbers whereas those in the rising third classes put multiple different numbers, such as "0-50" and "2 or 10." This variance decreased in the post-test where most answers were between 1-25 butterflies, with most answers in the single digits. Each class had a differing sample size so results are shown in percentage. About 60% of students at all schools had estimates between 1-25 for the pre-test except for School C (rising first-graders) where 67% of answers were greater than 50. Answers for 1-25 butterflies increased to 70%-80% for the post-test. Though no butterflies were captured, there were some passing through the schoolyard that were just beyond reach to be captured. Sample sizes for each school were 12 for School C, 20 for School A, and 15 for School B.

The post-test (n = 30) had more students responding between 1-6 butterflies seen (n = 20) though other students did not appear to follow instructions or understand the question as seen with answers above six butterflies in Figure 19. Most student answers followed what was actually seen in the school gardens. School B observed three butterflies, School C observed four butterflies, and School A observed two butterflies in their school garden, averaging around three butterflies.

Table 6 Student answers for if they think butterflies will be in the garden. 'yes and maybe' was a unique response from two students and counted as it's own answer choice.

Pre-Test: Do you think you'll see butterflies in the garden?	
Answer	**Percent of Answers**
Yes	85.4%
No	6.25%
'yes and maybe'	4.17%
Maybe	4.17%

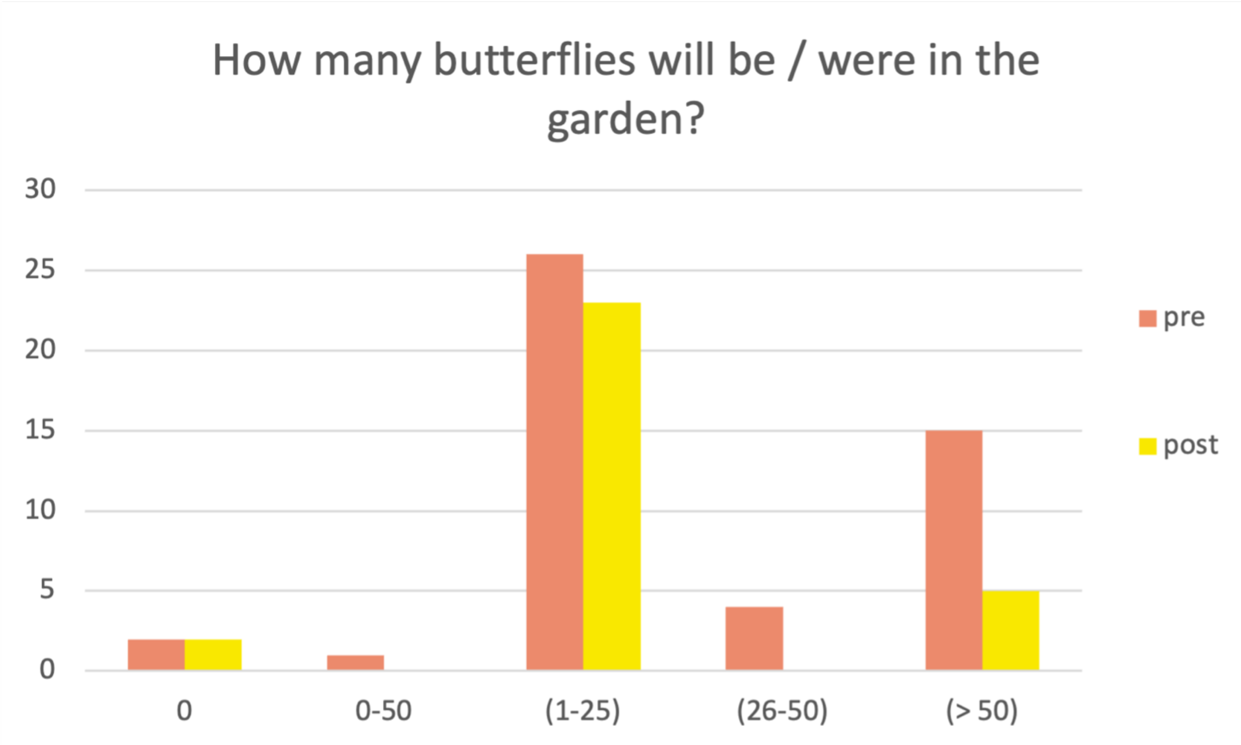


Figure 19. Pre/Post-Test student answers for the number of butterflies they predicted to be seen in their school garden. Answers that are not in parenthesis on the graphs were the direct answers given by students.

The second pre/post-test question had 42 and 29 students respectively. The correct response to this question of where to hold butterflies for research, referring to marking butterflies, was the edge of the forewing closest to the body. Here, student answers for 'body' was explained to reference the legs of the butterfly so these two categories were combined into 'body'. This had the highest number of selections from students for both the pre and post-test (43% and 66% respectively), most likely due to students explaining that they would hold the butterfly with open hands, having the butterfly walk along them (Fig. 20). In the pre-test, the 'edge of forewing' answer was the second highest selected answer (20%).

