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Brigid M. Morgan
University of Dayton

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UNIVERSITY HONORS PROGRAM
UNIVERSITY of DAYTON

Honors Thesis
Brigid Maeve Morgan
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Advisor: Chelse Prather, Ph.D.
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Abstract

Around the world, pollinator populations are decreasing due to climate change, habitat loss and fragmentation, invasive species, pesticide use, and disease. A solar prairie can provide that habitat space with native plants to attract and promote the growth of native pollinator populations. In this study at the University of Dayton in Dayton, Ohio, I sought to find out if native pollinators were using the habitats inside and around the solar panels at Curran Place. By using pan traps weekly throughout the summer months to collect the insects, I found that native pollinators are using the habitats between the rows of solar panels and the area outside of the panels with more flowering plants. No invasive honey bees were observed in the prairie. Members of sweat bee families were driving changes between the inside and outside habitats, but larger pollinators like bumble bees and carpenter bees were not. Maintenance, specifically mowing, of prairies is a standard method to keep them healthy and control any invasive species in the area. During week 2 of this research, the area in between the rows of the panels was mowed and led to a significant increase in pollinators in the inside habitat. There was no significant difference between weeks in the outside habitat. The solar prairie is providing a habitat for native pollinators and a renewable energy source for the University of Dayton. Additionally, it is combating some of the major causes of pollinator declines - climate change, habitat loss, and invasive species. The previously manicured lawn of Curran Place is now a biodiverse solar prairie to help increase the populations of native pollinators and solar energy use in the area to lead to a more sustainable future.

Acknowledgements

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University *of* Dayton

Table of Contents

Introduction

Throughout the world, wild and domesticated pollinator populations have been declining for decades (Potts et al. 2010). Pollinators are a vital group of animals that provide pollination to wild plants and crops allowing the plants to reproduce. Insects like bees, ants, wasps, butterflies, and moths as well as some vertebrates are common pollinators around the world (Buchmann and Nabhan 1997). However, habitat fragmentation and loss, invasive species, the spread of diseases, climate change, and pesticide use are all playing roles in the decline of pollinators globally (Potts et al. 2010, Shrestha et al. 2019). Invasive and nonnative species have been a particularly impactful cause of pollinator declines in North America, especially European honey bees, *Apis mellifera*. These invasive honey bees have been purposely brought outside of their native habitats in Europe and the Middle East to efficiently pollinate crops. In these areas, they have often taken over the native pollination systems and put those native pollinators in danger (Kato and Kawakita 2004). In the United States, honey bees are an invasive species competing with native pollinators, like bumble bees and carpenter bees, for food but provide "an estimated US$14.8 billion annually" in pollination services to agriculture alone (Pejchar and Mooney 2009). The European honey bees may be more efficient at pollination than native species, such as bumble bees, but they are one of the causes of other pollinator population declines around the world. One way to work on the solution for this problem is to promote the health and populations of native pollinators. Additionally, climate change is a major cause in the declines of pollinators, so implementing renewable energy resources could help to increase their populations. Therefore, restored prairies installed in the unused land underneath solar arrays may be a good solution for creating a habitat to slow pollinator declines, along with the benefits gained from decreasing carbon dioxide inputs to the atmosphere.

Installing solar panels and using a renewable energy source means a decrease in the usage of fossil fuels. They also help reduce acid rain, eutrophication, and emissions that come from burning fossil fuels (Turney and Fthenakis 2011). As such, solar panels may provide an effective way of improving the health of the environment and slowing climate change. Using the space outside of and underneath solar arrays to restore native habitat could help increase the population of native pollinators (Morales et al. 2017). Also, solar arrays can be placed in a variety of habitats, such as previously manicured lawns. Abandoned areas like golf courses would be a good place for a solar array to be implemented since the land was not being used and is likely in full sun. If the soil underneath the grass is healthy enough to support more wildlife, then a native prairie can be seeded underneath the array and a solar prairie can provide a new habitat for native pollinators. Landscapes that have native plants or are not mowed for aesthetic purposes are shown to have a higher pollinator abundance than those that are manicured. (Del Toro and Ribbons 2020, Burr et al. 2018). Not only can solar prairies provide a habitat for pollinators and increase the usage of renewable energy, but prairies do not have to be frequently mowed, limiting the land management in the area. There has been little research done on how the solar arrays are impacting wildlife, including pollinators, because wide-scale use is rather new. If done correctly, the use of solar prairies could significantly increase native pollinator population abundance (Dolezal et al 2021).

