Native Pollinator Conservation at Rauscher Farm: Project Report

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Interdisciplinary Qualifying Project

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Abstract

Native pollinators have been on the decline across the globe. Their role in the ecosystem provides a basis for plant proliferation and survival. However, creating a pollinator garden to help bolster native pollinator populations requires a complex and interconnected system of plants, pollinators, and maintenance. The team was tasked with researching and compiling the necessary components to create a comprehensive plan for Rauscher Farms (in Clinton, Massachusetts) to implement a pollinator garden. The team consulted with researchers as well as local conservation land managers to not only develop a stronger understanding of the problems native pollinators face, but to provide an adaptable plan for the management committee at Rauscher Farms to utilize.

Acknowledgements

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- **Project Advisor:** David I. Spanagel, Ph.D
- **Project Sponsor:** Gloria Parkinson and the Rauscher Farms Management Sub Committee
- **Key Contributors:** Robert Gegear, Ph.D; Matthew Morris; Freddie C. Gillespie

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Executive Summary

Native bumblebees like *Bombus fervidus* and *Bombus vagans* are a crucial component of native ecosystems. Not only do they provide the key ecological service of pollination for native plant species, but they also interact and comprise a more complex plant-pollinator system that allows for the proliferation of native plants that contribute to other key species native to Massachusetts. Loss of habitat is the primary contributing factor to native bee species decline. The primary goal of pollinator gardens is to reintroduce at-risk or missing plant species back into the land. However, careful consideration and planning must be taken not only in what species of plants to include, but also regarding the location of the garden, as well as the larger ecological system within which the garden will be located.

To better understand the issues that plague native bee species, the team sought the expertise from local experts in the field of bee ecology. Following the guidance of the project sponsor Gloria Parkinson, the team corresponded and interviewed with Dr. Robert Gegear. The team aimed to confirm our initial research as well as fill in any gaps in our knowledge on native pollinator conservation. The primary takeaway was a shift in our focus from specifically bumblebees to a wider ecological system. The second interview the team conducted with Matthew Morris of the Native Pollinator Task Force echoed many of the key points noted by Gegear.

From these interviews the team began further research into the areas highlighted by both Gegear and Morris. Primarily, the team split attention into two areas. First, we analyzed Gegear's established native pollinator plant list and determined what species could be added to complement the existing wildlife at Rauscher Farm. Our selections took into account both our preliminary research as well as what we learned from the interviews with both Gegear and

Morris. The team needed to consider nectar sources, pollen sources, as well as host plants for bumblebee, butterfly, and bird species. Furthermore, there needed to be pollen and nectar sources throughout the entire blooming season (from March to October). Second, the team searched for a local botanist/conservation land manager to gain insight on the process of starting and maintaining a pollinator garden. Morris suggested Frederica Gillespie of Breakneck Hill who has both experience in cultivating pollinator gardens as well as maintaining conservation land. Moreover, Gillespie worked with Gegear to study and test certain species of plants. She provided insight into various techniques employed in cultivating new plants for a garden and informed the team on maintenance tips in addition to issues they ran into and potential solutions. For maintenance, she referenced the information from Gegear in respect to field mowing and trimming, reporting success associated with a regime of yearly mowing in sections or lines to leave certain areas still growing while cutting back others.

Overall, the team compiled the information gathered both from research as well as our interviews and visits with experts to provide a summary of our suggestions to the sub-committee at Rauscher Farms. We provide a proposed location to plant the garden as well as a layout for the garden's structure. Furthermore, the team delivered an initial plant list to provide the necessities required for a comprehensive pollinator garden based on Gegear's established plant list for plant species native to central Massachusetts.

1. Introduction

Humans have influenced the global ecosystem and climate in a way that negatively affects our lives and futures (Myers et al. 2013; Myers and Patz 2009; Martens et al., 1997). From steadily rising global temperatures to loss of agricultural sustainability, a host of issues threaten the longevity of our current society. One issue is an underlying concern about the decline of pollinators that contributed to our current situation.

The importance of pollinators and their decline has been a growing concern among researchers (Palmer et al., 2004; Klein et al., 2007; Ricketts et al., 2008; Potts et al., 2010). Heightened awareness of the issue has brought about new national and international biodiversity assessments, monitoring initiatives, and action plans. . Insects, most notably bees, play an essential role in the majority of terrestrial ecosystems; providing the ecosystem services necessary for both agricultural productivity (Klein et al., 2007; Ricketts et al., 2008) and maintenance of wild plant habitats (Ashman et al., 2004; Aguilar et al., 2006). The ecological services the bees and other pollinators (butterflies and birds) provide (and their vulnerability) has been well understood by researchers for some time (Palmer et al., 2004). Overall, the loss of habitat is the most crucial factor in the decline of bees (Potts et al., 2010). Furthermore, the decline of bees and the decline of suitable habitats for pollinators are intertwined in an unfortunate negative feedback loop. The decrease of habitats reduces the population of pollinators able to bolster the viability of habitats, resulting in further loss of habitats for pollinators.

A variety of means have been implemented in the effort to combat the decline of pollinators. Just over the last half-century landmark policies have been passed as well as foundations and agencies being created to protect pollinators. For example, the National

Resources Conservation Service (NRCS) of the United States Department of Agriculture since 2014 has been making efforts to bolster the states where two-thirds of the pollinators migrate to during the summer; enhancing around 35,000 acres of land. More efforts include international non-profit organizations like the Xerces Society founded in 1971 to research and protect endangered invertebrates. Other means include more localized efforts like pollinator gardens and habitat maintenance that have shown to be effective means for local revitalization of pollinator habitats (Fukase & Simons, 2015, p. 304-305; Eubanks et al., 2019; Baldock, 2020). Nonetheless, pollinators are still on the decline and crop food viability and sustainability continue to fall.

In the past decade, focus has shifted from pollinators to pollinator systems. Pollinators are meaningless unless there are plants involved. Moreover, research began concentrating on the diversity of plants and their generalized use among pollinators (Johnson & Steiner, 2000; Sahli & Conner, 2006). Furthermore, researchers heightened focus on the entire ecosystem in respect to pollinators (Saunders et al., 2015). Studies have found conflicting results with flower and plant visitation from pollinators. General understanding until recently has been that the majority of angiosperm flowers are specialized for pollination by a specific pollinator (bees, butterflies, or birds). With the advent of more ecological system focused pollinator research, more studies observe widespread generalization in pollinator systems, especially in non-tropic ecosystems (Johnson & Steiner, 2000; Sahli & Conner, 2006).

However, within the general population, individuals are often intimidated when faced with the scope of the global issue. Many still lack knowledge on pollinators and the plight they face. As a result, it is difficult to garner public support and interest in bees and other pollinators as public opinion of these pollinators are typically negative and fearful (Schönfelder & Bogner,

2017). Educating the general population yields the best means for combating pollinator decline (Marselle et al., 2020).

Rauscher Farm began with a public campaign from the town of Clinton to purchase the land for a recreational environmentally managed open space. From its conception as a public park and education platform, it has run numerous volunteer and education programs to educate the general public. When lobbying for the purchase of Rauscher Farm during the mid to late 2000s, emphasis on pollinators was not a key vision for the plot of land in Clinton Massachusetts. However, Rauscher Farm's sixty-two acres of open fields, woodlands, and wetlands were deemed worth protecting by the people both for their betterment in the short term, as well as the long term. Harking back to the widening body of research, pollinators, specifically bees, are an essential cornerstone in maintaining a sustainable ecosystem (Aizen et al., 2009; Gallai et al., 2008; Potts et al., 2010; Hallmann et al., 2017; Coache et al., 2018; van Klink et al., 2020). Rauscher Farm has a vision of providing a better long-term future for the residents of Clinton that resonates deeply with the ongoing conservation movement surrounding pollinators and global sustainability. In addition, it provides an avenue to better enhance and understand habitat conditions for pollinator species as a field "laboratory". Finally, the farm stands as a platform for educating the general public about an essential cornerstone in the ecological services we all depend on for the food we eat.

At Rauscher Farm, the team has three project goals: to devise plans for a pollinator garden and habitat maintenance, to perform a meta-analysis regarding the intricacies related to balancing pollinator habitats within the existing ecosystem on the farm, and to recommend avenues for the Farm to provide an enriching educational experience to the general public.

2. Background

2.1 Brief History of Rauscher Farm

Rauscher Farm contains approximately 62 acres of fields, forest, and wetlands, and includes part of the shore of Clamshell Pond. It was a family farm for generations, but in 2006 the land became available for purchase and a real estate developer proposed to convert the farm into a large residential development. In response to a vigorous group of citizens' efforts to forestall that plan, the town voted to purchase the farm in 2008 through a bond after a successful campaign that marketed Rauscher Farm as one of the last large open spaces the public could enjoy. The Clinton Conservation Committee created the Rauscher Farm Management Subcommittee to maintain and protect the farm. Currently, Rauscher Farm is open to the public and frequently hosts events to attract and inform visitors and volunteers to connect with and enjoy what nature has to offer. One of the RFMSC's focuses is the conservation of pollinators.

2.2 Biodiversity and Bees

Bees are among the most important pollinators, both in agriculture and in the ecosystem. They pollinate 80% of wild plant species, 66% of the world's cultivars, and 75% of agricultural crops used directly for human food (Heather et al., 2017, p. 5). Since different bee species pollinate different plants, the diversity of plants relies on the diversity of bees. Likewise, the diversity of bees relies on the diversity of the plants available. Other animals and insects also rely on plants which depend upon bee pollination.

2.2.1 Difference Between Bumblebees and Honey Bees

Two types of the many types of bees are honey bees, *Apis*, and bumblebees, *Bombus*. These two bees differ greatly in their lifecycle and behavior. Honey bee hives can have tens of thousands of bees and colonies live for a long time. Since they have to last through winters, they create excess amounts of honey in preparation and this is what makes them ideal for domestication. Bumblebee hives are much smaller with up to a few hundred bees depending on the species, and their nests do not survive the winter so the amount of honey they produce is only just enough to support the hive for a short time. They can also sting more than once, unlike honey bees, but bumblebees will only sting when truly provoked and they do not swarm like honey bees.