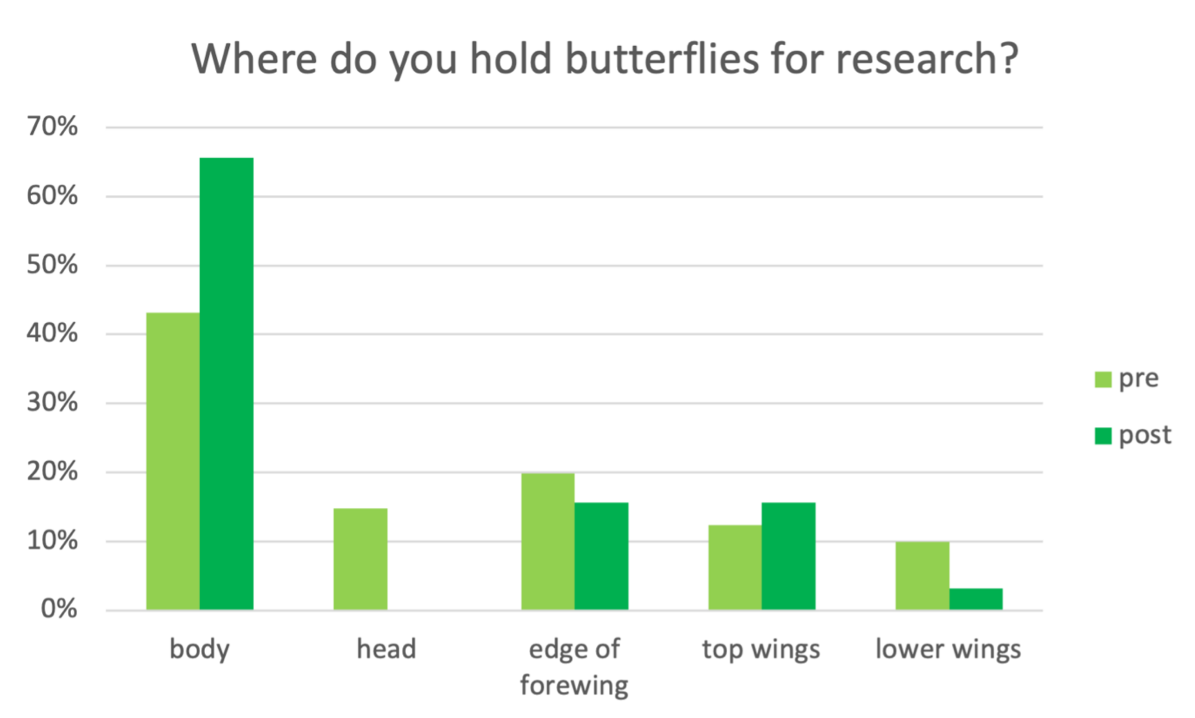


Figure 20. Pre and post-tests student answers for where butterflies should be held for traditional marking techniques of mark-recapture studies.

Where do you want to see more trees/butterflies? (Weeks 2 & 3). The top three answers for where students would like to see more trees (n = 44) and butterflies (n = 25) were for their school garden, forest parks, and their neighborhood. The choice for highways was among the lowest for both questions (Figure 21). The biggest difference between questions was the choice for 'my city,' where it was not seen as high of a priority for locations to see butterflies compared to trees.

Where do you want to see more trees?	Number Selected by Students	Percent
Forest park	29	15.0
Highways	22	11.4
My city	28	14.5
My neighborhood	29	15.0
My school garden	34	17.6
Playgrounds	27	14.0
Shopping areas	24	12.4

Where do you want to see more butterflies?	Number Selected by Students	Percent
Forest park	21	16.5
Highways	15	11.8
My city	15	11.8
My neighborhood	20	15.7
My school garden	21	16.5
Playgrounds	19	15.0
Shopping areas	16	12.6

Figure 21. Student selections for where they wanted to see more trees (left) and butterflies (right). Students could select multiple answers. School B only had two students complete the section for more butterflies.

Draw a butterfly in the garden (Week 4). Only third-grade data for butterfly drawings were collected due to the first-grade FoodPrints program combining this activity with one of theirs. However, during this activity first-grade students would observe their reared painted lady butterflies while attempting to draw them. During this activity, students noticed butterfly anatomy such as the proboscis when several students were "licked" by the butterflies extending their proboscis as they crawled up the mesh siding of their enclosure. Butterfly behaviors were also observed such as butterflies drinking sugar water from a cotton ball and vibrating their wings. Rising first-grade students also noticed the multiple different colors on the butterfly wings and used small magnifying glasses to see close-up details of butterflies walking up the side of the enclosure.

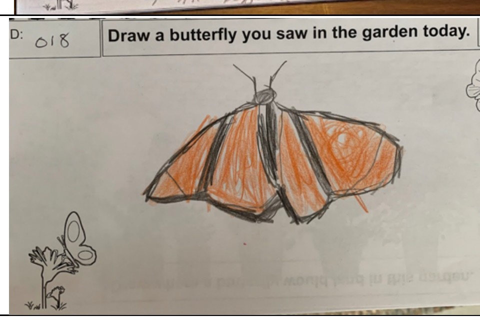
For third-grade data, pictures were described by several themes observed in the students' drawings. These themes are shown in Table 8 with three examples of categorized drawings shown in Table 9. Most students' drawings highlighted the diversity of butterflies, meaning different colors and patterns were present on the butterfly drawings. One student wrote out their answer instead of drawing, saying "I saw the painted lady butterfly outside and their chrysalis," identifying the species of butterfly and their life stages. 61% and 75% of students for School A (n = 13) and School B (n = 20) respectively had evidence of the 'butterfly diversity' theme.

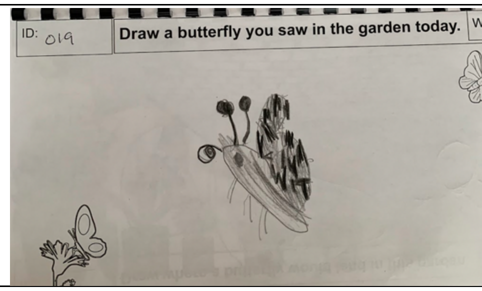
Table 8. Categories describing student butterfly drawings for School A and School B.

School A (n = 13)		
Categories	**Pictures per Category**	**Percent of Pictures**
Butterfly diversity	11	61.1%
Butterfly habitat	2	11.1%
Butterfly life stages	2	11.1%
Butterfly anatomy	2	11.1%
Biodiversity	1	5.56%
Catching butterflies	0	0.00%

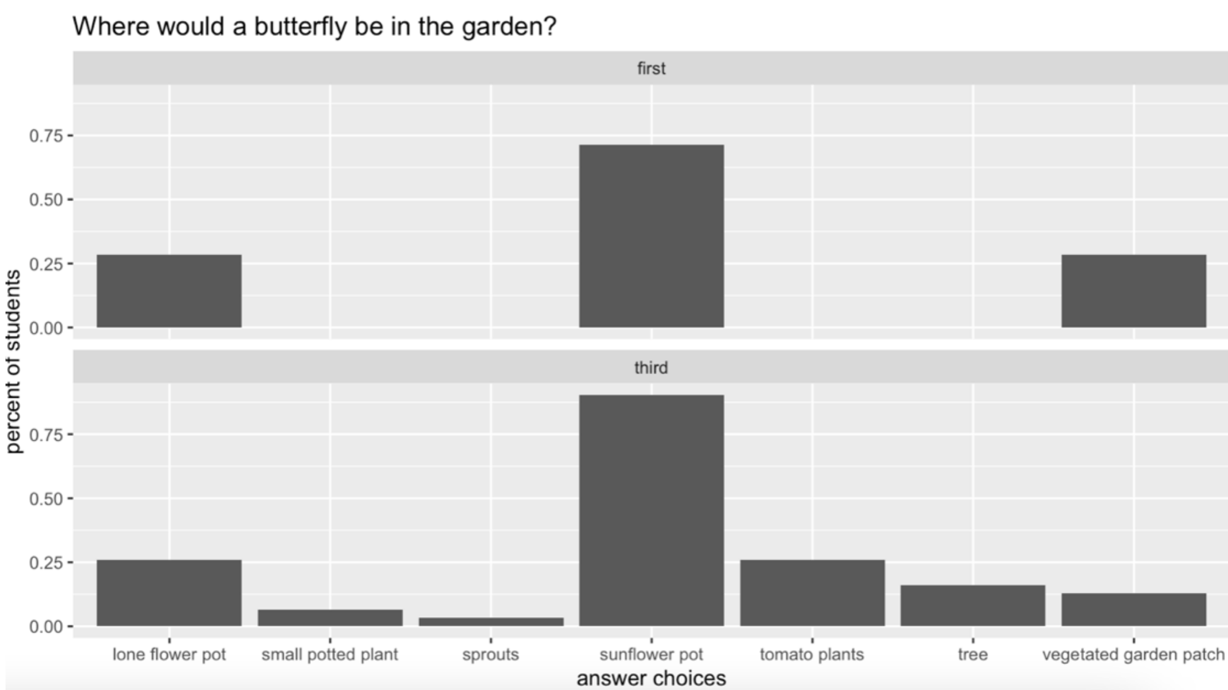
School B (n = 20)		
Categories	**Pictures per Category**	**Percent of Pictures**
Butterfly diversity	20	74.1%
Butterfly habitat	1	3.70%
Butterfly life stages	1	3.70%
Butterfly anatomy	4	14.8%
Biodiversity	0	0.00%
Catching butterflies	1	3.70%

