Tree Species Surveying at Rauscher Farm: Project Report

Interdisciplinary Qualifying Project

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By:

Lauren Faulkner

Megan Haley

Patrick Salisbury

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Professor David I. Spanagel

Department of Humanities & Arts

Abstract

Forests are vital ecosystems in New England that have been managed by humans for centuries in North America. In order to choose the best forest management methods, information on the forest's composition and condition must be acquired. Rauscher Farm, a conservation space in Clinton, Massachusetts strives to preserve the natural beauty and biodiversity of its land. This IQP was tasked with understanding and providing solutions for the problems facing the farm created by climate change. The IQP team designed a tree survey to provide data on the species and health of Rauscher Farm forests. Our survey methods will be a blueprint for other surveying events, which will provide data to ensure Rauscher Farm volunteers can work effectively to maintain ecosystems resilient to climate change.

Acknowledgements

The team would like to thank our project advisor Professor David Spanagel for advising us in our endeavors. We especially want to thank our sponsor Gloria Parkinson and the RFMSC for providing guidance and assistance throughout the project. The team would also like to recognize Professor Stephen McCauley and his project team for allowing us to use materials developed in their report, *Elevating Citizen Science Through an Evaluation Rubric.* Additionally, we also extend our thanks to the volunteers who attended our tree surveying event.

Executive Summary

Rauscher Farm occupies a 62 acre conservation and open space located in Clinton, Massachusetts. The area is open for public enjoyment, and features woodlands, wetlands, and grasslands. Goals of the farm's management include providing a space for nature recreation, educating visitors, and preserving the ecosystems for future generations to enjoy. Recently, the Rauscher Farm Management Subcommittee has developed concerns on how climate change will impact the farm, and how best to counteract its effects.

Studying a region's trees can provide vital insight into the past, present, and future of the area. Forests are a prominent feature in the New England landscape and home to a variety of important species. However, human intervention and the increasing force of global climate change puts these habitats at risk. Various forest management strategies are available to prevent and treat the effects of climate change, building more robust, resilient forests. Because each forest is unique, understanding the forest's composition is the first step to documenting, assessing, monitoring, and where possible treating climate effects.

The team researched the impact of climate change on the various species found in Massachusetts. Under recommendations from project sponsor Gloria Parkinson, the team focused on the influence insects have on forest ecosystems. Various methods of assessing the well-being of the entire ecosystem and specific species were explored. Use of tree damage as an indicator for invasive insect presence and wider forest health was found to be particularly important.

Building upon Rauscher Farm's previous volunteer and educational events, the team designed a tree surveying event. Educational resources were developed to teach untrained volunteers how to identify tree species and signs of tree sickness or damage. Data was collected

on a section of new-growth forest. Afterwards, analysis was done to determine trends in species distribution and tree health.

The results of the tree survey revealed that the survey area spans several forest subtypes in a relatively small patch of land. The eastern end of the survey area was rich in birch and oak trees, while in the middle of the survey area the birch trees suddenly disappeared and were replaced with a more diverse forest habitat. Some tree species, like maples, were found exclusively in the lower elevations within the survey area, revealing that these trees may prefer wetter soil conditions. Many of the oldest trees in the survey area were found bordering the stone walls as a direct result of the land use history of the farm. The survey did not find any abnormal or unexpected damage during the survey, however the high concentration of dying young pines in the survey area may become important if a similar situation is found across the rest of the farm forests.

It was important for our project to act as a blueprint for the Rauscher Farm Management Subcommittee. The team's methodology and recommendations can then be used to replicate similar surveying events in the future. Just because one survey found a relatively healthy forest habitat does not imply that other areas of the farm are similarly healthy. In order to fully understand the problems facing the conservation area, the managers will need information from various parts of the farm throughout the year. Repeated surveys will provide data to be used to ensure focus and resources go to the highest priority concerns, and that the best possible interventions are used to solve problems.

Table of Contents

1. Introduction

Climate change has affected many areas of life that most people are not aware of. A common example of overlooked climate change impacts are the damages that can be done to many tree and plant species (Connecticut Department of Energy & Environmental Protection 2021). Many meteorological and climatic changes have been the underlying cause for a decrease in specific tree populations.