Bumblebees are also more resistant to bad weather such as cold and rain, and they can forage in cooler temperatures and with limited light conditions. They are not as integral to agriculture as honey bees, but they are able to perform “buzz pollination” where the bee dislodges trapped pollen by vibrating its wing musculature. Plants such as tomatoes, peppers, and cranberries benefit significantly from buzz pollination (Xerces Society, n. d.).

Lastly, concerns over honey bee declines are due to the significance of their pollination services in agriculture. They are not native to North America so they are not significant to the native ecosystem. Bumblebees are native to North America, and in Massachusetts there are ten species. The two species that are relevant to this project are *Bombus fervidus* and *Bombus vagans* which can be distinguished by their distinct coloration patterns.

2.2.2 *Bombus fervidus* and *Bombus vagans*

The half-black bumblebee, *Bombus vagans*, has a medium tongue length, nests on the ground and underground, and has been observed foraging in heavily shaded areas within forests (Colla et al., 2011, p. 26). The head, thorax, and part of the abdomen are mostly yellow and the rest of the abdomen is black. Its appearance can be confused with *Bombus sandersoni*, *Bombus perplexus*, *Bombus impatiens*, and *Bombus affinis*. The half-black bumblebee has been observed foraging from Penstemon (Beardtongues), Asclepias (Milkweed), Asters, Cirsium (Thistles), Eupatorium, and Spirea (Meadowsweet).

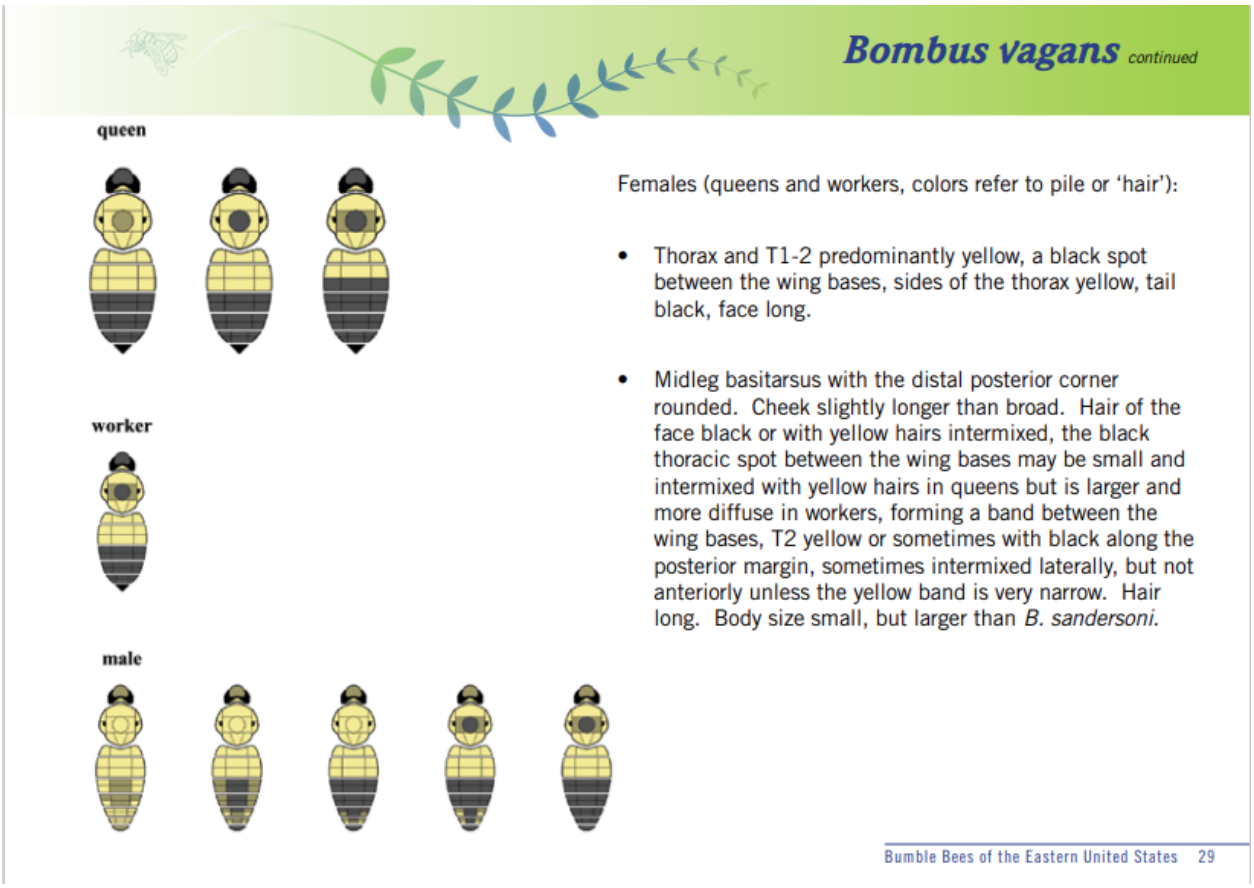

Figure 1. *Identification Chart for Bombus vagans* (Colla et al., 2011, p. 29)

The yellow bumble bee, *Bombus fervidus*, has a long tongue length, nests on the ground and underground, and has been observed in open fields and meadows (Colla et al., 2011, p. 62). They are predominantly colored yellow with some black on their thorax and abdomen. Its appearance can be confused with *Bombus borealis*. The yellow bumble bee has been observed foraging from Lonicera (Honeysuckle), Cirsium (Thistle), Trifolium (Clover), Penstemon (Beardtongues), and Lythrum (Loosestrifes).

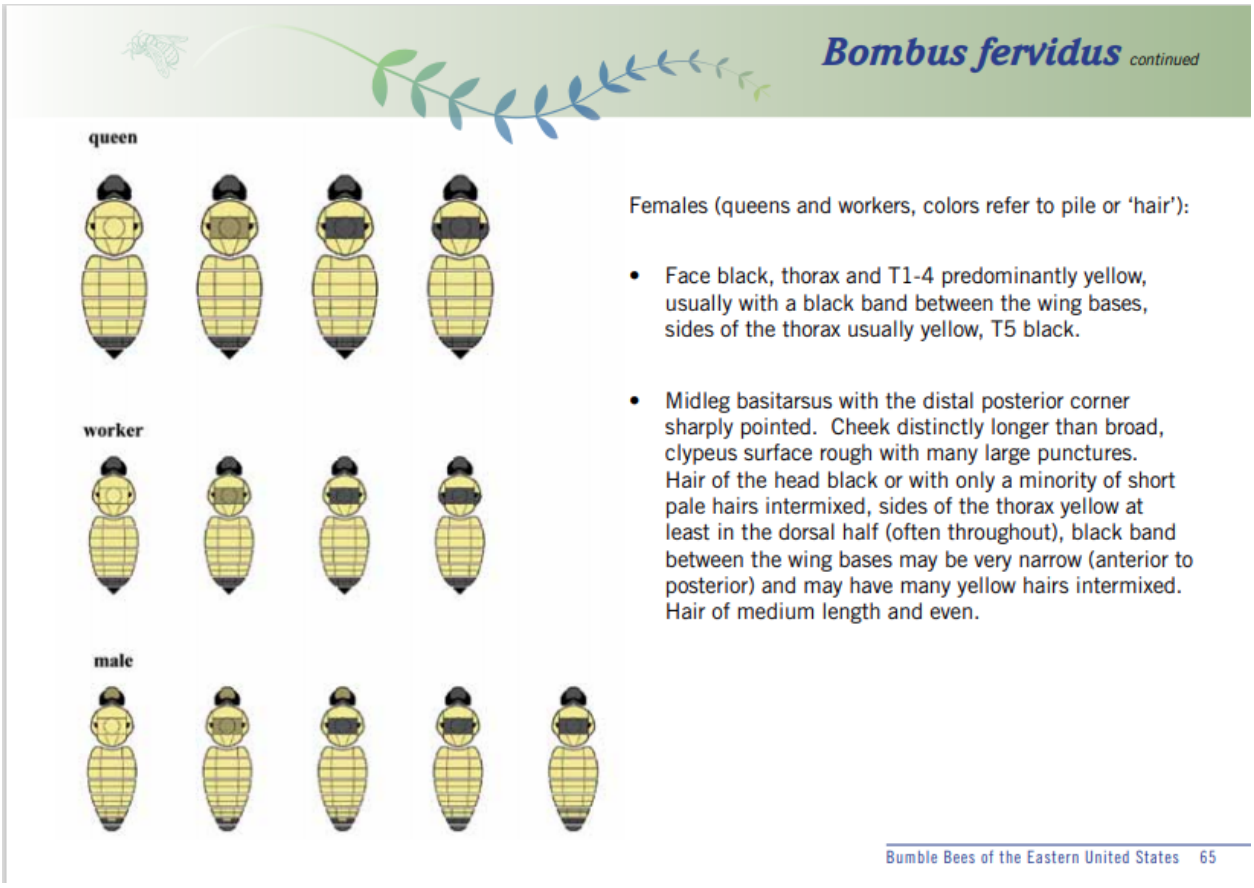

Figure 2. *Identification Chart for Bombus fervidus* (Colla et al., 2011, p. 65)

2.2.2 Bumblebee Lifecycle

In early spring, queens wake up from hibernation and search for a nest site such as a hole in the ground or a tussock of grass. Once the queen finds a location, she collects pollen and lays

eggs. Larvae hatch after several days and the queen feeds them by continuing to collect pollen and nectar. It takes about four or five weeks for the first eggs to emerge as adult workers. These workers are female and they live for one to two months. Throughout early summer, they continue to forage for nectar and pollen while the queen remains at the nest to lay eggs for more workers. Late summer, the nest will produce new queens and male drones who leave the nest to mate. The mated queens forage to prepare for hibernation and they overwinter underground. The old nest dies out and is not reused. When spring comes again, the hibernating queens emerge to repeat the cycle (Xerces Society, n.d.).