Table 9. Examples of pictures and their categories.

School	Picture Example	Categories
School A		• butterfly habitat • butterfly life stages • biodiversity • butterfly diversity
School B		• butterfly anatomy • butterfly diversity

		• butterfly anatomy • butterfly diversity

Where would a butterfly be in the garden? (Week 4). Out of 38 students, rising first and third-graders combined, the majority (51%) drew butterflies on the sunflower pot from the given garden picture (Figure 22). The next two objects that had the most butterflies drawn were the lone flowerpot and the tomato plants. Rising third-graders had more diverse answers than first-graders for where they drew their butterflies in the garden picture (Fig. 22). For rising first-graders, there were only three plants chosen: the lone flowerpot, sunflower pot, and the vegetated garden patch. Sample sizes for rising first and third-graders were 7 and 31 respectively.



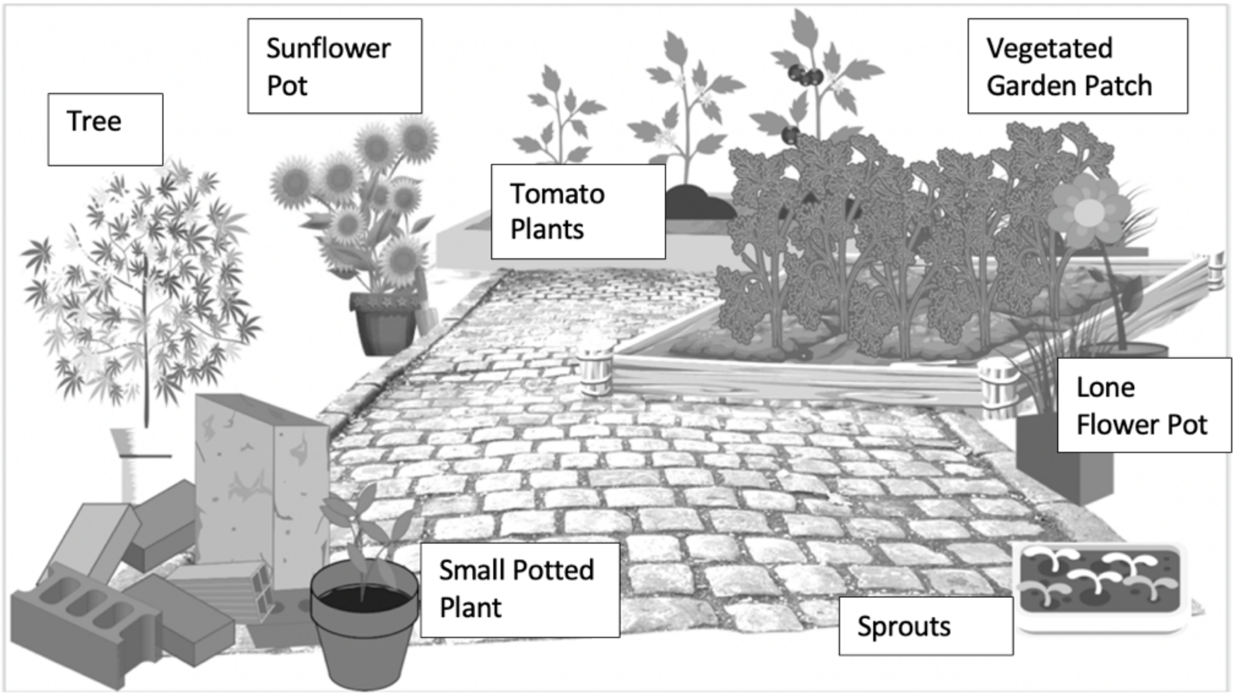


Figure 22. Student answers for where they might see a butterfly with the garden picture from their Butterfly Book. The sample size for first-graders was 7 students and 31 for third-graders. The garden picture from students' Butterfly Book below the chart shows references to how answer choices were labeled.

What flowers would butterflies like? (Week 4). There are certain colors of flowers, provided in students' butterfly books, that butterflies seem attracted to more than others, which are orange, red, and pink. When asked during Week 4 what colors would butterflies like, a picture of different plants in color was presented, and students drew butterflies or circles to which plant butterflies may be attracted more (Figure 23). The plant with red berries was counted as a 'green plant' in Figure 23 because it did not contain flowers. Orange (27.6% and 32.6%) and pink (24.1% and 24.4%) were the top two flower colors for rising first and third-graders respectively. Rising first-graders had their top three color choices as orange, pink, and red, where rising third-graders had orange, pink, and blue (Table 7).