Last year, New England experienced a historically high average temperature for the summer. Tree and plant species suffered due to the massive drought that decreased the volume of, and in some cases dried up numerous lakes and ponds. There are trees that are present within the northeast that are not necessarily drought resistant. Deciduous trees like oak and birch will drop their leaves prematurely when undergoing drought stress, sometimes before the autumn season begins. This untimely accumulation of organic matter impacts the animal and plant species that are primarily confined to the floor of the forest, such as small bushes, ferns and non-climbing mammals. With much of the forest floor covered, it becomes harder for some animal species to access their food.

Diversity among tree species within a forest carries great importance (Tang et al. 2022). Without diversity in a forest many individual ecosystems would not survive. For example, if suddenly, there were to be no more oak trees in a forest, the squirrel population would rapidly diminish. Oak trees produce acorns, a major food source for squirrels, but is also a secondary food source for other land mammals such as deer, mice and rabbits.

When considering the actual damage caused to the trees, climate change has cast a great toll. As previously mentioned, during a drought deciduous trees can sometimes lose their leaves prematurely. When a tree loses its leaves too early, it doesn't generally harm the tree to the point of dying, but too many consistent years of abscission can cause the tree to weaken and eventually die. Furthermore, lack of water can cause many other forms of damage to a tree, such as root damage and wood rot. Younger trees also have a higher sensitivity to drought, along with damage. Due to their age and lack of leaf coverage, young trees can be considered 'drought resilient' while older trees can be considered 'drought tolerant'.

Further damage has been caused to native trees by invasive insect species. As a result of human intervention, through foreign firewood and travel, many invasive insect species have been introduced to the forests of New England. These species are usually temperature sensitive and would die off in the winter; with the shorter and warmer winters created by climate change, the insects have been able to spread. Given the right conditions, these invasive insects can severely damage or even completely destroy entire populations of trees. As these insects continue to spread north due to their habitable range increasing, efforts must be undertaken to prevent previously unthreatened tree populations from falling victim to the spread of these pests.

We, the students of Worcester Polytechnic Institute (WPI), had the pleasure of working with the amazing citizen members of the Rauscher Farm Management Subcommittee (RFMSC) for the duration of the project. In September 2022, a team of students formed an Interactive Qualifying Project group to address issues that were brought forward by the RFMSC. The story of the farm and how it came to be was shared by Gloria Parkinson, one of the members of the subcommittee. Some of the information shared include land management practices, general habitat facts, and a brief history of the farm. The farm currently functions as an educational outlet as well as a place for visitors to take in nature on some of the walking trails. The farm has a long-term goal of keeping these 62 acres of varied natural habitats as an open space for all to enjoy. The work that the RFMSC puts into caring for the farm to achieve this goal is evident in their care and appreciation for all that step foot onto the land.

Since climate change is such an important issue facing the farm in the future, it was only natural that a project focusing on preserving the farm in the future would take on a focus relating to climate change as a whole. Due to the seasonal constraints presented by the project, the team chose to focus on how climate change might affect the forests of Rauscher Farm, as opposed to the other habitats found on the property. During the research phase of the project, we discovered that there was very little, if any, data on the Rauscher Farm forests as a whole. Instead of trying to work around this lack of data, the project team decided to instead focus specifically on providing this data as their project focus. Not only would this data be important in the present for detecting how climate change was already affecting the forests, it would be even more useful in the future as a benchmark to gauge the cumulative impact of climate change on Rauscher Farm.

2. Background

2.1 Rauscher Farm

2.1.1 Brief History of the Farm

Rauscher Farm is a 62 acre conservation and recreation area owned by Clinton, Massachusetts. Previously a working dairy farm, the land is now an open space managed by the RFMSC, under the Clinton Conservatory Commission. The committee is focused on providing recreation, habitat enhancement, and seasonal events for visitors to enjoy. The conservation area hosts grass pastures, woodlands, and wetlands. When the farm was purchased by the town in 2008, a management plan was created for the new open space. Their goals are to preserve and protect the natural environment and encourage species diversity, to make the space a natural refuge for visitors of all ages to enjoy. Currently, the RFMSC is working with a variety of experts to write a new, adaptive management plan with sustainability in mind (Clinton Conservation Commission 2008).