With this project, I will determine what pollinators have colonized this prairie, and how the solar panels themselves are affecting pollinator populations at Curran Place. I will answer the following three questions and test the following hypotheses:

Question 1: What is the composition of pollinators that are using this prairie?
Hypothesis 1: I predict that honey bees will be at a higher relative abundance in the pollinator population than native pollinators due to being invasive species and outcompeting the native pollinators. Honey bees are an invasive species to Ohio, and this may create competition with the native pollinators (Morales et al. 2017), leaving native species at a lower abundance than honey bees.

Question 2: How are the solar panels affecting pollinators? Is the composition and behavior of pollinators different inside and outside of the solar panels?
Hypothesis 2: I predict that the habitats inside and outside of the prairie will be different, but both will still provide habitats for the pollinators. I predict this because shaded environments were found to have less visitations by pollinators than the same plant in a sunny area (Cao et al. 2017). In previous research at this location about the effects of the panels on Odonates laying eggs, it was found that the panels did not have any effects on damselfly and dragonfly behavior, but that Odonates were not found using the prairie under the solar panels (Ott and Prather, unpublished). Originally, these panels were suspected to confuse the Odonates because the light reflected off the horizontal panels looked like the reflection of water. Because the pollinators are not species that lay their eggs in water, I think they will be able to use the solar prairie as a native habitat.

Question 3: How does the pollinator community change over the course of the summer?
Hypothesis 3: I think that as plants begin to bloom and grow in June and mid-summer, there will be more bumble bees and large pollinators that are attracted to the flowering plants. I predict this because the plants in the solar prairie are designed to attract native pollinators as they grow throughout the summer.

Here we test the hypotheses with pan trapping to determine how the community of pollinators are being affected by the solar panels.

Methods

Site Description

This research took place at Curran Place at the University of Dayton in Dayton, Ohio, United States of America. In regard to the maintenance of this solar prairie, all maintenance is done by the Facilities Management Office of Sustainability.

In 2018, the University of Dayton in Dayton, Ohio installed a solar array at Curran Place and a pollinator prairie was planned under the solar panels in the spring of 2019. Before it was a solar prairie, it was a large, manicured lawn in front of the building but is now one of the first solar prairies in the state of Ohio. Not only does this show UD's commitment to reduce its carbon footprint and their value of education in natural areas, but it also allows for native pollinators and wildlife to come to the prairie. Several kinds of pollinators, grasshoppers, birds, and other wildlife species were spotted in the solar prairie just a year after it was implemented (Gokavi 2019). As the solar prairie continues to grow and age, it will become more complex and become a healthier habitat for native pollinators and wildlife. This is something that the previously manicured lawn in front of the building would not have been able to provide to the ecosystem.

No research of pollinators has been done in our prairie, but there has been research on the Odonates (dragonflies and damselflies). Bioblitzes can record citizen science data using Seek and iNaturalist from the prairie, and one of these occurred in the fall of 2021. As renewable energy becomes more popular, people and businesses looking to use renewable energy will look at the benefits and consequences of each type. One of the downfalls of solar energy is that it takes up a lot of space. But for places like UD where the lawn was previously just a manicured lawn with no purpose, solar panels fit in well. To further maximize the use of the space, a prairie underneath to support native pollinators is a great step in the right direction.

Experimental Design

This experiment uses pan trapping to capture insects in the solar prairie. I painted plastic jars to be blue, yellow, and white with UV and acrylic paint. This is standard practice for using pan traps to attract pollinators of all kinds from different habitats (Saunders and Luck 2012, Shreshtha et al. 2019). I had 8 sites: 4 underneath solar panels and 4 in the prairie along the outside of the solar panels. At each site, there were 3 jars (blue, yellow, and white) for a total of 24 jars. Sites were chosen that had similar topography and vegetation with each other. There needed to be flat land so they would not tip over as often and could be found again after a few days outside. The sites also needed to be away from woody plants and thistle because Facilities Management began spraying herbicide to control the invasive thistle. (Leah Ceperley, personal communication). Each pan trap was filled with water and a few drops of colorless, unscented soap to attract the insects and then trap them inside. They spent two to three days in the prairie and then were picked up, sealed with their lid, and taken back to the lab. They were stored in the fridge to keep them fresh until I sorted them to order.

Sorting

The first step in the sorting and identification process was sorting the insects to order. There were twelve orders that I identified: Hymenoptera (bees, wasps, ants), Hemiptera (true bugs), Diptera (flies), Collembola (springtails), Thysanoptera (thrips), Lepidoptera (butterflies, moths), Coleoptera (beetles), Araneae (spiders), Neuroptera (lacewings), Orthoptera (grasshoppers, katydids, crickets), Acari (mites, ticks), and Unknown (individuals that could not be identified). The insects were sorted to order and recorded in my notebook and spreadsheets after each jar was sorted. I took pictures of many of the individuals from the orders so I could have references when sorting them. I then organized the vials in boxes in the lab for storage.