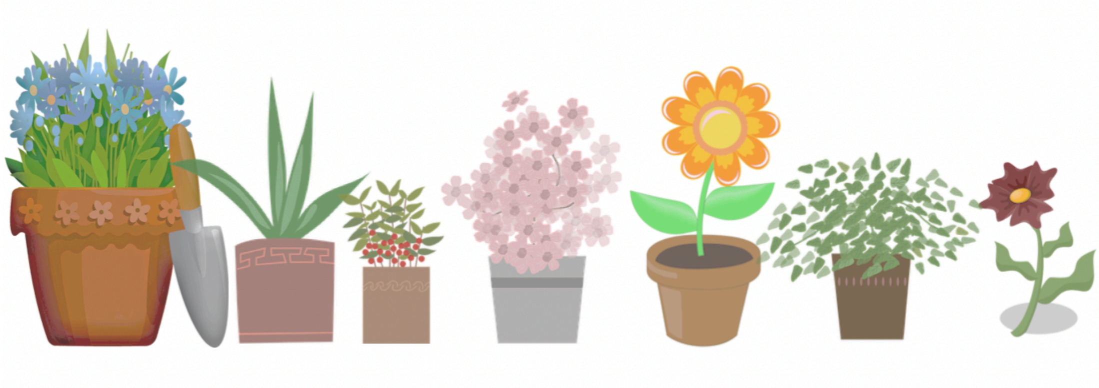


Figure 23. Flower picture provided in students' Butterfly Book. Students drew butterflies on the plants they thought would be most attractive to butterflies.

Answer Choices	Rising First-Grader Percent of Responses (n = 8)	Rising Third-Grader Percent of Responses (n = 34)
Red	24.1%	15.1%
Pink	24.1%	24.4%
Orange	27.6%	32.6%
Blue	17.2%	22.1%
Green plant	6.90%	5.81%

Table 7. Percent of students' answers per grade level for answering what color flowers butterflies would like the most (Fig. 23). Students could choose more than one plant.

In what order were the following steps done? (Week 5). On the last day of the program, students were asked to order the following steps: catch butterfly, hold butterfly, release butterflies, and write information. The correct order was to catch the butterfly first, then write information on the butterfly, hold the butterfly to mark it, and then release the butterfly. Since this was not able to be actively applied because of the absence of butterflies, students had to use information learned from daily lessons to know what order would be best for collecting butterfly data. Most students had 'catch butterfly' as their first step (94%) and releasing butterflies as their last step (81%; Fig. 24). However, there was a lot of variation in where 'hold butterfly' and 'write information' was ordered (Fig. 24)

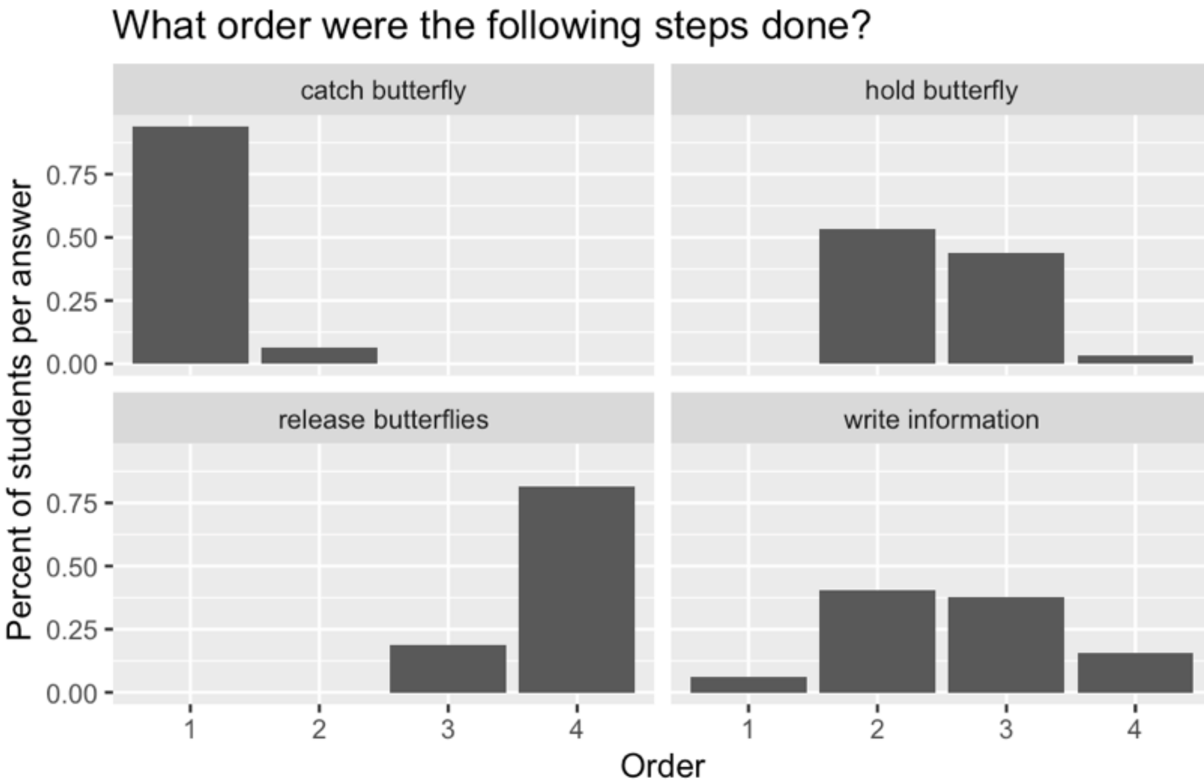


Figure 24. Student answer choices for the order that steps were done when collecting data on butterflies (n = 32).

Discussion

The goal of this chapter was to determine if students have more of an awareness of urban nature after participating in data collection in their school gardens. In the summer of 2022, I collaborated with FRESHFARM FoodPrints to conduct a pilot program involving students in urban butterfly research. Evaluations of student engagement were completed using the following tools: the Sticker Board, Movement Questions, Debriefing Questions, and Butterfly Book. Materials and the type of data collected need to be improved to increase student engagement with their observations in their school gardens. Movement questions prompted students to have more discussions about their answer choices and perspectives about nature in the city. The

Sticker Board provided valuable feedback about what students enjoyed the most in the program and what would need to be changed to adapt to students' activity levels. Debriefing Questions gained student insights about garden observations and what their interests were regarding urban ecology, research, and wildlife. The Butterfly Book provided data pre and post-tests, showing that most students anticipated seeing many more butterflies than actually appeared in the garden. Student hypotheses about how many butterflies they thought they would see prompted questions from them about butterfly habitat, behaviors, and life cycles. The results from this pilot program shows the potential for this program to engage elementary students in current environmental issues and collect data on the impacts of school gardens on Lepidoptera and other insect pollinators.

Materials

The Butterfly Book was the least enjoyed activity with students (Fig. 1) possibly due to its worksheet-like nature. Workbooks can be updated to be more involved with what students are actually observing in the garden even if target species (butterflies) are not present. This could include daily data collection not depending on butterfly appearance and areas for students to record daily observations in their garden (Bascom & Miller, 2021). The Butterfly Book, specifically can be improved to be a guide for students in identifying insect species, show the progress of data collected, and be a source of inspiration to learn. To collect data from students to assess the program, questions within the Butterfly Book needed to be more clear for students to fully understand what is being asked. With more clear instructions and pointed questions, student answers would be more consistent across schools and help researchers understand the intentions of student responses.