2.3 Factors Contributing to Pollinator Declines

The decline of pollinators, particularly bees, has been a growing concern in agriculture and for wild plant and pollinator diversity. The domesticated honey bee stocks have been declining in certain regions, causing concern about the future of honeybee pollination services for agricultural crops that depend on a single species. The beekeeping industry is declining in the USA, and most wild and feral honey bee colonies in the USA have disappeared. As of 2010, the best documented pollinators are bumblebees and butterflies, but data on other pollinators are lacking (Potts et al., p. 346). Native North American bumblebee species have declined in abundance by up to 96%, and geographic range from 23-87% (Levasseur et al., 2018, p. 5). Currently, the suspected causes of bumblebee decline are habitat loss, agrochemicals, alien species, diseases, and climate change. The generalized concept of pollinator declines does not mean all species are on the decline, especially in respect to native ecosystems and habitat loss. Specifically, although honey/managed bees are essential for the agricultural side of pollinator protection, when focusing on native ecosystems, honey/managed bees play no role as non-native

species of bees. The key is access to the necessary native plants for the pollinators native to that ecosystem. Certain pollinators prefer certain species of plants, and thus the plant is just as important as the animal when referring to pollinator decline. Moreover, bees specifically require both nectar and pollen to survive and reproduce. Nectar acts as a source of energy, and pollen as a source of protein. Critically, bees cannot reproduce without pollen. Therefore pollinators must have access to both nectar and pollen bearing plants. Pollinators are not pollinators until they help the plant reproduce, and with the decline of key native plants, re-establishing the connection between native plants and pollinators is the priority as the building blocks of ecosystems.

2.3.1 Habitat Loss and Fragmentation

The loss of habitats for bees is considered by many experts and advocates to be the primary reason for their decline. Land conversion for infrastructure or agriculture removes and fragments habitats, and less space means fewer resources and fewer locations to nest. Fewer floral resources means less food for bees, and lack of nesting habitats fragments bee colonies. “Several studies” have shown that certain bee species can tolerate moderate habitat loss because bees are mobile and have adapted to using patchy resources (Potts et al., 2010, p. 349). Urban settings also may present locations for certain bees to nest, but overall, the effects of urbanization require more investigation and not all types of bees can adapt to the loss of their habitat. Fragmentation of bee colonies occurs with the loss of the nest and habitat, and with a colony split into smaller parts there aren’t enough bees to ensure survival.

2.3.2 Agrochemicals

The expansion of agriculture has also led to the increased usage of agrochemicals which can pollute nearby habitats and directly affect bees. Herbicides and fertilizers can decrease floral resources that bees rely on, and insecticides can kill bees directly through intoxication, leading to a decline in bee diversity and abundance. Pesticides are assessed for their effects on honey bees without consideration for other species of pollinators and have been shown to have effects on the long term survival of other pollinator populations. In the case of bumblebees, pesticides affect the memory of bumblebees and, when the bees' memories of the flowers they prefer are impaired, they fly to random flowers and cross pollinate, preventing flowers from reproducing (Heather et al., 2017,p. 9-10). More evidence of the effects of agrochemicals on bees can be found in a comparison between fallow strips next to organic and conventional wheat fields. Both the adjacency to organic fields and the proportion of the farmed landscape significantly increased bee diversity and abundance (Potts et al., 2010, p. 349-50).

2.3.3 Alien Species and Competition

Some invasive species of plants that flower can provide an additional source for pollen and nectar in the event of a shortage due to environmental change; however, the negative effects of invasive species of plants on native plants generally outweigh the positive effects which are limited to generalist pollinators (Potts et al., 2010, p. 350). Invasive plants disrupt and displace native species, and the decline of native plants is detrimental to pollinators who prefer certain plants or are specialists. Left unchecked, invasive plants that attract generalist pollinators will continue to spread, increasing competition with native plants for space and resources and quickly worsening their indirect influence on other pollinators who rely on the native plants.

The honey bee itself is not native to North America, and there is evidence that domesticated honey bees can harm biodiversity through competition, pollination of invasive plants, the spread of pathogens, and direct interactions. Honey bees make use of the same resources as bumblebees, so the presence of domesticated honey bees reduces the pollen and nectar available for native species. As generalists, they also aid in the spread of invasive plants through pollination. Pathogens and parasites can also be passed from translocated honey bees to endemic bumblebees. Lastly, some managed honey bees can interbreed with endemic bumblebees, reducing genetic diversity of native bees or even eliminating subspecies (Potts et al., 2010, p. 350).

2.3.4 Diseases

Disease is another cause for concern on the decline of both honey bees and bumblebees, especially because pathogens can be passed from one to the other. One example is the deformed wing virus which is spread by mites. Though it originates in honey bees, it can infect other bee species and data suggests the virulence of the virus is higher in bumblebees (Potts et al., 2010, p. 350). Translocated alien bees increase the risk of various pathogens being spread to native populations, and other factors such as climate change, land-use change, pesticides, or lack of resources might also increase susceptibility to pests and pathogens, or vice versa.

2.3.5 Climate Change

The effects of climate change on pollinators are predicted to have a severe impact on pollinators in the future. Both bees and plants rely on the weather as seasons change, and if weather patterns and temperatures change then bees and plants may become out of sync. The

blooming time of flowering plants may be affected. Bees need a steady supply of pollen and nectar because they do not stockpile their resources, and if there is an extended gap of time between available resources, colonies will lack sources of food and will be in danger of dying.

2.3.6 Impacts of Pollinator Declines

A decline of honey bees threatens commercial agriculture, and therefore threatens our economy and major source of food. A majority of all crops used directly for human food worldwide rely on insect pollination that is primarily bees, and although there is still an average yield increase over time, the increase is due to the use of commercial pollinators where honey bees are rented to pollinate crops (Potts et al., 2010, p. 347).

Bumblebees, on the other hand, are important to the ecosystem. A healthy ecosystem is biodiverse, and bumblebees are not the only pollinators. Butterflies, flies, and birds are also an integral part of the pollination system. Unfortunately, the decline of the diversity of pollinators perpetuates itself. The decline of pollinators will inevitably lead to the decline of the flowering plants and crops that depend on them. The decline of the flowering plants, particularly wild native plants, likewise leads to a decline in the diversity and abundance of the pollinators that rely on them. In addition, other animals and insects that rely on the plants will also be negatively affected and will lead to the collapse of the ecosystem, a drastic decline in biodiversity.

2.4 Public Awareness and the Beecology Project

The decline of pollinators is not a problem any person can solve alone, so it is important to raise public awareness to inform people and encourage their involvement. Two challenges in efforts to conserve pollinators is spreading awareness and engaging the public in aiding scientists

in their research. The international Xerces Society for Invertebrate Conservation is one example of a non-profit organization whose purpose is to conserve invertebrates and their habitats while also offering a library of research and resources anyone can use. Another example based in Massachusetts is the Metrowest Conservation Alliance (MCA) Native Pollinator Task Force (NPTF) which includes members from the Southborough Open Space Preservation Commission, Sudbury Valley Trustees, Lincoln Land Conservation Trust, Marlborough Conservation Commission, and Concord Pollinator Health Advisory Committee (Sudbury Valley Trustees 2021).

In addition to their work to conserve pollinators, the NPTF also promotes the work and research of Dr. Robert J. Gegear, a biology professor at UMass Dartmouth whose research focuses on pollinators in Massachusetts, particularly bumblebees. Dr. Gegear compiled a list of plants based on his field research on the interactions between bumblebees and other native pollinators with those plants, creating a list of recommended plants for pollinator gardens (Gegear 2019). His list has largely influenced the conservation efforts of the NTPF as well as our research into the conservation of pollinators at Rauscher Farm.

Another resource created by Dr. Gegear working with an interdisciplinary team is the Beecology Project. The project is a web application designed to teach the public about bumblebees and the importance of native pollinator diversity, and to act as a platform through which citizen scientists could contribute data for visual analysis (Levasseur et al., 2018). Any person could become a citizen scientist for the Beecology Project by learning how to identify bumblebees and their behaviors around flowers and then log bumblebee sightings on the Beecology Project web application. Through applications such as the Beecology Project and

through organizations such as the NTPF, the public can become more aware of the decline of native bumblebees and learn what they can do to conserve them.

3. Methodology

In this section, the team details our project objectives, approaches, and the criteria we applied for gathering materials as well as methods for testing and data collection. Working closely with Professor Spanagel and the members of the RFMSC we examined various means to bolster native pollinator habitation and educational services to the public at Rauscher Farm. The primary source of existing information utilized by the team comes from the research of Professor Gegear and his lab. Prof. Gegear has extensive experience and knowledge of native pollinators as well as a comprehensive collection of keyplants and ecological interaction that acted as the basis of our research and planning.

3.1 Interviews

The team conducted interviews with pollinator researchers as well as experienced botanists local to Worcester to gather beneficial insight into creating a pollinator garden. In particular, we sought the advice of Dr. Robert Gegear for his extensive research and experience, as well as others with experience for creating a pollinator garden. Interviews were scheduled and conducted over Zoom due to the current COVID pandemic. The most important questions we asked were designed to convey our project's purpose and importance, to learn how to maintain a habitat to support the bees in decline, specific details and advice for garden plans, and to acquire some practical understanding and appreciation for the scope of the physical labor required. Another aspect of our interviews was to inquire about other resources and experts we could contact for more information.

3.1.1 Experts

To find additional experts, the team began by looking for other researchers and practitioners who were utilizing Dr. Gegear's research. We learned about and contacted Matthew Morris of the Native Pollinator Task Force, however Morris was an event organizer and had limited first hand experience in making pollinator gardens. He instead recommended that we get in touch with Frederica Gillespie who had experience in creating a pollinator garden at Breakneck Hill in Southborough, MA.

3.1.2 Site Visit

We also wanted to visit an established pollinator garden site to examine as an example for our plans. It was also important for us to visualize the physical dimensions and configuration of the garden we were planning. We asked for pollinator garden locations in our interview with Matthew Morris and were told about a location in Lincoln, Massachusetts. We instead chose to visit Breakneck Hill in Southborough, Massachusetts because it was closer to Worcester where the team resides and because we wanted to contact Frederica Gillespie for her experience in planting a pollinator garden.