After sorting the insects to order, I sorted the Hymenoptera and Lepidoptera into morphospecies. I chose to sort these two orders further because they are the main insect pollinators that are known to be in the prairie. Morphospecies is an identification of individuals based on looks and appearance instead of genetic phylogeny. This practice occurs due to the difficulty of identifying insects to species within the timeframe I was working. The Hymenoptera and Lepidoptera were sorted in a similar way to the previous insects, but I recorded detailed descriptions of each individual morphospecies and took pictures of all of them. There were a few guides I used to help sort them: Common Bees of Eastern North America by Olivia Messinger Carril and Joseph S. Wilson, Field Guide to Insects of North America by Eric R. Eaton and Kenn Kaufman, Bugguide.com, and Seek by iNaturalist.

Data Analysis

The final step in this experiment was to perform data analysis. We did multivariate general linear models - one model for the order data and different models for morphospecies for each major family. These groups include the ants, bees, and wasps. Dependent variables were each group’s abundance and independent variables were time and habitat type. Morphospecies were only included in analyses if they were found in over five total sites. We then did a principal component analysis to see if orders and then morphospecies clustered over time or by habitat type. I also did a rank abundance curve for the ants, bees, and wasps since these were the groups that I sorted to morphospecies.

Results

Looking at all the orders together, Collembola were always the most abundant in the pan traps with 1,646 individuals across all of the weeks and an average abundance of 3.15 +/- 1.71 individuals/jar/day inside and 8.25 +/- 3.83 individuals/jar/day outside of the panels (Figure 1). However, these were bycatch from the pan traps since they are not major pollinators in the solar prairie. Hymenoptera and Lepidoptera are the major pollinators that I expected to find, but there were only 7 Lepidoptera caught during weeks four and five. Because of this, there is not enough data to do proper data analysis with this order of pollinators. With Hymenoptera, there were 572 individuals caught overall with an average abundance of 2.19 +/- 1.44 individuals/jar/day inside and 2.09 +/- 0.80 individuals/jar/day outside of the panels (Figure 1). The Hymenoptera outside of the solar panels were not more abundant than the Hymenoptera community inside of the solar panels overall. However, when breaking down the average abundance of Hymenoptera by week (Figure 2), the inside population was only significantly more abundant than the outside population during week two (Table 1). During week two of this research, mowing maintenance occurred in between the rows of solar panels to keep the tall grasses from getting caught in the panels and may have disrupted the pollinator community. The results from week two from the inside sites were significantly different ($p<0.001$) from each other (Figure 3). For the outside sites, there was no significant difference between weeks ($p=0.75$, Figure 3).

When considering the morphospecies of this solar prairie, the Hymenoptera were broken down into groups of ants, bees, and wasps. The ant family (Formicidae) had 216 individuals and 17 morphospecies. The Honey Colored Ants (likely the High Noon Ants) were the most abundant morphospecies with an inside abundance percentage of 35.25% and an outside abundance percentage of 29.23% (Figure 4). This morphospecies also had a significant difference in abundance when the inside and outside sites were compared ($p=0.012$). The wasp group contained many different families, including paper wasps and parasitic wasps, and had 167 individuals with 39 morphospecies. The White Leg Wasps (unable to be identified to species) were the most abundant morphospecies with an inside abundance percentage of 51.33% and an outside abundance percentage of 25.50% (Figure 5). This morphospecies differed significantly by date ($p<0.001$) with an increase in abundance during week two and was statistically significant when comparing date and site ($p=0.02$) with a higher abundance in the inside sites.

Although wasps and ants can be pollinators, the major pollinators in our solar prairie are bees. The bee group contained many different families, mostly Halictidae and Apidae, and had 189 individuals and 12 morphospecies. The Striped Sweat Bee (genus *Agapostemon*) was the most abundant morphospecies with an inside abundance percentage of 84.25% and an outside abundance percentage of 54.91% (Figure 6). This morphospecies differed significantly by date ($p<0.001$) with a sharp increase in abundance during week two of the research. In a PCA plot, communities inside the solar panels and outside the solar panels formed two different clusters, showing that there were differences in overall community composition (Figure 7). Some morphospecies were driving the changes between the two communities, mainly caused by differences in the Dotted Sweat Bees, Pure Green Sweat Bees, Plain Sweat Bees, and Dark Green Bees. All the morphospecies that were causing changes in the community composition were members of the sweat bee family and none were bumble bees, carpenter bees, or honey bees. In fact, no honey bees were observed or captured in this solar prairie during the experiment. There were 46 morphospecies of ants, bees, and wasps identified in the inside sites, while there were 56 morphospecies identified in outside sites (Figures 4, 5, and 6).