Data Collection

The type of data collected may also need to accommodate different student energy levels, both physically and mentally. Students, especially third-graders, vocalized that they didn't like "waiting a long time for the butterfly" and were "bored waiting for butterflies" because they "like doing stuff." The summer heat was also challenging with many students struggling to enjoy the activity because it was "hot" "being out in the sun." Collecting data and observations from nature takes time and energy, so students' morale and motivation need to be maintained through engaging activities. Adjusting the student data collection to be more about discoveries may help restore this in addition to explanations of how their work and opinions are valued (Avraamidou & Zembal, 2005).

Data Quality

The quality of the data collected on student engagement appeared to be influenced by many factors, most of which were uncontrollable. I believe that the quality of data increased when students were asking more questions about how to complete the assignment in their Butterfly Book, explaining their answers during the Movement Game, and discovering novelties about interactions in their urban school garden.

Factors that decreased data quality were uncomfortable environments (hot temperatures; wasp/bee fears), distractions (talking to people walking by the school; not using material properly), and the absence of butterflies. Responses during debriefings had repeated answers from previous visits ("it's hot") or had a lack of explanation for their answers. The main factor for decreasing data quality might have been the lack of student data recording of third-graders in their school garden. Student engagement may have been higher in third-graders, leading to better data quality, if they started with a daily data collection in the Butterfly Book, instead of only recording data when there was a butterfly. Having them collect data on their garden for other insect species may result in a better experience for them as citizen scientists.

Movement Questions

Asking students if cities were a good place for butterflies invoked a couple of follow-up responses from students for why they said yes, no, or maybe. They argued that "cities are definitely bad," there is "lots of noise," and "smoke, gas, cars – some people have loud sounds from their car like 'DON DON'" at night which the student explained that they had to "close [their] ears with [their] pillows." The topic of noise was also brought up as a reason in the rising first-grade class for why butterflies would not like the city. These follow-up conversations brought up the topics of pollution and air quality, which students recognize affect wildlife, even insects. They also included the concern of ambient noise that can affect other organisms, including their quality of rest and the discomfort butterflies may feel. School B students that answered 'maybe' had similar answers to those that said 'no', though their responses included what butterflies might need for cities to be better habitats. For example, students said cities might not be a good place for butterflies because of cars, people, buildings, and air pollution, though they also identified how they need gardens and plants, and how "gardens are not in the wild, they're in cities." The "countryside has much more plants than the city" and people might not know if a bug they find is good or bad, meaning that students identified that cities appeared to be risky and more dangerous for butterflies because of potential interactions and the existence of habitat.

I also found it interesting to hear one of the rising third-graders differentiate how gardens are man-made things, not found in nature, which ties into how gardens are being defined. This could link to identifying how gardens might not be supporting butterflies and other insects within the students' gardens and potentially lead to actions towards making their garden more 'habitat-inclusive' for butterflies. School-wise, this would fit into lessons on ecosystem functions, native versus non-native species, and keystone species during classes, and activities reinforcing these topics in their garden (Tatarchuk & Eick, 2011; Eick, 2012).

Overall, the Movement Questions seemed to invoke more organic conversations amongst students and more insights from students when asked to explain their answer compared to the rest of the activities in this program. This may help students learn and connect concepts better than sedentary activities inside the classroom may not achieve (Beemer et al., 2019; Borsos, 2019). Having students be active, outside, and engaged through game-like assessments may be able to enhance participation and critical thinking about how observations in their school garden connect to urban ecology (Manner, 1995; Ravensbergen, 2012).

Sticker Board

Writing information or using the butterfly book was the least enjoyed activity for the students as described above. However, most students enjoyed the puzzles at the back of the book relating to butterfly terms and symmetry. These are fun games for students, though the book has the potential to become more engaging with the students by acting more as a research guide to help students interpret trends in the abundance of insects and patterns they observe in their garden. Gamifying assessment activities and lessons about urban ecology can appeal to students and help the program experience become more engaging (Zainuddin et al., 2020).

The part of the project involving catching butterflies may have been challenging for students to answer. Not all students were able to catch butterflies, but they all were able to practice using their 3D-printed butterfly models and catching bubbles (an activity conducted to help students learn to be gentle with their nets). Students may have been unsure if they liked that portion of the program based on their specific experiences with the activities. The program should focus on multiple taxa for students to engage with more organisms in the garden, enabling students to better share their experiences about capturing insects and their observations about organismal interactions.

The differences in group responses at (School B) did not occur at the other schools in the program. This may have been because students in the second group were working on their Butterfly Books during this activity and I had to resort to students raising their hands instead of placing stickers on the board due to time restraints.

Debriefing Questions

Some challenges with this activity included decreased engagement if students were uncomfortable from the heat, and having students explain their answers. Not all students gave further reasonings for their answers unless they were trying to argue their point with another student and there was enough time to probe students for explanations. Most students gave single-word responses to questions compared to other activities such as the Movement Questions that sparked discussions among students. In the future, students should be asked to be further explained to understand the reasoning for their answers. The debriefing question about handling butterflies should also be removed and replaced with questions about the research methods being used. These questions should focus on how the students are acting as researchers and how the methods being used help to answer questions about their school gardens.

There may also need to be an incentive to increase student motivation to participate in discussions. For example, using stickers as an incentive for participation and repeating to students each session how their opinions are valuable and essential to the researchers may help to increase participation.

Butterfly Book prompts will also need to be adjusted to match the abilities of each grade level and the space in which the project is taking place. Types of data collection will also need to match students' physical and mental stimulation (Byra & Jenkins, 2000). For example, rising third-graders were limited by space and taxa of interest since they were unable to go elsewhere around their school to look for butterflies, and the only species they recorded data for were butterflies. The program can adapt to students' interests by increasing the range of taxa they would look for in their school garden, or having students collect data around their homes and neighborhoods.

Daily Butterfly Book Activities

Pre and Post Tests (Weeks 2 & 5). When asking students the number of butterflies they think they will see in their garden, some students wrote more than one number. To better understand the reasoning behind multiple responses, the question should explicitly inform students to write only one number, and then the researcher should ask students why they chose that answer. On the post-tests, some students that said more than the average number of butterflies seen (3) may have been counting butterflies seen during the rest of the week since research visits were only once per week during the student's summer school program.