3.2 Pollinator Garden

Pollinator gardens are the primary method shown to improve local pollinator population and habitation (Fukase & Simon, 2015, p. 304-305; Eubanks et al., 2019; Baldock 2020). Pollinator gardens are typically defined as a plot of land with a diverse set of beneficial vegetation for pollinators. A pollinator garden allows for safe habitation for pollinators

(dependent on the types of flowers and plants in the garden) and provides a natural aesthetic for public parks like Rauscher Farm.

The diversity of plants that compose the pollinator garden are certainly the most important factors to consider when planning a pollinator garden. However, there are a multitude of other factors that needed consideration. Components of a pollinator garden we considered are compiled and detailed below.

3.2.1 Objectives for Pollinator Garden Planning

3.2.1.1 Native Pollinators

The primary focus of the garden is to bolster native pollinator populations. Therefore, the team started by researching the plight of native pollinators. At the start the team thought the honey and other managed bee species were part of this category, but quickly learned our focus would be on two specific species of bumble bees. To better understand both the needs and threats of native pollinators, the team contacted experts on New England plant and pollinator ecology. The project sponsor, Gloria Parkinson directed the team to Professor Robert Gegear because of his previous work with Rauscher Farms as well as his extensive research into native pollinator species, especially bees. In conjunction with contacting Prof. Gegear, the team looked into other researchers utilizing Gegear's lab's data and recommendations about ecological systems. The NPTF is one organization using Dr. Gegear's research, so we contacted Matthew Morris who is an event organizer. We also learned about WPI's involvement with the Beecology Project. Our investigation shifted the team's attention away from the narrow focus on bees to a greater awareness of the dynamic system in which plants and pollinators act out their role in the larger ecosystem.

3.2.1.2 Plant Selection

The next criterion for the pollinator garden the team considered was the types of plants. The first area the team investigated was how to select the types of plants to have in the garden. Per our talk with Prof. Gegear, the team focused on native plants at risk. The team cross-referenced with Gegear's native pollinator plant and other information sources (Xerces Society plant database; Mass Audubon, and Freddie Gillespie of Breakneck Hill), and compiled a list of at risk native plants that are known benefactors for the two species of bumble bee we aim to bolster. Our last criterion for plant selection was whether the plants benefited other pollinators besides the target bumblebees as well as talked to individuals who had experience tending to conservation land. We accounted for the larger ecosystem and plant pollinator system described by both Gegear and Morris and wanted to ensure we were not overlooking issues already documented (rampant growth and species choking out other native species) that other conservation land had experienced.

3.2.1.3 Location Requirements

Two locations on Rauscher Farm were suggested to us to begin with, and we evaluated them and other potential locations for the pollinator garden. There were many important factors to consider when choosing any prospective location. Most obvious was the space requirement. There needed to be enough room for the square meter grid, including space for paths in between. The location also had to be accessible, with particular attention given to travel distance and available sources of water for the garden. In addition, the garden should also be in a location with low risk of environmental damage such as erosion, and it should be kept away from encroaching invasive species. The type of soil and amount of shade are also important factors to consider about the location because it affects what plants will grow best. Lastly, for bumblebees,

it is very important for the garden to be relatively close to preferred nesting sites due to the bumblebees' limited range.

3.3 Rauscher Farm's Habitat Maintenance

The team designed a comprehensive guideline for habitat maintenance at Rauscher Farm as a plan to be used in conjunction with the pollinator garden or as an alternative for the garden. Through our research on and off the farm, the team gathered and analyzed data on the current state of the farm. The data the team aimed to collect and analyze is outlined below:

- Catalog of existing plants beneficial to pollinators on the farm
- Soil composition and measurements
    - pH, Salt content, Nitrate/Nitrites

The primary goal of this guideline is broken into two elements. The first is to provide a quantitative and qualitative analysis of Rauscher Farm to assess ways to better provide for native pollinators through the regular maintenance of the property. Through our research and analysis of data outlined above, we compiled a plan/guideline for the maintenance crew at Rauscher Farm with edited means of maintenance to better accommodate native pollinators.

3.4 Methods for Raising Public Awareness

The team examined the methods used by the Farm currently as well as methods used by other organizations and projects to decide what events and resources would be most useful in raising public awareness on the decline and conservation of pollinators. Rauscher Farm has held

a number of events promoting the education of pollinators, and the most recent event featured Dr. Gegear in 2019. The NPTF hosts webinar events to inform the public on how to conserve native pollinators, and the Xerces Society offers a library of research and information on their website. Dr. Gegear's Beecology Project also provides an opportunity to educate and engage the public.

4. Results

4.1 Ecological Relationships

The primary information gathered from both our visits to local conservation lands, as well as our interviews with experts in the field has led us to careful consideration of the ecological relationships and systems at play when creating a pollinator garden (Gegear, 2021; Morris, 2021). Foremost, our aim is to provide a habitat to bolster the populations of at-risk native pollinators, namely *Bombus fervidus* and *Bombus vagans*. However, the critical connection between varying trophic levels in the ecological system at Rauscher Farm must also be considered (Gegear, 2021). Although both species of bumble bee are the target, other pollinators and members of their ecological system must be accounted for. The focus shifts from pollinator decline to restoring the ecological niche that they account for, as well as the other members that contribute to that niche. Gegear specifically prefers to refer to this issue as "pollination systems" instead of the pollinator problem because the term pollinators is meaningless unless there are plants involved. Plants are what are being pollinated; pollinators like bees and butterflies are simply flower visitors, or more specifically, nectarivores and pollenivores. They do not become pollinators until they benefit the plant by helping them reproduce (Gegear, 2021). Therefore, bolstering native bumble bee populations requires a more comprehensive effort to restore native plant species that have been in decline or contention from other invasive plants. In essence, conservation of pollinators should not focus exclusively on bumble bees, but instead should restore the connection between native pollinators and their

respective native plant matches as the crucial building blocks of ecosystems. Moreover, the relationship between plants and pollinators is extremely complex.

A diverse set of considerations must be examined when creating a habitat for native pollinators. Although endangered bumble bee species are the focus, butterflies and birds are deeply connected with the plants supporting those at-risk species (Gegear, 2021). For example, at the larval stage, butterflies are a primary food source for birds, in turn, the birds provide the bees service by keeping pest insects that prey on the bee eggs at bay. However, host plants for these butterflies must not be allowed to infringe on the tall grass needed for nesting by the bees and other bird species. Monarch butterflies specifically require milkweed to hatch larvae on. However, besides acting as a host plant, the milkweed is not a source of pollen or nectar for butterflies or native bees (Gillespie, 2021). In addition to balancing both the species of plants and their role in terms of the various trophic levels, it is also critical to select plants based on their usage.

Bees, and pollinators in general require access to three main sources from plants; nectar, pollen, and habitation. Nectar acts as an energy source for bees. Moreover, nectar is a source of energy for other pollinators like butterflies and certain birds. Next, pollen provides a source of protein for reproduction. For bees, pollen allows for reproduction and without pollen, regardless of if they have a nectar source for food and energy, they will not be able to reproduce (Gegear, 2021). Furthermore, the bees are actively seeking nectar whereas the pollen is collected passively as a result of seeking nectar for energy. Therefore, there must be both an even composition of nectar and pollen plant sources in the garden. Finally, there must be an available habitat for the bees and other pollinators to nest safely. Certain species have requirements. For example, Monarchs require milkweed as a host plant, but not as a food source (Agrawal, 2017). Bumble

bees mainly nest in fields that include tall grass and trees. Crucially though, this nesting area must be in close proximity to the necessary nectar and pollen sources (around 50 meters). In order to guard against the dangers of pollinator hyperspecificity, the focus of the garden, its location, and its plant composition must not solely be tailored to the bumble bee species in decline as it may be detrimental to the other necessary wildlife in the ecosystem.

4.2 Pollinator Garden Plans

4.2.1 Design

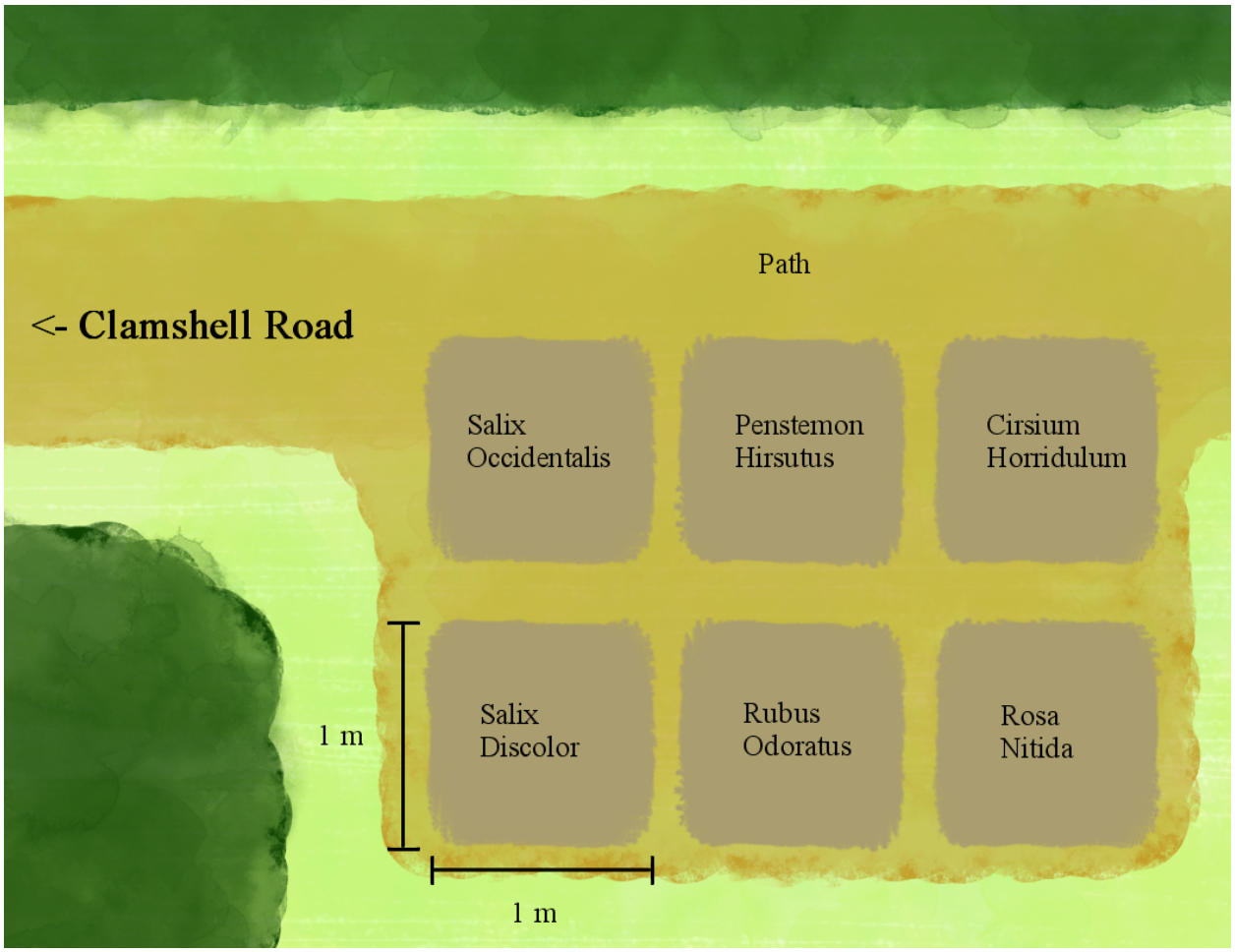

Figure 3. *Example Pollinator Garden Layout Plan*, featuring pollen and nectar sources from Mar to Sept, based on the location detailed in 4.2.3 Figure 4 and using the Plant List in Appendix A