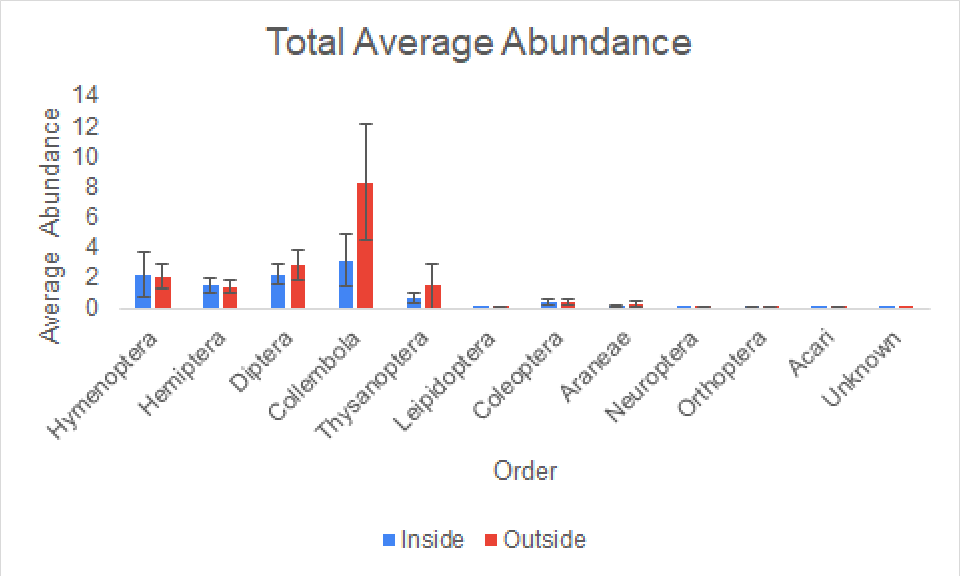

Figure 1. Total average abundance for all orders across all weeks of the experiment. Collembola were the most abundant order overall, but these are bycatch from the pan traps. Hymenoptera and Lepidoptera are the major pollinators of the prairie, but only 7 individuals from Lepidoptera were caught. Hymenoptera inside and outside of the solar prairie do not have a statistically significant difference with all weeks combined (p=0.5706).

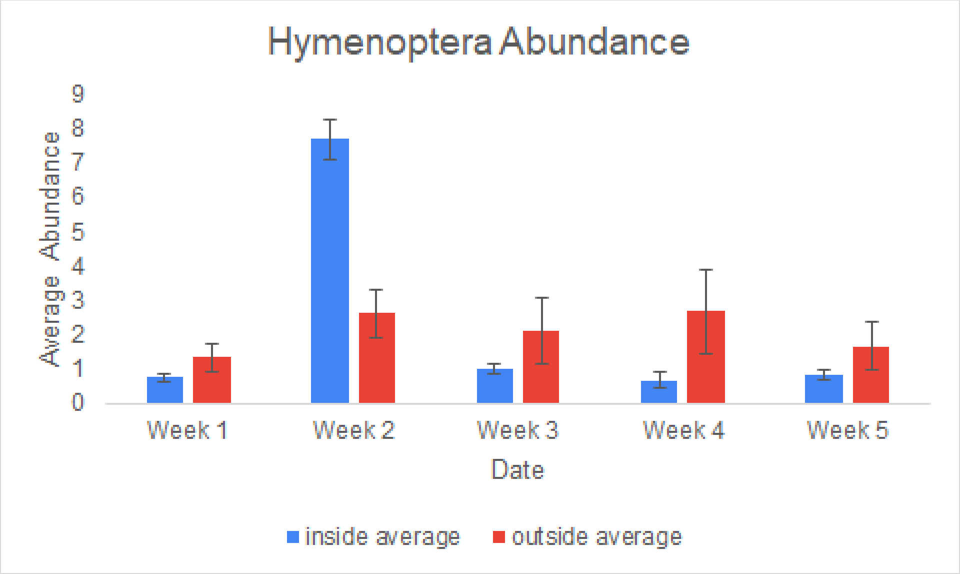

Figure 2. Average abundance of Hymenoptera across all weeks of the experiment. During week 2, the inside habitat was statistically significant from the outside habitat (p<0.001). In all other weeks, the inside habitats show a tread to be less abundant than the outside habitats, but it was not statistically significant (p>0.05).