For the second pre-test, students chose more than one answer, which should be refined in the future for students to choose explicitly one option to decrease confusion about how to hold butterflies for certain methods like marking. However, during the program I was able to mark caught butterflies through my net, removing the need to handle butterflies when there are not multiple butterflies caught at once. This improvement along with students' not experiencing holding butterflies most likely influenced their answers.

The pre-test's second highest answer (edge of forewing) was most likely due to students completing this pre-test after leaders demonstrated where to hold butterflies with their 3D butterfly models. The body/legs of the butterfly had the highest number of selections from students for both the pre and post-test (43% and 66% respectively), most likely due to students explaining that they would hold the butterfly with open hands, having the butterfly walk along them. Without the experience of getting to hold butterflies for the marking process, students relied on their own opinions to answer how they would handle butterflies.

Where do you want to see more trees/butterflies? (Weeks 2 & 3). Rising first-graders had neighborhoods as one of their top choices for wanting more trees, which was not seen in answers from third-graders. This may be related to the income levels surrounding each school. Rising first-graders at School C are located within Ward 8, which has the highest rates of poverty in DC at 30.2% of people below the poverty line (Sustainable DC 2.0 Plan, https://sustainable.dc.gov/node/1447351; U.S. Census Bureau, 2021a). School A and School B held the rising third-graders, which are in Wards 1 and 6 respectively, each with 11.3% and 11.9% of people below the poverty line (U.S. Census Bureau, 2021b; U.S. Census Bureau, 2021c). Urban locations that are historically low socioeconomic areas were often subject to redlining, resulting in reduced tree canopy coverage in those areas (Locke et al., 2021). Ward 8 has lower canopy coverage compared to these other wards (Sustainable DC 2.0 Plan), which may be one reason students had more selections for more trees in their neighborhoods. Rising first-graders may be more aware of the lack of trees around their homes due to living near School C in Ward 8 and may have more interest in increasing their appearances. Educational projects such as this one can lead to systemic solutions by creating community awareness and support for change.

Draw a butterfly in the garden (Week 4). Collecting data from the butterfly pictures of rising third-graders was subjective and difficult to quantify. To improve the Butterfly Book, a survey should go out to the students of the program ideally, but the teachers may also be able to give insight into what parts of the Book were the most enjoyable for students. Many drawings gave high levels of detail for butterfly designs meaning that most students willingly put more effort into this activity. This may indicate that most students did enjoy this section (Cronin-Jones, 2005; Wilson et al., 1987). The Butterfly Book should be utilized for data collection from students, but also as a fun field guide for young ecologists. The program may be more engaging for students if there were more activities such as drawing novel things they saw in their school garden or developing games for detecting different species and organisms in their garden (Drew et al., 2017).

Where would a butterfly be in the garden? (Week 4). Rising first-graders only select the lone flowerpot, sunflower pot, and vegetated garden patch for where a butterfly would be in the garden. This may be because of the clearer pictures of the flowers on the sunflower plant and lone flowerpot since the flowers on the tomato plants were not as easy to see. Students at School C may have also chosen the vegetated garden patch because it was similar to their own garden and where they would go to look for butterflies. Rising third-graders had a larger range of choices compared to the rising first-graders. The diversity of locations chosen by rising third-graders may be from the understanding that flowers can attract butterflies as a food source, but they are not the only location where butterflies may be seen. To understand student choices, group interviews with students after they've completed this activity would be useful but limited to available time (Chung & Huang, 2010).

The lone flowerpot and the tomato plants were the second most chosen plants that all students drew butterflies on. This could be due to the knowledge that butterflies are often found on flowers to drink nectar. Some students even included butterfly anatomy such as their proboscis to drink the nectar from the flower. This exploratory question identifies that butterflies are seen as nectar drinkers and have a relationship with flowers. However, this is one source of food that butterflies may seek out. Other butterflies have a behavior called “puddling” where groups of male butterflies will gather on mud puddles, feces, or rotting meat to collect water, sodium, and other nutrients (Arms et al., 1974). This information was not part of the pilot program, however, it identifies some knowledge gaps about butterfly habitats and what will attract butterflies. In the future, this question should include topics about butterfly diets and habitats that attract them so students understand how and where to observe them outside of the program.

What flowers would butterflies like? (Week 4). The purpose of providing diverse pictures of plants for this activity was to mimic their school gardens and parks where there are many different species and amounts of plants. School B and School C had very similar results and correctly selected orange, pink, and red as the top three flower colors that butterflies would be most attracted to. School A had the blue flowers as their top choice. This may be due to the fact that the students were also taught that more flowers are good for butterflies, and the density of blue flowers was greater (Table 7).

Plants that did not have flowers, called green plants, were low for all classes, which identifies the common knowledge that butterflies will be attracted to plants with flowers than without them. However, the specific color of flowers that attract butterflies the most may not be known to students unless included within the daily lesson while looking for butterflies. Answer results would be more similar if this was an explicit part of the program for researchers or teachers to include while in the gardens. In the future, butterfly habitat in relation to life cycles should also be included for students to grasp the concept of habitat diversity that is needed to promote observations of butterflies and their conservation.

In what order were the following steps done? (Week 5). Even without students recording data, most students had the first and last steps as catching and releasing the butterfly. This is logical since writing down information and holding the butterfly can be interchangeable for steps two or three (Fig. 24). This question would have provided more discussions or comments from students if they were able to conduct the mark-recapture protocol each day of the program in their school garden. In the future, applying the mark-recapture protocol may not be feasible without teacher training. A different protocol should be used for leaders to easily implement, such as walking transects or doing a Pollard walk (Baumgartner & Zabin, 2006) so that students would be actively collecting data regardless of the presence of the target organism.

Conclusion

This chapter described a pilot program that was applied in the summer of 2022 by collaborating with DCPS and FRESHFARM FoodPrints. The goal of this project was to answer the research question "do students have more awareness of urban nature through participating in collecting data on large-bodied butterflies in their school gardens?", and if the program could be continued each year for public schools collaborating with FRESHFARM FoodPrints. School gardens can be used to connect students to natural processes and increase positive attitudes and empathy toward nature (Fisher-Maltese & Zimmerman, 2015). Students enjoyed looking for butterflies and catching them, though the program needs several improvements to adapt to rising first and third-grade capabilities and interests. Student discussions were valuable to determine student interests and understanding of urban nature, thus future questions and assessments should allow for more agency in following up their answers with a discussion period. Procedures of collecting and viewing data, after being collected, need to be incorporated into lessons and assessments for students to experience conducting fieldwork and analyzing their data as a scientist or researcher would. These improvements will be applied in Chapter 3 of this thesis.