Based on our observations and conversations with the several experts that we consulted, our recommended layout for the garden is a 1x1 square meter grid with space for paths in between. These dimensions are recommended and currently assumed to be the best practice. According to Matthew Morris, it has not been fully researched yet, but it is important to have at

least a square meter of blooms per season. Each square should include only a single plant with sufficiently high density to ensure that it can both outcompete any other native or exotic plant that might also take advantage of the cleared space and ensure it will attract pollinators.

4.2.2 Plants

Deciding what species of plants to use in a pollinator garden requires complex calculations and planning. Foremost, soil composition and conditions (pH, salt content, nitrate/nitrite content) need to be ascertained and cataloged to determine what plants are viable based on the available land at Rauscher Farm. Other factors to consider are bloom time and costs. Another important consideration is the size of land being dedicated for planting. Based on our interviews with experts (Gegear, 2021; Gillespie, 2021; Morris, 2021) we found a one meter by one meter square plot for one specific plant is the minimum for an ideal pollinator plant system. Moreover, there should be space in between each squared section for a walkway for visitors as well as maintenance. Therefore, a relatively large area needs to be planted to achieve the necessary diversity for both pollen and nectar providing plants. Another factor in the number of plants to place is bloom time. Per our expert sources, there should be at least one nectar and pollen source per bloom season, from the first snowmelt to the first hard frost (Essentially from March to October). Furthermore, when choosing plants, the wildlife attracted by those plants is a critical factor the team found needed consideration. Obviously what pollinators the plant benefits is at the forefront of decision making. However, keeping track of potential pest insects and invasive species also attracted to the plant is crucial in keeping Rauscher Farm a native conservation sanctuary. The importance of using native plants and avoiding non natives and cultivars. Sometimes the plants in decline are driving the decline of a species of pollinator.

Lastly, we needed to consider which pollinator species prefers which plants to select plants favored by multiple different pollinators in order to encourage and support ecological diversity.

In Figure 3, we chose the six plants based on our recommended plants list in Appendix B. The plants selected for the example are sources of pollen and nectar. *Salix occidentalis* and *Salix discolor* bloom in March and April. *Penstemon hirsutus* and *Rubus odoratus* bloom May, June, and July. *Cirsium horridulum* and *Rosa nitida* bloom in June to September. These six plants ensure that pollinators will have access to pollen and nectar from March to September. Most support both *Bombus vagans*, *Bombus fervidus*, and butterflies.

4.2.3 Location

The team recommends the rectangular area marked in purple off Clamshell Road in Figure 4 below. Pictures of the location can be found in Appendix C. We chose this location because it fits the criteria outlined in the methodology. The land was relatively flat, away from the wetlands, with plenty of space. It is also already partially fenced off, making it easier to keep out larger animals, and it is a safe distance from areas of the farm struggling with encroaching invasive species such as oriental bittersweet. There is not much shade, but the pollinator garden at Breakneck Hill in Southborough also did not have any shade, so it should not be an issue. The location is also accessible, just off Clamshell Road and close to public parking. The homes surrounding the location are private property so water availability isn't guaranteed, but even if water has to be transported from another place, the location for the garden is close enough to the road that hauling water would be feasible.

However, the team was not able to survey the farm for potential locations based on existing plants available, nor did we consider many possible locations. We recommend the location marked in Figure 3 based on our research on selecting a location for a pollinator garden,

but we also suggest conducting a thorough survey of land to see if there are alternative locations that meet the same requirements..

Figure 4. *Map of Rauscher Farm* (Webster 2021)

4.2.4 Management

Research showed the vast benefits of altered maintenance for pollinator habitation (Baldock, 2020; Westerhold et al., 2018); small changes like frequency of grassland mowing, brush clearing, and types of chemical agents used all can result in a more comprehensive native pollinator sanctuary. Specifically, when looking at the endangered bombus fervidus, accessibility to tall grass each year is crucial. Moreover, if invasive species are a factor in the grasslands, more

targeted mowing would need to be implemented to reduce the invasives while still allowing enough tall grass for native pollinator nesting (Gegear, 2021).

4.2.5 Public Awareness

Events and online resources are the preferred existing methods to educate the public. The team suggests the Farm should consider hosting additional events to educate visitors on pollinators and the pollination system. It would also be prudent to inform visitors about Dr. Gegear's Beecology Project and other resources such as the Xerces Society website. While the team was unable to analyze and calculate the effectiveness and costs for signage, brochures, and similar methods to educate the public, we suggest expanding the Rauscher Farm website with information about and links to resources such as the Beecology Project, the NPTF, and Xerces Society. Once the pollinator garden is established, the team recommends signage to allow visitors to read and learn about the garden, the research behind it, and the resources available to them.

5. Concluding Thoughts

5.1 Project Reflection

At the start of the project, the team's knowledge on pollinators was sparse. Like many people, we have been exposed to articles and new stories on the danger of declining pollinator populations. However, our information was only partially correct and mostly mistaken.

First, there was a misconception that all pollinators were in decline and there was a particular concern for honey bees. The team learned about the differences between honey bees and bumblebees and that the former is not at all necessary for the stability and sustainability of the native ecosystem. In addition, honey bees, as an invasive species, instead propagate the spread of invasive species of plants. In order to conserve the native ecosystem, pollinators such as the native bumblebees are important, however they are only one part of a massive interconnected ecosystem. The plants they pollinate are equally as important.

Originally, the idea of a pollinator garden meant planting a few plants either in a traditional garden format, or throughout the farm land. We didn’t quite understand the individual benefits of certain plants (pollen sources, nectar sources, or host plants) assuming certain plants were simply “beneficial” to pollinators. Moreover, the importance of plant density and location to host sites was not something we thought we had to consider. Furthermore, the project name of pollinator garden meant to the team a garden targeting bees. Although bees are a key species of pollinators, the team quickly learned of the importance of establishing diverse plant-pollinator systems rather than isolated and targeted gardens.

5.2 Limitations

Throughout the project, the team faced limitations both from the global pandemic as well as time constraints from the project timeline. Although the team was able to conduct interviews and, later in the project, in-person site tours, social distancing proved an issue to meetings and visitations. The interviews with both Professor Gegear and Mr. Morris were conducted through Zoom and some, but very minimal, information was lost through poor connection. Although social distancing wasn't a major limitation, it did create difficulty in visiting local conservation grounds. Scheduling meetings and visits needed extra consideration and approval from the site manager to ensure both the team and the host would be safe.

A major limitation to the project was the timeline. The project ran over 3 separate terms starting in WPI's B-term (late October) and concluded at the end of D-term (early May). Due to the nature of pollinator gardens and their reliance on plant bloom seasons, the project unfortunately had two-thirds of the project over non-bloom seasons. This posed the limitation of not being able to visit and observe active pollinator gardens or conservation land. Moreover, the team was mainly limited to interviews to gather information at Rauscher Farms. Although the Farm is open over the winter, for the majority of the project weather conditions like snow and rain prevented meaningful data gathering at the project site. For example, an initial criterion the team hoped to gather was soil conditions at potential locations for the garden. However, due to cold weather and snow, such measurements were unable to be analyzed.

5.3 Future Work

The team recommends continued research on the relationship between pollinators and plants, such as what plants are preferred by what pollinators. Dr. Gegear's plant list is

continuously being refined with additional research and data, and the pollinators studied should not only include bumblebees, but also other bees and pollinators, such as butterflies, native to Massachusetts. A future project could include further field research on Rauscher Farm to study pollinators and the results of the pollinator garden. Furthermore, Dr. Gegear's lab is developing an app to log and track bee and other pollinator sightings which can aid in the research and analysis at Rauscher Farm. Finally, we recommend such a project take place from spring to fall rather than over winter to allow for the best timeline for meaningful results.

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Appendices

Appendix A: Interview Transcripts

Gegear Interview Transcript

2/16/21
Interviewers: Joy Tartaglia, David Chen
Interviewee: Robert Gegear

Chen: We know you founded the Beecology Project here at WPI and that was our main source of information when we first started this project, so first of all we really wanted to thank you for that. It's been an outstanding resource for us, especially in terms of our project. We've read up a lot about your work now. You were one of the first people Gloria kind of direct us into talking to and really scoping out your research to give us a really good understanding of what research has been done and what we really know. Based on our research and our project—so to give a little overview, our goal of our project is to essentially start a blueprint and have a project blueprint laid out for Rauscher Farms to impediment some way of pollinator conservation. Our idea to start right now is a combination of farm management as well as introducing a pollinator garden or potentially multiple pollinator gardens on the farm. We want to create a plan so they have all the blueprint laid out for them, so the size of the farm, what plants would be in there, specific species, etc., how big, how many plants we want in there. Obviously with our research we learned that it's general knowledge that pollinators are on the decline, more specifically certain pollinators are on the decline. It's not necessarily that pollinators in general are in decline, it's certain species of pollinators are in decline. Some pollinators like managed pollinators are doing better in certain cases.