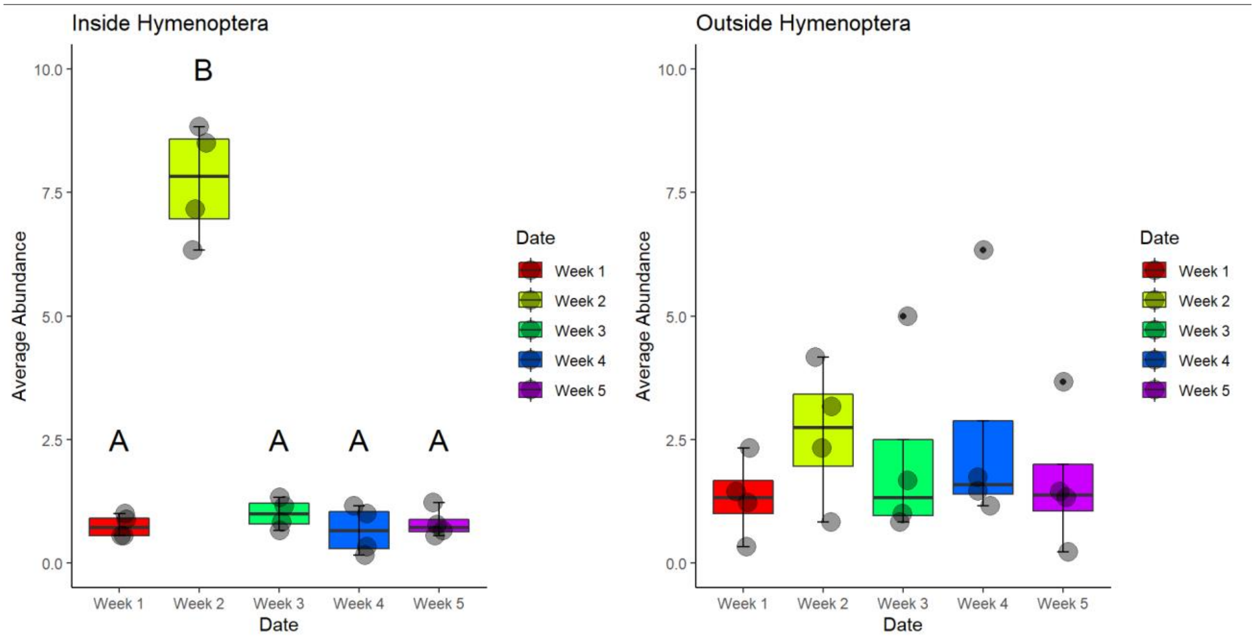

Figure 3. The inside Hymenoptera abundance during week 2 was statistically significant (p<0.001) from the other weeks while the outside sites were not statistically significant from each other across weeks (p=0.7538).

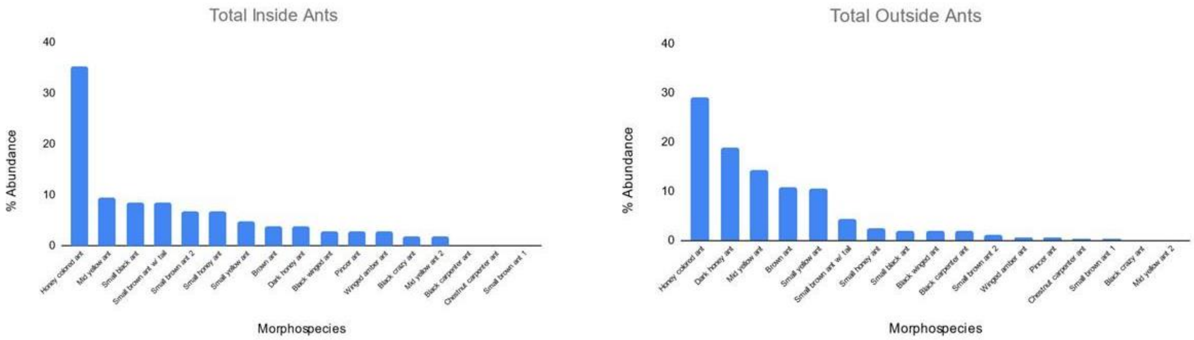

Figure 4. Ant rank abundance curve. Honey Colored Ants were the most abundant morphospecies in both habitats but more abundant in inside sites. There were 14 morphospecies inside the panels and 15 morphospecies outside of the panels.