This project engaged students in topics in urban ecology but needs more research to understand the impacts school gardens have on urban biodiversity and what the human perspectives are on this topic (Kabisch et al., 2016; Schwarz et al., 2017). Projects like this pilot program have the potential to collect valuable data on urban biodiversity to be used for scientific research while involving the potential next generation of scientists. Projects – like this one – that engage the public, especially the next generation, can lead to greater advocacy for more biodiversity in cities and improved well-being for urban residents.

CHAPTER THREE: DC SCHOOL GARDEN URBAN BUTTERFLY AND INSECT POLLINATOR PROJECT MODULE

INTRODUCTION

This chapter focuses on improving the module and lesson objectives used in Chapter Two by applying program interventions and lessons learned from the 2022 pilot project. The Chapter Three format is inspired by FRESHFARM FoodPrints' Lesson Plan, The Garden Ecosystem, to act as a draft for future implementations of this program. This module will be applicable to lower and upper elementary students in FoodPrints' summer program and can be applied to their fall and spring lesson plans for life cycles, pollination, ecology, and ecosystems while collecting data for monitoring biodiversity in students' school gardens. These activities will help to monitor the effects of school garden habitats and biodiversity conservation within urban areas.

Theme: Urban Ecology – Insect Pollinators **Time:** 1 hour; program – 4 weeks	**Big Idea:** Green spaces like school gardens in urban areas can aid with pollinator biodiversity restoration and conservation.
Objective: By the end of the lesson, students will be able to identify areas of high and low biodiversity in their garden and how their garden helps support biodiversity in a city.	**Guiding Questions:** **WK1:** Do you think cities are a good place for butterflies or other pollinators? **WK2:** What is biodiversity? **WK3:** What plants have a lot of pollinators on them / butterflies visiting them? **WK4:** What areas of the garden don't have any insect pollinators or butterflies? Why do you think so?

LESSON SUMMARY

The purpose of this program is to give students an ecological background on urban ecology, green spaces for conservation, and the effects of biodiversity. This lesson will guide students in exploring their school gardens for butterfly or insect community biodiversity and look at how to record data to be used for scientific research. This module supports sections from Next Generation Science Standards 3-LS2-1, 3-LS4-3, 3-LS4-4, and ESS3.C *Human Impacts on Earth Systems* (NGSS, 2013).

Materials List	**Vocabulary**
Butterfly Book Stickers iNaturalist Seek © Plants (recommended): Gallon sized potted plants – Mexican sunflowers, milkweeds, and parsley	**urban**: a city or town **ecology**: the relationships between living things and their environment **habitat**: the natural home for a living thing **biodiversity**: the many different types of living things in a habitat or ecosystem **species:** different types of **pollination:** the process of how seeds, fruits, and vegetables are made/transferring pollen of a plant to the stigma which fertilizes the plant **pollinator:** the animal that transfers pollen and pollinates plants

ENGAGE

This section describes the lesson topics for each week of the program. The goal of each lesson is to introduce students to concepts in urban ecology and get them curious about how this applies to their school garden and in their neighborhoods.

Week 1: Studying nature in the city

- Start the lesson by telling students that they will act as researchers in this project to find butterflies and other insect pollinators that visit their garden.
- Start with asking if students if they know what **urban** and **ecology** are and then define urban ecology, the study of how wildlife interacts with its surroundings in a city.
- Ask students if they think cities are good places for pollinators to live. Explain that cities can make it difficult for wildlife to survive due to the removal of their **habitat,**

the natural homes of living things. Places like their school garden can provide homes for insect pollinators.

- Tell students they will explore their school garden today for butterflies and insect pollinators and record data in their Butterfly Books.

Week 2: Biodiversity and urban ecology

- Remind students that they are acting as researchers in this project to record data on butterflies and insect pollinators that visit their gardens.
- Ask students if they've heard of the term **biodiversity** and explain what it means. Then ask students if urban places, or cities, might have high or low biodiversity compared to a forest park to tie in the impact that areas of urbanization decreases biodiversity. Explain that one would expect there to be lower biodiversity because urbanization removes **habitat** and limits the wildlife able to live there.
- Explain how areas of higher **biodiversity** make healthy ecosystems and places to live. Different animals, not only insects, pollinate different plants to create the variety of foods that people eat. Some animals also help clean up leftovers, like what goes in the compost bin, and break it down for plants to eat. Without these living things, the planet would be a hard place to live in.
- Tell students they will explore their school garden again today for butterflies and insect pollinators and record that data in their Butterfly Books. Remind them at the end of the project, they will need to use this information to make conclusions about their school garden.

Week 3: Habitat homes in the city for insect pollinators

- Remind students that they are acting as researchers in this project to record data on butterflies and insect pollinators that visit their gardens.
- Ask a student to describe what a **habitat** is, and then remind them that the school garden provides many habitats to insect **pollinators** too. Ask students to provide examples of some habitats in the garden.
- Give examples of insect pollinators' habitats provided below and show a model or picture of the insect while describing their habitat.
    - Bumblebees & Solitary Bees
        - Live in the ground. They look for bare patches of dirt to make their homes.
        - Bumblebees are like honey bees but have small families that live together underground.
        - Solitary bees live by themselves and make a burrow in the ground where they put their young. They bring food for their young and seal it off to protect their young while they develop into a solitary bee.
    - Butterflies
        - Butterflies have two jobs – looking for a mate and a plant (called a "host plant") to lay their eggs that hatch into caterpillars. The host plant provides the caterpillars with food and shelter

- Most butterflies only live for about 2 weeks, and most of their life is spent as a caterpillar and pupae
- You are more likely to find their larval stages in the school garden.

  - Some caterpillars are picky eaters only like one type of host plant and others like a variety of food and can eat different types of plant leaves. Adults are the butterflies that also drink a variety of things like flower nectar, water in mud puddles, rotting meat.
  - Butterflies can be shy and fly fast. They are looking for specific things (a mate and host plants) so they might not be in the school garden unless these things are present.

- *(Fun Fact) Flies are important pollinators and are ranked second in pollinating the most percent of crops! Bees are in first place.

- Tell students they will explore their school garden again today for butterflies and insect pollinators and record that data in their Butterfly Books. Remind them at the end of the project, they will need to use this information to make conclusions about their school garden.