Gegear: So are the wild bees. That's one of the biggest issues. The first one that honeybees are thought to be the type of bee, the species, that we need to conserve ,which is false, and that they play a role in ecosystems, which is false. The other is that everything's in decline, so if I see a bunch of bees flying around I'm doing a good job, which is also false, so I'm trying to correct that. Before we get started, who is your advisor on this?

Chen: Professor Spanagel, David Spanagel.

Gegear: What department?

Tartaglia: History.

Gegear: So It's not biology or any biology ties.

Tartaglia: Not significant that I know of.

Gegear: And are you aware of the group that I'm working with? So Carolina Ruiz, there's Ryder, we've got a team of computer science students working on Beecology, and grant funding, just polished a paper with Kevin [3:29.5 unclear] who's in the BCB department there. Are you aware of those connections?

Tartaglia: We are not.

Gegear: Okay. Which departments are you in?

Chen: I'm biomedical engineering.

Tartaglia: I'm in interactive media.

Gegear: We meet weekly and have been, and so all of the computer science support, the tech that we have is me collaborating with the WPI computer science and BCB folk, so I guess Liz is in bio as well. So just to make you aware that there's a lot going on on campus with respect to Beecology and getting it into curriculum, high school curriculum. We meet weekly to develop more tools and do different things. Just wanted to let you know about that.

Chen: That's awesome. Is there potential that we could sit in on one of those meetings?

Gegear: I think it would be worthwhile for you to contact Liz and Carolina just to let them know what you're doing and see if they have any thoughts. In terms of on the ground plant selection and assessment and all of the bio side, that's all me, but all of the tech and the interface with the public and what we're going to help the citizen science part is all working with them 'cause it's all computer science, the web app, the visualization tools, that's all them. I bring the bio side but they bring the CS side and collectively what you see on the web, the Beecology site which is continuously being developed and improved. I'm guiding it but they're certainly the key players in development.

Chen: Thank you. I think we will contact them because another part of our project is to help the education aspect and I think that's something the Beecology Project is doing an amazing job of really integrating the public, the public awareness aspect where you could really involve people

like the app where you can take pictures, videos, of bees you see out in the field, so I think that's something that I want to aspire, like in our project where we can have that piece that incorporates the public into our project so that awareness is raised more soundly. Like you said, I think that is that misconception. Everyone hears this term like bees are dying, we have to save the pollinators, but I think, at least when I started this project, in my head, it seemed like such a monumental task that I felt scared to do anything because you're faced with this task of agriculture and colonization is in the decline because bee populations are down but you don't know there's very intricate ecological systems that play into that. I feel, as a general person of the public, it was very difficult for me to wrap my head around what I can do to help. After reading the Beecology page, that gave me that sense of like, there is stuff I can do to help and I really want to integrate that into our project, so thank you for that.

Gegear: You're welcome. Beecology started with helping me to collect data but now we're in the implementation phase, so based on my primary research, the Beecology data just supports what I'm finding in the field through my primary research, so now I have groups actually putting plants in. I talked to Gloria. I had plans to help Gloria in Rauscher Farm develop things but then Covid hit and things got put on the back burner a little bit, but I've had groups this past spring that have put in plants from my list, and then one year we've already seen a change. We've already seen the species at risk visiting the plants where they weren't there before, and it's not just about the bees. I'm doing butterflies as well and not just bumblebees or other bees that are being helped. I talk about pollination systems instead of pollinators because the term pollinator's meaningless unless you have a plant involved. That's what's pollinating. Pollinators, bees, and other things are flower visitors, and if you want to get fancy, they're nectarivores or pollenivores, meaning they feed on nectar, pollen or both, but they're not a pollinator until they help the plant reproduce, and they have native plant matches that are also in decline, so we need to restore those connections because they're the building blocks of ecosystems. That's the basic message, so that's why if you just throw in something like black-eyed susan or mountain mint that will get tons of honeybees and common bees but not help the ones that are in trouble. We're not restoring biodiversity, so these native plants are connections to wildlife at other tropic levels. There are birds that prefer native seeds, there are butterflies that prefer native plants as host plants, and so that plant is just as important as the animal, and together that plant-pollinator system, the pollination system, is what is helping ecologically. It's not just the bees. We could put up feeders and feed every bee species on the planet and we're doing nothing because we're not doing anything to maintain their function in the ecosystem. That's where ecology comes in and separates things from taxonomy where they're just focused on the bees, the bees, the bees, but not their function. They assume that's agricultural I guess, but only about five percent of native bees and butterflies, well bees, the number's much, much lower, probably less than a percent of butterflies are visiting agricultural crops. So for the ones in trouble aren't visiting the crops and we're trying to protect them, it just doesn't make sense. There are two sides to the issue: agricultural side where the honeybee plays the dominant role and some managed bees. The

ecological side, the honeybee has no business because it's a non-native species and there's no plant that depends on honeybees for pollination. In fact they're helping non-native plants to spread and knock out our native plants, which is causing more harm than good, so honeybees need to be kept out of conservation plans and off of conservation lands.

Chen: In terms of plants, we want to be targeting plants for the pollinator specifically. I guess in our case, we focused in on *Bombus fervidus* and *Bombus vagans*. In terms of plants, when we're looking, making a pollinator garden specifically for those two species, we would want to be targeting plants for them. You had a interview with a radio show. We listened over that and I know you talked about how there's that key difference between when bees go to flowers for nectar versus pollen. Could you explain that to us a little more?

Gegear: First of all, I assume you've seen my lab website, not the Beecology site, my lab website, the plant list and information for bees and butterflies. I'd say that any sort of habitat you're creating has to include the butterflies. All species at risk, targeting bees is not the way you want to go 'cause there are plants, and at the larval stage, butterflies are a major food source for birds at risk. Everything is connected, so I would say to treat those equally. Think about host plants as much as you think about the nectar plants. Timing, we can talk about that later. For bees, they need two things. They need nectar, that's their source of energy, and pollen, that's their source of protein. They cannot make new bees without pollen. I can get bees to live for long periods of time on nectar alone, but they can't make any new bees if they don't' give them pollen. If I give them only pollen, they die within twenty-four hours, so they need the energy, but pollen's critical. When we see what the bees are doing in the field, my approach has always been: let the bees tell me what they want. I'm not gonna pick plants for the bees, they're gonna tell me what they want, so I'll go and observe them and see what they prefer, and it's very clear that they prefer certain plants for pollen. When I see them on the plants, they're actively collecting pollen. I don't see that on other plants where they're just collecting nectar, so you can separate plants where they seem to really prefer the pollen versus those that they're just visiting for nectar. They're still collecting pollen but it's passively, meaning they're primary goal is to get the nectar and they get the pollen as a consequence of the nectar versus actively taking pollen and forgetting about the nectar. There are a few plant species that seem to be highly preferred for pollen and those need to be included. I'm figuring out with a group from Cornell what it is about the pollen that they like, but right now I know they have a preference and I'm assuming that that preference is because there's something in that pollen that is good for them in some way, so those plants need to be in there as much as the nectar plants, so you need both nectar and pollen and you need those plants on site in bloom from when the snow melts through to when we get the first hard frost. Early on is critical because if you don't have proper food for the butterflies and bees in the spring, they're never gonna make it to the summer, and one of the problems with the current "pollinator gardens" is that they start blooming in June in good number and the bees have been around for two months and if they don't have things to eat they're not gonna make it that

far, so having things like willow in the spring is critical, and I have multiple willow species, but you need to build the nectar and pollen sources and really plan it out through the whole season. On the list that I have on the website you can see that I have bloom times, and soil types, you need to think about all of those things when you're piecing together or creating this plant list.

Tartaglia: Unfortunately, our project ends in the spring, so we will be unable to actually implement any of our garden plans. We're assuming that any work to actually create the pollinator garden will begin next year. You said right after the snow melts?

Gegear: Yeah. [15:00.3 unclear] snow on the ground in some places, so willow blooming right away. By the way, I don't think you're putting plants in, right? You're just giving them a plant. That right?

Chen: I think so.

Gegear: You're not buying plants for them and putting them in the ground, are you?

Chen: I don't think so.

Gegear: Your project ends in May.

Chen: Yeah.

Gegear: You're gonna give them a plan of action, but all I'm saying is that the plants need to go in the ground whenever, but they need to bloom in the spring, and willow is the main one that you're gonna find in the spring. There's lupin, there's another big one for the spring. There's [16:01.1 unclear] that's good. It's all on the list. All I'm saying is that when you make a plan you need to have it as early as possible in the spring through to showy goldenrod I think is the last one in the fall in terms of nectar, and you need the pollen in there too.

Chen: Is there an ideal proportion to nectar flowers versus pollen flowers? Should it be fifty-fifty? More towards nectar? More towards pollen?

Gegear: It's a fifty-fifty. The key is how much you put in and I'd say no less than a square meter. I have students working on this issue, what is the optimal size. You want them to be in clumps. You do not want to spread the plants out. You're creating populations of things so you want to keep them close together and they'll grow into each other, so you've got these clumps that are at least a meter square around the habitat because that will facilitate cross pollination. You could have multiple clumps.

Chen: So in that meter square, we'd want it to be varied in what plants we have?

Gegear: No. One plant. A single plant species that takes up an area of a meter square at least. You've got these patches. You can think of it as meter grids, like a grid that's a meter square, and each grid you've got a plant with some room to move. When you're thinking about plants, you want to make sure that that area is covered with the plant. The bumblebees we're trying to figure out, but the solitary bees and the butterflies, that's enough to support individuals.

Chen: Another idea we had was for general maintenance around the farm, I don't know if that's an area that you looked into, but we want to know if you knew anything about beneficial things we could do around the farm like cutting, trimming large grassy fields less.

Gegear: Yes, less.

Chen: That would benefit the types of bees we were talking about.