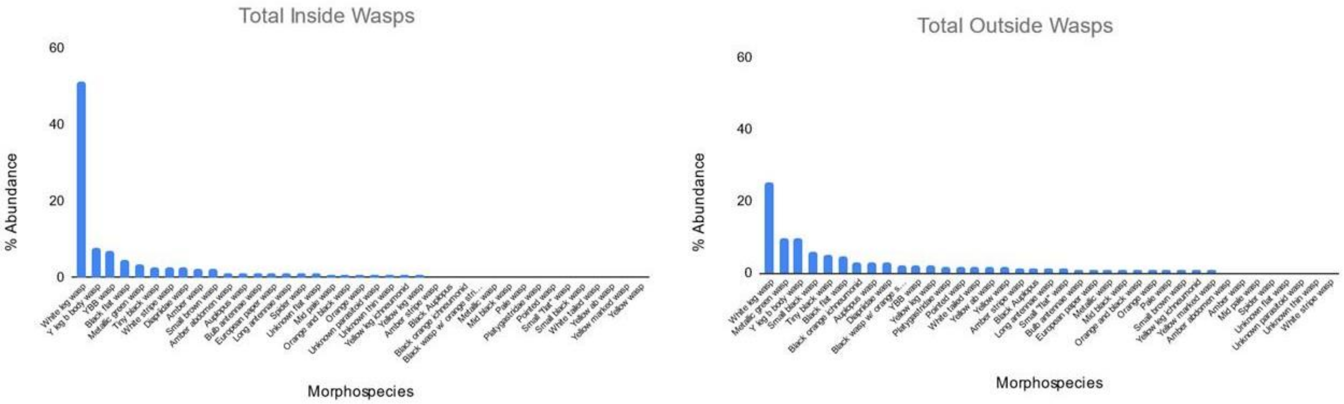

Figure 5. Wasp rank abundance curve. White Leg Wasps were the most abundant morphospecies in both sites but more abundant in inside sites. There were 24 morphospecies identified in inside sites and 31 morphospecies identified in outside sites.

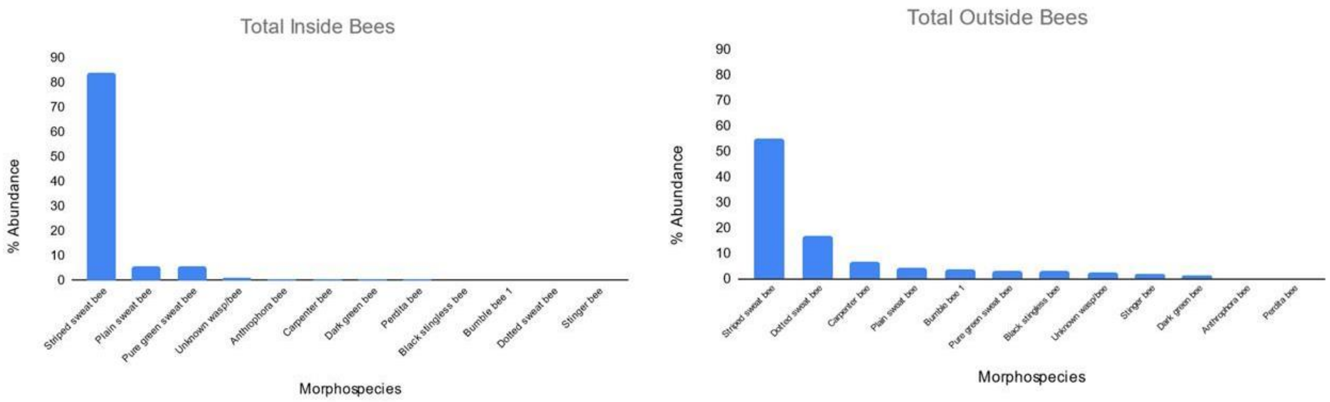

Figure 6. Bee rank abundance curve. Striped Sweat Bees were the most abundant morphospecies for inside and outside habitats. There were 8 morphospecies in inside habitats and 10 morphospecies in outside habitats.