Week 4: Analyzing urban garden data

- Remind students that they are acting as researchers in this project to record data on butterflies and insect pollinators that visit their gardens. This is the last day they'll collect data.
- Tell students when they come back inside, they will make conclusions about what they found using the data they collected.
- Remind students about the big idea, that green spaces like school gardens in **urban** areas can aid with **pollinator biodiversity** restoration and conservation. Tell them to think about how their school garden is helping increase insect pollinator biodiversity while they are collecting their data
- Tell students they will explore their school garden again today for butterflies and insect pollinators and record that data in their Butterfly Books.

EXPLORE

This section of the lesson will bring students and leaders into the school garden. Leaders will help students find insects and within the students' garden sections and record data. Leaders will also encourage curiosity about the insects and interactions in their garden space. Please choose from the following activities that would best fit with your students, class time, and learning goals. This activity will be repeated each week to have enough data to analyze at the end of the program. **Week 4 will have an additional activity to visualize the data collected and discuss these results with students.**

Exploring Insect Communities (older students)
(10-20 minutes depending on the amount of garden sections and amount of insects present)

This activity will challenge students to identify different types of insect pollinators that live in their school garden and record data in their Butterfly Book. Start the activity with students writing the date and temperature on their data sheets in the Book. Students will have assigned sections of the garden they will observe for 2-3 minutes and rotate to the next one. At each section of the garden, they will record the type of plant and butterfly/insect pollinators on their plant. Leaders may use identification tools such as iNaturalist and Seek on their phones. Seek will provide faster results.

Exploring Butterfly Habitat (younger students)
(5-10 minutes outside depending on butterfly activity and temperature)

Students will use the flower color guide in the Butterfly Book to find locations in their garden that might be attractive for butterflies. Also remind students that caterpillars are the life stage before butterflies and like to eat plant leaves. Tell students to also look at plant leaves for any pieces missing which might lead to caterpillars. The presence of caterpillars means a butterfly had visited their garden at some point. Teachers will need to record any presence of butterflies on the datasheet in the Butterfly Book to review at the end of the program with students. Teachers can engage students by asking for details about the butterfly they're seeing, such as the color, size, and what plant it landed on and record this information.

WEEK 4 ONLY:
Analyzing Data (all students)
(10-30 minutes)

After coming inside from the school garden, teachers will use the white board/chalk board/projector to display results to students.

Exploring Insect Communities

- First, teachers can ask for each students' data and organize information by plant and insect type. The number of insect species can be averaged since students should have very similar numbers after rotating in the garden.
- Next, teachers will guide students to analyze the data by looking first at all insects combined in the garden and then by plant. Help students answer, "What type of insect was seen the most in our garden?", "What plant had the most insects?", and "What plant had the most types of insects?"
- Then look at unusual things in the data, such as "what plants had the fewest insect pollinators / no insects?," and "Are there any plants that only had one type of insect pollinator?" (maybe some plants rely on nocturnal pollinators or pollination by abiotic factors like wind; native plants might also have more insects attracted to it)
- Ask students to think about why these might be the results they found and what this means for their garden. (look at Discussion Questions in the EVALUATE AND CLOSE section)

Exploring Butterfly Habitat

- While students are having a snack or settling from coming back inside, teachers will summarize the collected data on their datasheet in the Butterfly Book. The summaries can be displayed on a white board and shown to students AFTER the next step. Results should be displayed in a creative way that is easy for younger students to understand (ex: draw the number of butterflies seen on each flower color using the color of that flower – orange, pink, red,…)
- Teachers will ask students their guesses for the results by calling on raised hands (such as numbers of butterflies seen, if they thought most butterflies they saw were large or small,…)
- Show students the results for each set of data collected and explain how to read the results.
- Ask students what these results might mean for their garden. (look at Discussion Questions in the EVALUATE AND CLOSE section)

EVALUATE AND CLOSE

This time will be used for student discussions to reflect on their activity relating to urban ecology and their role as a researcher in their school garden. These discussions should be recorded to evaluate the program's effectiveness.

Week 1
Discussion Questions:
What bugs did you see in the garden today?
What was your favorite one?
What was your favorite part about today?

Week 2
Discussion Questions:
What areas have the highest biodiversity?
What would you do to increase biodiversity in your school garden?
What was your favorite part about today?

Week 3
Discussion Questions:
What types of habitats did you see in your school garden today for insect pollinators?
Are there any host plants or areas that would be attractive for butterflies in your garden?
What was your favorite part about today?

Week 4
This section will take longer than the previous weeks for students/teachers to create their bar graphs of the total data they collected. This will be used to answer the discussion questions.

Visualizing Data Questions and Discussion Questions:

Exploring Insect Communities
Which plants had the most amount of insects (total abundances)?
Which plants had the most types of insects (different species)?
What plants are attracting the most biodiversity? (most number of different species)

What bugs do you want to see more of in your garden? What could be added to the garden to do this?
What insect was found the most on your vegetable plants? And on flowers?
Why do you think you had (result)? Is the result what you thought you would get?

What was the most interesting thing you found from the data you collected?
What was your favorite part about today?

Exploring Butterfly Habitat
Did the garden support a lot of butterflies?
Were there some plants that were really good at attracting butterflies compared to other plants?
Was the garden good at supporting lots of caterpillars?

Why do you think you had (result)? Is the result what you thought you would get?

What was the most interesting thing you found from the data you collected?
What was your favorite part about today?

APPENDIX

Appendix A

2022 Summer DC School Garden Butterfly Project Information Sheet

Program Description:
This research project is being conducted by George Mason University master's graduate student, Katherine Pontarelli, by working with FRESHFARM FoodPrints during the summer to involve students in the research process of studying urban wildlife. Students participating will be able to learn how to collect data on butterflies in their garden, identify butterfly species, and provide feedback on their experience and views on urban ecology.

Program Overview:
The goal of this graduate research project is to 1) describe the urban ecology of butterflies in school gardens within schools participating with FoodPrints Summer 2022, and 2) to study the impact of engaging elementary-aged students in the data collection process on student awareness and value toward urban ecology.

The majority of the project will be time for students to capture and identify butterflies, with research and FoodPrints staff aiding in marking butterflies to indicate if the butterfly has already been caught. Students will also be trained on how to hold butterflies gently in a way that does not harm the butterfly for purposes of being able to mark them and cause unnecessary stress to the butterfly, though this participation in the project is optional for the students. All students will receive a 3D printed butterfly model to practice holding techniques whether or not they will be holding live butterflies. Students will be able to keep these models.

Outcomes:
At the end of the program, students will be able to do simple analyses of the data they collected and discuss their experience in the project. Students will have gained awareness of wildlife within urban locations and how these urban areas are still habitats for some animals.

Engagement will be demonstrated by:

- Correct butterfly handling technique
- Butterfly identification
- Evidence of curiosity and involvement within urban ecology research

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