Gegear: First of all, if I remember correctly, they have a large wetland area and there's an area that's well-drained, there's a field. I had talked to them about what to put in in those areas and I have more data now, so I was hoping Gloria would be here so I could talk to her about some of those things and see what they've been doing since that time. If there's native grasses in an area, you don't mow at all. Mowing is only to keep invasives at bay. Ideally, you would have native grasses and sedges dominating the landscape, and then you'd have these areas where you have things in bloom. Grasses and sedges are just as important as the flowers because that's where *Bombus fervidus* is gonna be nesting. You need to have large areas with taller native grasses that don't get mowed, and you have to think about mowing regime if you've got invasives. You want to selectively mow. I don't know what their invasive issue is, but you need to think about when you mow. Having a fall cleanup is a no-no because that's all the habitat. The leaves serve as an insulating layer for the bees that are digging into the ground to overwinter. Unless you have invasives, you shouldn't touch anything. If you have invasives, then that's a whole other strategy that we would need to discuss 'cause I'd need to know where they are.

Tartaglia: I believe that they typically mow in the late fall. That's what they were doing when we visited last year. We visited in August, didn't we?

Chen: August, September? I think September.

Gegear: Right, so if there're grass-dominant areas, only half of it should be mowed. You shouldn't mow everything from year to year because when you mow it, the grass isn't there for the bees to nest in. The bees are using a [21:38.0 unclear] or tufts of grass, and when you mow you just destroy everything. *Fervidus* won't nest anywhere else. If you don't have long grass,

fervidus is in trouble. It's gonna find an area with long grass. If you leave strips of long grass, which is what I'm doing at all of my sites across the state, then *fervidus* will find those nest sites. That's what happened last year at two sites because of Covid they didn't mow and *fervidus* nests showed up on those sites where they'd mow every year before that and there were no *fervidus* nests. It's similar with the willow. When you're mowing, if you mow the willow, which people often do, that resource is gone in the spring, and so a lot of places, I've said, "Don't mow the willow," and the first year that they didn't mow, I had queens, bumblebee queens and butterflies and everything else on those willow in just one year, and the second year they didn't mow, the number tripled. Mowing is not a good practice in general. It is needed for invasive species pressure, but it can be done in a way that is selective and more beneficial. It's like a patchwork mowing strategy where you leave an area that's grass-dominant for a year and then you mow it the next year and let another area go through the winter so that that habitat is always there.

Chen: I think Gloria mentioned they have someone who is managing bees on the Rauscher Farm site, standard honeybees. Would there be any interference with that? They having more than we anticipated, more species of bee come in? Are there ways to manage which bees we can get and which ones we're trying to bolster, which ones we don't want necessarily? Is that something we should be looking out for?

Gegear: Yes, definitely. The species on my list are preferred by honeybees typically. Honeybees don't like to pry open tubular flowers that are typically bumblebee-pollinated, and they certainly don't have a long tongue. They have a very short tongue which is why everybody wants to throw composites in everywhere because honeybees love anything with a short tube or a shallow flower. If you put things on my list at the sizes, meter square, those honeybees will be deterred, and they'll go off and visit other things. Tongue length is to your advantage when it comes to honeybee issues. Anything, even the pollen I haven't seen honeybees collecting pollen from the pollum plants that the bumblebees are, which is good. They tend to go to non-natives. Everything on my list targets, that's the whole point of the list is to target the ones that need it. I would say that with the other bees, just like with the bumblebees, you need nesting habitat. You need the nesting habitat to be close to the floral resource. For nesting habitat, they like a sandy, dry, bare soil, sandy soil. You dig down about four inches and you fill it with the sandy loam mix, and you get a good-sized area there. You can build up certain areas so you've got more of a 3D effect. You need those nests sites as well, 'cause if you don't have nest sites, again just like the host plants, you can plant all you want flower-wise and you're not gonna get anything because they don't have a place to live or overwinter.

Tartaglia: You said the grassy areas are for *fervidus* and sandy soil is…

Gegear: Sandy soil is for other bees that are at risk that are on the list on my website. There are a good number of them. Some of them are in and out by way of those other bees. Their cycle is

done by the beginning of June, so if you don't plant things that bloom in good number before June, that species is gonna be in trouble because it has nothing to eat. They don't like non-natives. They don't want to live on dandelion and other junk that's around, non-native-wise, that's what I mean by junk. You've gotta really make an effort to load up the spring with all of these things. Every single "pollinator habitat" that I've ever seen, that's the problem. There are bees out feeding and these things are still dormant and they don't come into bloom until June and these bees are already gone. Bumblebees need that source of food to get enough to build their nest and get the first brood of worker bees out. If they don't have pollen source, it's just not gonna happen. You can kill a population before June for sure. Those early months right out of spring, out of hibernation, are critical.

Chen: Is there a proximity? You mentioned you want the nesting area near the floral arrangement. Is there an ideal proximity within a certain distance you want it?

Gegear: I have a student looking at this for butterflies, how close does the host plant and the nectar plant need to be? What's their range? Bumblebees can fly a mile from their nest, but the smaller bees, we're just talking about a few hundred feet. You wanna have this nesting strip close to the floral resource just to be safe.

Tartaglia: What about sources of water? Do bees need additional sources of water?

Gegear: Not bumblebees. They get it from nectar. Butterflies puddle, but at Rauscher it's a wetland so I don't think that's gonna be an issue. Honeybees need water but no other bees do.

Tartaglia: That's good to know.

Gegear: You need water for the plants.

Chen: To wrap up, I got a good sense for this, but I feel like you have so much more experience in this obviously, I want to know what you feel should be our real focus. What do you think will have the most bang for our buck if we really took the time in and researched it down? What is something that people say is important but might not be as important for us? If we had to really sit down and focus on that, perhaps the ecological system you were talking about.

Gegear: What are your plans for the agricultural side?

Chen: We just wanted to know what we could do. At the start of this project, our project statement was something along the lines of "raise awareness for pollinators" and form a plan for conservation. At its core, we're trying to just provide a means to educate the public on what they can do to help bolster the declining populations and provide a means to bolster that population at

Rauscher Farm. Do you think the pollinator garden would be most beneficial, or just generally putting together plans, maybe over the next two-three years at Rauscher Farms, implementing and changing how they manage the landscape to make it a better habitat for *Bombus fervidus* and *Bombus vagans*.

Gegear: First of all, I would say that you should include everything. Don't just focus on bumblebees, because this bee-centric view has to change. There are butterfly-pollinated plants that aren't looking for bumblebees or any other bees. There are other animals that are not looking for bumblebees. Again, agriculture has biased public perception of pollinators, and certainly bees are important but they're not the only thing that's important. Flies are just as important or more important than bees for a lot of plants. The plants are targeting the flies. It's more of a biodiversity, again pollinator system. You want diversity of pollination systems and maximize those in the habitat because you'll get maximal ecosystem diversity and functioning coming out of it. For example, if you have a wide range of native plants, that increase carbon sequestration. What gets into the soil, you don't want non-native plants, you want a diversity of native plants. You want to increase the complexity of forested areas. That's just not with trees but understory and shrubland. All of that increases carbon sequestration, water purification, and they have a wetlands system. The native plants are doing that. It's gotta be beyond just pollinator garden to pollination system and biodiversity conservation. That's what people need to be aware of. I would say that when you create something, management is part of it. What do they have? I know they have mimulus on site so you need to do an inventory of what they have and add things to complement what they already have, and do it in a way that gets integrated into the landscape if you can, and if you can't, you're putting in certain areas that are habitat that would have signage or something that would increase public awareness of things. If education is their view, the people need to know what they're looking for first of all. I run a lot of workshops to teach them how to spot a *vagans* or a *fervidus* versus the eight other species that they may encounter, certainly tell the difference between the common species like *Bombus impatiens* and those other ones. I'm expanding things as I said to include butterflies. I see lots of butterflies but how do I know they're at risk butterflies? Well you need to know be able to ID the butterflies at some level, so I've got students that are making sheets like wanted posters so people could take them home and see what's in their garden, add things, and really participate in the science part of it. Management is one thing and public education is a separate thing. You can pick one of those two to focus on. Management takes a lot more work because you need to know what's there to implement an effective management plan. If you wanted to add an area that could be used as habitat and public education similar to what I'm doing then I would say you want to put things in that certainly cover bumblebees, other bees, and butterflies, and also that are good to attract certain birds that you may see. You can develop a plan that way and then you get signage on site to educate the public on "do you see this bee" or however you want to do it. That's what I'm doing at my sites across the state. I run these training sessions to get the public aware.

Morris Interview Transcript

2/17/21
Interviewers: Joy Tartaglia, David Chen
Interviewee: Matthew Morris

Tartaglia: So, the 1x1 meter grid, how many of those should we plan for? We know we need flowers for every season, but how many of those squares should we plant?

Morris: I can't give an exact answer because a lot of pollinator research, it's still budding. That meter square, that's still even not a hundred percent researched yet but what's the best practice. The latest I know is that, I have two understandings. I don't know which is right. One is that you need just for one type of plant. So say, penstemon, you would need a meter square of that one plant for the bees to find it. Or you need a meter square worth of plants in bloom at any given time. So I don't know which is true or how much it matters. Based off of my judgement I would say that a meter square of total things blooming at one time would be important. I think a good person to email this question to would be Rober Gegear who used to be a professor at…

Tartaglia: Yeah.

Morris: You know him. Know of him. That's the best answer I can give.

Chen: We talked to him yesterday actually.

Morris: Oh nice.

Tartaglia: Also, about plants, we understand that variety is very important, so I assume that we should try to plant flowers that will attract the two bees, the two bumblebees that are in decline, that would be *fervidus* and *vagans*, so for flowers that will attract both, according to the plant list both bees will go to the same flower, is that one meter square of that is enough for both or should we plant more?

Morris: I think if they're just the one meter square I think both will use it. I think that should be fine.

Tartaglia: So it's enough for both?

Morris: Yeah.

Tartaglia: Okay. Now we know honey bees are definitely not our target and may be detrimental rather than helpful, and on Rauscher Farm at the moment there are five hives. Should they go? Completely?

Morris: I would say yes, or I guess a couple questions. Are those hives owned by the farm?

Tartaglia: They're owned by one of the committee members, not the farm specifically.