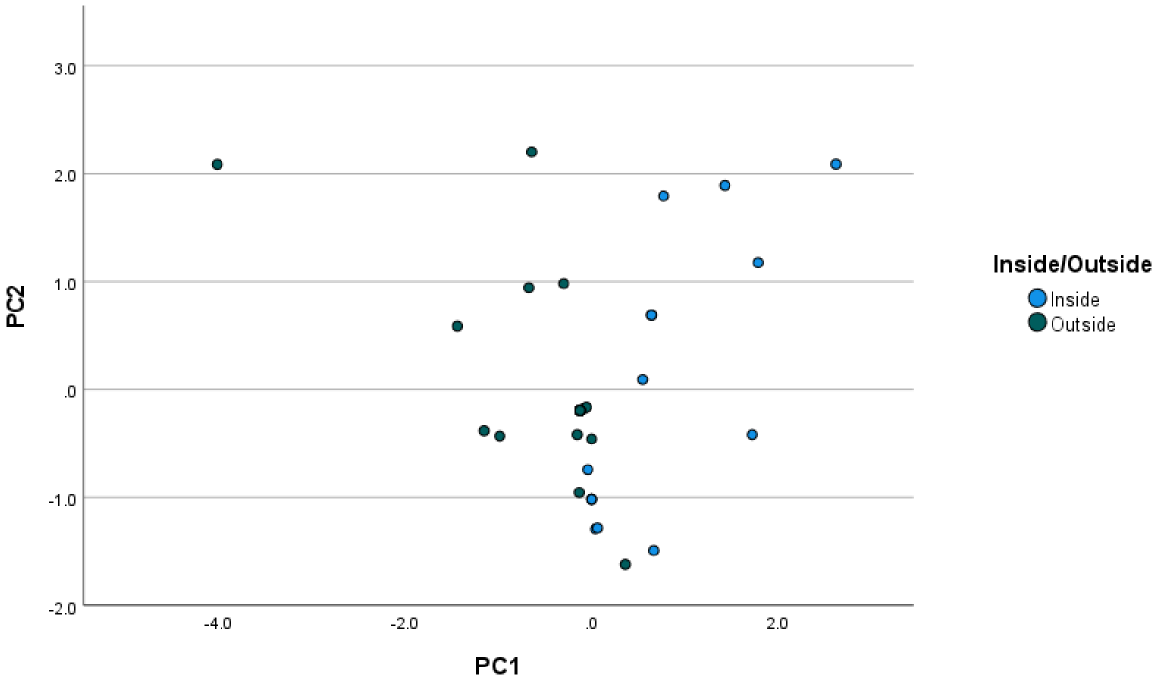

Figure 7. PCA chart showing how the inside and outside communities differed from each other. On the x axis, the Dotted Sweat Bees (-0.595) were leading the outside community

in the negative direction while the Pure Green Sweat Bees (0.701) were leading the inside community in a positive direction. On the y axis, the Plain Sweat Bees (-0.579) were driving the inside community in a negative direction and the Dark Green Bees (0.581) were leading it in a positive direction. All these morphospecies are members of sweat bee families.

Discussion

My results from this experiment show that pollinators are using the solar prairie at Curran Place. There are slight differences between the inside and outside sites with changes happening throughout the summer. I will discuss these findings in more detail to determine if my results can affirm or reject my hypotheses.

The prairie attracted a range of native pollinator species, and thus is performing the major function that was intended. There were some differences in the community composition of Hymenoptera between the inside and outside sites (Figures 2, 3, and 7). Some weeks differed from each other due to the maintenance of the solar prairie during week 2 of this research (Figures 1 and 2). During most weeks, outside habitats attracted more pollinators than the habitats in between the rows of panels (Figure 2) but was not statistically significant. This phenomenon is likely seen because the outside habitat had a different seed mix than the inside habitat. The area outside of the panels is exposed to more sunlight than the area underneath the panels and has a lot more flowering and colorful plants than the plants that were seeded in between the panels. The results of week 2 shows that the abundance of Hymenoptera was significantly different from the other weeks in the inside habitat (Figure 3). During this week, there was maintenance in the solar prairie. This maintenance included mowing in between the solar panels to keep the tall grasses from getting caught in the solar panels when they rotate throughout the day. Additionally, maintenance is needed to keep the solar prairie healthy and stop invasive species from spreading throughout the prairie. Since this maintenance was not planned to be a part of the experiment originally, I do not have any results to show how the inside sites would have attracted pollinators without the mowing. But I can expect that there would not have been a sudden increase in pollinators in the inside habitat because the mowing made my pan traps much more visible once the tall grasses were gone.

The solar prairie attracted lots of morphospecies of pollinators such as sweat bees, bumble bees, carpenter bees, and ants. Honey Colored Ants and Striped Sweat Bees (Figures 4 and 6) were caught in abundance in the traps, but lots of bumble bees and carpenter bees were seen flying in the prairie when I was collecting my traps each week. This is likely because my pan traps were painted with blue, yellow, and white paint to attract a variety of pollinators. If I wanted to attract only bumble bees or butterflies, I could have used yellow and purple pan traps instead. I wanted to know all of the pollinators that were in this prairie instead of making it catered to the native, larger pollinators. Additionally, Lepidoptera did not seem attracted to my pan traps. I only caught 7 Lepidoptera and 5 of those individuals were larvae. If similar research is done in the future, other methods that also sample larger pollinators and Lepidoptera could show a more specialized result to these orders.

I originally predicted that there would be more honey bees than native pollinators in this solar prairie because they are invasive to North America. Not only did I not catch any honey bees, but I also never saw any while being out in the prairie. Bumble bees, carpenter bees, and sweat bees were the most abundant native pollinators that I saw in the prairie (Figure 6), even though I did not catch many of these bigger pollinators. However, there were no honey bees caught in the traps or that I saw during my field work in the prairie. There are honey bee nests in the area, but this shows that they are likely not attracted to the native plants in the prairie and are preferring to go elsewhere for pollen and do not have to compete with the native pollinators.