Morris: With this project in mind and the goal of helping these at-risk bees I would ask them to remove those hives because one, they have the competition for our at-risk native bees as well as potentially introducing some disease, and also in the northeast, honeybees aren't really necessary for even agriculture because we're not at the large scale where it needs it, and so keeping bees in this region is purely recreational and not really needed. There's not much of an agricultural need or really there's definitely not an ecological need either. I would ask for those hives to go.

Tartaglia: Okay. It felt a little bit awkward bringing that up to the person in particular because they're one of the people interested in conservation and it's just… yup. The next question, about the plants, are we choosing the plants and then finding a location or should we try to find a suitable location first and then the plants that will grow in that place? Because Rauscher farm has a lot of different habitats. They have a pond, forests that used to be agricultural, they also have a lot of wetlands and there are some drier hills and fields. Considering that the bees are ground nesters, should we also, kind of connects all those different areas, the fields do, what should we consider when choosing the location and the plants to grow?

Morris: I would definitely choose the site first and then the plants. When looking for a site, I would look for a spot that's easy to get to and easy to take care of, but also lower chances of erosion, so the garden literally just being washed away by a big storm, so probably like a hillside or even top of the hill might not be the best spot, so maybe something a little more in the lower area. Site conditions matters 'cause if you're going for those two at-risk bees, think most of those plants on that list, they tend to like more sunny and more medium soils.

Tartaglia: Medium as in wetness, dryness.

Morris: Yeah.

Tartaglia: Okay. Does the quality of the soil matter or will we be planting, putting a lot of mulch there, fertilizer?

Morris: I don't think so. I think that as long as there's low weed pressure and the plants have that first care for the first year, I think that they'll be fine on their own.

Tartaglia: Okay. That's good to know. There's also a small invasive species issue, I believe bittersweet, when we visited the farm there was an entire section where they had to cut away the bittersweet. One of the locations that they are considering planting the garden is kind of close to that, which means they will have to mow. They do mow I believe every other year currently. We've heard that patchwork mowing is advised in order to leave areas for nesting. Also considering the location of the farm - considering the bittersweet, should there be patchwork mowing around the bittersweet as well or…?

Morris: Is this to just kind of control the bittersweet or just get rid of it?

Tartaglia: Currently they're controlling it.

Morris: I think mowing will be good to keep it at bay, but if they eventually want to control it, herbicide might be the best option. I don't know how close you'd want to put a pollinator garden where you're doing a lot of work, especially if they will later introduce herbicide for that bittersweet.

Tartaglia: That is something to consider. I believe those are most of the questions about the garden itself. Are there any other challenges we can possibly expect to encounter? Some typical difficulties?

Morris: Yeah. One that pops in mind immediately is making a garden like this, it's new so a lot of the plants for this garden aren't super available so something to keep in mind is that it will be a challenge to find all the plants and get them all together. You'll definitely have to visit multiple nurseries throughout the season because native plants are typically only available when they're in bloom, so definitely plan for that. Another thing, I'm sure you know that it's important to provide nectar and pollen from April to October and all that. All the plants that the golden northern bee uses, they're also used by the half black, so if you just plant for *Bombus fervidus*, you're pretty much covered for the other one as well. That can kind of limit that huge list from a hundred plants to thirty plants to browse through. You asked if I had any resource to share, and I'm just going to share my screen.

Morris: On the website for the Native Pollinator Task Force, we have this pollination preservation toolkit, so here's a bunch of things that you might find useful, one of which is the plant lists as well as some excel versions including one just for *Bombus fervidus*. When you're planning the garden, this is just a blank sheet where you can just write in the plants and see what's covered when to help you plan. With finding the plants, this can be challenging, so these three sources, they'll tell you which plants you should be able to find where.

Tartaglia: Yeah, those will be helpful. David, are there any other questions that you have?

Chen: I honestly think that you covered them all. You did a really good job.

Tartaglia: There are just a couple other questions unrelated to the farm itself, but still to the topic. Breakneck Hill isn't terribly far away so we can probably visit it ourselves at some point. Are there any other locations that you know of? Other pollinator gardens that we can visit?

Morris: There's the Birches School in Lincoln, Mass. It's a little further from Worcester, but that's definitely a recent planting where they used all of these plants to create a habitat for these at-risk bees. The Birches School in Lincoln, there's also the Places for Pollinators Meadow also in Lincoln. I don't know exactly where that is. That's really it for now for gardens that are already kind of up and running. A lot of them are still in the planning phase. The Native Pollinator Task Force is trying to get people like you guys to start to make these gardens so as more time goes by hopefully there'll be a lot more.

Tartaglia: Yeah. Can you recommend other people to talk to besides Gegear who we have already contacted?

Morris: Yeah. I'm from the Native Pollinator Task Force. There's Freddie Gillespie, she's also from the Task Force and has a lot more experience with this than I do and a lot more experience making gardens than I do. There's Evan Abramson who works with Gegear a lot. He makes a lot of design plans for these types of gardens.

Appendix B: Plant List Selected for Rauscher Farm

Early Bloom time (March - May)

Scientific Name	**Common Name**	**Pollen or Nectar Source**	**Bloom time**	**Plant Type**	**Light**	**Soil Conditions**	**Supports**	**Plant at Risk?**
Salix discolor	Pussy Willow	Pollen (male) Nectar (female)	Mar - Apr	Shrub	Full	Med, wet	*Bombas vagans*, butterflies (female plant), other bees	No
Salix occidentalis	Dwarf Prairie willow	Pollen (male) Nectar (female)	Mar - Apr	Shrub	Full, part shade	Med, dry	*Bombus vagans*, butterflies (female plant), other bees	No
Salix humilis	Prairie Willow	Pollen (male) Nectar (female)	Apr - May	Shrub	Full, part shade	Med, dry	*Bombus vagans*, butterflies (female plant), other bees	No
Salix petiolaris	Meadow Willow	Pollen (male) Nectar (female)	Apr - May	Shrub/ small tree	Full, part shade	Med	*Bombus vagans*, butterflies (female plant), other bees	No
Pediculans canadensis	Wood betony	Nectar	Apr - May	Perennial Herb	Full, part shade	Wet, med, dry	*Bombus vagans*, *Bombus fervidus*, butterflies	No
Ilex opaca	American Holly	Nectar	Mar - June	Tree	Full, part shade	Med, dry	*Bombus vagans*, butterflies	No

Mid Bloom Time (June - July)

Scientific Name	Common Name	Pollen or Nectar Source	Bloom time	Plant Type	Light	Soil Conditions	Comments	Plant at Risk?
Hypericum ascyron	Great st. John's-wort	Pollen	July	Perennial Herb	Full, part shade	Med	*Bombus vagans*, other bees	Yes
Hypericum majus	Greater St. John's - Wort	Pollen	July - Sept	Perennial Herb	Full, part shade	Med, wet	*Bombus vagans*, other bees	Yes
Rosa acicularis	Bristly Rose	Pollen	June - July	Shrub	Full, shade	Med, dry	*Bombus vagans*, other bees	Yes
Rosa nitida	Shining Rose	Pollen	June - Sept	Shrub	Full, part shade	Wet, med	*Bombus vagans*, *Bombus fervidus*	No
Rubus odoratus	Flowering Raspberry	Pollen	June - July	Shrub	Full, part shade	Med	*Bombus vagans*, *Bombus fervidus*	No
Asclepias purpurascens	Purple Milkweed	Nectar	June - July	Perennial Herb	Full, part shade	Wet, med, dry	*Bombus vagans*, butterflies	Yes
Acelpias verticillata	Whorled Milkweed	Nectar	July - Sept	Perennial Herb	Full, part shade	Med, dry	*Bombus vagans*, butterflies	Yes
Baptisia tinctoria	Yellow wild indigo	Nectar	June - Aug	Perennial Herb	Full, part shade	Wet, med, dry	*Bombus vagans*, *Bombus fervidus*, butterflies	No
Cirsium horridulum	Yellow thistle	Nectar	June - Sept	Perennial Herb	Full	Med, dry	*Bombus vagans*, *Bombus fervidus*, butterflies	Yes
Penstemon hirsutus	Northeastern Beardtongue	Nectar	May - June	Perennial Herb	Full, shade	Wet, med, dry	*Bombus vagans*, *Bombus fervidus*, butterflies	Yes

Late Bloom Time (August - October)

Scientific Name	Common Name	Pollen or Nectar Source	Bloom time	Plant Type	Light	Soil Conditions	Comments	Plant at Risk?
Hypericum majus	Greater St. John's - Wort	Pollen	July - Sept	Perennial Herb	Full, part shade	Med, wet	*Bombus vagans*, other bees	Yes
Hypericum punctatum	Spotted St. John's - Wort	Pollen	July - Sept	Perennial Herb	Full, part shade	Med, dry	*Bombus vagans*, butterflies, other bees	No
Spireaea alba	White Meadowsweet	Pollen	June - Sept	Shrub	Full, part shade	Wet, med	*Bombus vagans*, Bombus fervidus	No
Rosa nitida	Shining Rose	Pollen	June - Sept	Shrub	Full, part shade	Wet, med	*Bombus vagans*, Bombus fervidus	No
Solidago speciosa	Snowy Goldenrod	nectar	Aug - Oct	Perennial Herb	Part Shade	Med	*Bombus vagans*, butterflies	Yes
Cirsium discolor	Field Thistle	Nectar	Aug - Oct	Perennial Herb	Full, part shade	Med, dry	*Bombus vagans*, *Bombus fervidus*, butterflies	No
Cirsium muticum	Swamp Thistle	Nectar	June - Oct	Perennial Herb	Full, part shade	Wet, med	*Bombus vagans*, *Bombus fervidus*, butterflies	No
Cirsium horridulum	Yellow thistle	Nectar	June - Sept	Perennial Herb	Full	Med, dry	*Bombus vagans*, *Bombus fervidus*, butterflies	Yes

Appendix C: Photos of Rauscher Farm

Invasive oriental bittersweet suffocating a tree

Invasive oriental bittersweet reaches the top of a tree

Suggested pollinator garden location, facing east

Suggested pollinator garden location, facing south

Suggested pollinator garden location, facing southeast

Suggested pollinator garden location facing northeast