I thought the solar panels would not deter the pollinator community and would provide a habitat for them, and my data supports this. Although the panels may seem to affect where the pollinators prefer to be, they are not causing the pollinators to disappear inside of the solar array (Figure 2). The pollinators prefer to live in the area outside of the panels, but this is likely because the outside locations have more flowering plants than the space in between the rows of panels. Additionally, there were some morphospecies that were driving the changes between the inside and outside habitats (Figure 7). All these individuals were from sweat bee families, and no bumble bees or carpenter bees were the individuals responsible for changing the composition of the inside and outside sites. This shows that both the inside and outside areas of the solar prairie are providing habitats for different pollinators, but also that lots of pollinators are using this prairie.

In terms of how the pollinator community would change throughout the summer, I was correct in thinking that different morphospecies would be more abundant at times as different flowers bloomed. It was hard to tell from my results because of the maintenance that happened in the prairie, but my observations when picking up the pan traps noted that there were new plants that bloomed in early July that brought more bumble bees and carpenter bees to the prairie. There used to be 8 acres of grass to mow, and now there is only 1.5 acres, leading to less time and expenses spent toward mowing (Leah Ceperley).

One of the main goals of this solar prairie was to increase the abundance of native species of plants and animals. There were many particular groups that I identified during the sorting process of this experiment. Starting with sweat bees, these were the individuals that changed when maintenance occurred, and their abundance increased significantly in between the rows of panels directly after maintenance. Their numbers then went back to average numbers in following weeks. But they were shown to be driving changes in composition between the inside and outside habitats (Figure 7). Honey Colored Ants, most likely the High Noon Ant, are native to North America and have mutualistic interactions with insects and plants. Most of the wasps that I sorted belonged to the category of parasitic wasps which might be the most diverse group in the world, surpassing beetles (Kimsey et al. 2017, Forbes et al. 2018). These individuals are extremely small and hard to identify since most of them remain unknown. Parasitic wasps are important to this ecosystem because a lot of parasites keep insects and plant populations in check so they do not dominate the environment. This allows for many communities to thrive in the ecosystem. European Paper Wasps are not parasitic and were originally invasive species but have started to coexist with our native paper wasps. They use the solar panels as a place to build their nests on the underside of the panels. This shows how our solar panels are providing a habitat for them to build their nests and add to the diversity of our prairie. For bees, individuals from the sweat bee family were the most abundant in my traps, but I observed far more larger bees like bumble bees than I caught in the pan traps. These sweat bee families have a large habitat range in the United States, but do not seem to be invasive to the area. During early July, a plant I identified as lemon bee balm began to bloom and there were lots of bumble bees on these plants, way more than I observed in previous weeks. As expected with a native prairie with flowering plants, the composition of the pollinators changed throughout the summer as new plants began to bloom.

From this research came a lot of room for improvement and future directions of experiments. Originally, I was going to research the paper wasps that made their nests on the underside of the moving solar panels. These nests were destroyed sometime during my research, but it would be interesting to know more about how they find their own nests since all of the solar panels look the same and move throughout the day. The maintenance that occurred during the experiment was not expected in the beginning, so a study about how maintenance affects the prairie using control areas would further demonstrate how necessary maintenance affects the pollinator community of the solar prairie. There are a few invasive species that are in the prairie, such as thistles or honeysuckle, and this could be studied to see how they are impacting the insect or plant community of the prairie. When placing my traps in the prairie, I purposefully avoided these plants to try and observe how pollinators responded to only the native plants. In the future, a similar experiment could be done but with pan traps that are purposefully placed by these invasive woody thistles. As mentioned before, the pan traps I used were probably not the ideal method for trapping larger pollinators. They produced a lot of bycatch with insects, like Collembola, that were not pollinators and hardly caught the big pollinators that were seen flying around the prairie. If this experiment is replicated in the future, using other colors, or perhaps just observing the larger pollinators would be beneficial to the scientific community.

Pollinator numbers are decreasing all over the world, but the implementation of native prairies could help increase their abundance. Turning unused land into a solar array is a productive way to increase the use of renewable energy. When that land is suitable for a prairie, turning it into a solar prairie may be the best use of the land. Before this area was a solar prairie, it was a manicured lawn in front of Curran Place. This did not promote biodiversity and was a lot for facilities to mow and maintain the looks of this lawn even though it was never being used. Now, the area promotes biodiversity and the use of solar energy to people who visit our university. This solar prairie is much better for our environment and ecosystem than a plain manicured lawn. Some of the main causes of pollinator declines around the globe are climate change, habitat loss, and invasive species. A solar prairie combats all three of these causes and can help increase pollinator populations and renewable energy for a more sustainable future. The solar prairie also helps to dismantle the idea that a manicured, green lawn is a more beautiful landscape than a biodiverse native prairie.

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