2.1.2 Rauscher Farm Forests

The Rauscher Farm forest habitat is a textbook example of the variegated new growth left behind by total land clearing. Although there are older individual tree specimens, the average age of the trees reveals that the forests were previously used as fields. The southwestern forest of Rauscher Farm near Clamshell Pond is labeled in the forest management plan as a white pine/hardwood forest area. Preliminary surveys conducted by the IQP team revealed that the primary species in this forest area are white pine (as noted), various oak species, black birch, and the occasional paper birch and maple scattered throughout.

Understanding a more specific forestry composition is very important when studying invasive pests; as an example, this forest area would be unlikely to be affected by species like the hemlock wooly adelgid simply because there are no hemlock trees to be attacked. On the contrary, the lack of tree species diversity in some areas of the forest means that a single invasive insect species could be devastating to a huge number of trees. Some examples are the spongy moth, which tends to feed on oak tree species, and the Asian longhorned beetle, a species that feeds on the birch trees present in the forest and was devastating enough to the Worcester area that an entire section is devoted to the pest.

The intricate forest composition on the farm has important implications for preparing for climate change as well. Inevitably, new invasive insects will be introduced into the region in the future, and the increasing temperatures in the region will enable invasive species to spread further north and infest new areas of forest that were previously out of their temperature range. As drought becomes more common, understanding which regions of the property have more drought-tolerant species enables one to build a more clear future forest health outlook. As acid rain continues to fall, the pH of forest soils is lowered, and certain species are damaged while others flourish. Whatever happens to the forests of Rauscher Farm in the future, having a deep understanding of the forests themselves and what species are present is the first step to ensuring that the forests continue to thrive for future generations.

2.2 Historical Perspectives

2.2.1 The History of New England Land Clearing

For too many generations of previous scholars, it has been customary to start an examination of land clearing in North America at the start of European settlement in the region. To examine the real history of the clearing of forests, however, the story begins far, far earlier. At the same time as the first large civilizations were being formed around the world, the first large-scale land clearing was taking place in the river valleys of North America. These early American civilizations were clearing forested areas for cultivation starting at least 10,000 years ago, dating almost twice as far back as the beginnings of ancient Egypt (Williams 2002, 63). For millennia, these clearings were either foraged or planted with many of the primitive crops of the region that they resided in. Although this type of land use is completely different from the more modernized, highly productive type of farming that the Eurpoeans would later bring, it formed a clear foundation for how land would be used in the future.

Around AD 1000, maize was introduced from Central and South America into North America, transforming how significant land clearing would shape the forests of the future (Williams 2002, 64). Unlike past crops, maize was productive enough to become the primary component of the diet of many of these early Americans. As a grain, it could be processed and preserved to last for the length of the winter as a food supply. The pollination requirements of the crop meant that it benefited from being planted and cultivated very closely together in completely clear fields. Most importantly, the crop was productive enough to support large numbers of people for a given cultivation area, giving rise to larger and larger villages and eventually civilizations.

With larger villages came exponentially larger lumber needs. Villages with populations ranging from 50 to 1500 people often had exhausted the lumber supply for miles in every direction from the village center (Williams 2002, 65). Beyond this area, clearing still took place in the form of fire hunting. This fire hunting was very impactful; when settlers arrived in Rhode Island, they found that the Narragansett had cleared the land for timber and through fire hunting for 8-10 miles inland from the coastline (Williams 2002, 67). Similar clearings occurred throughout southern New England, and many 17th century European settlers described the "open" feeling of the forests of the area without realizing this was actually due to the clearing of land by Native American fire. When contrasting these open forests with the much more dense, nearly impossible to travel through forests of northern Maine, it becomes clear how much the forests had already been changed before the Europeans ever arrived (Cronon 1983, 25-33).

The arrival of the Europeans meant the start of the final, most aggressive period of land clearing. The natives now had access to the steel hatchet, a potent tool that significantly increased the rate that trees could be felled. By this time, Native American villages were inhabited by enough people and clearing forests fast enough to where they had to change location every few decades due to running out of nearby resources (Williams 2002, 69). Obviously, the forests did not immediately grow back when the village relocated, increasing the amount of cleared land per individual by quite a significant amount. One estimate places this amount of cleared land in North America at 8.7 million acres, based on pre-European population estimates (Williams 2002, 70). This very significant amount of already cleared land, coupled with the imminent arrival of the Europeans and their forest-destructive agricultural practices, meant that by 1700 the forests of New England were already spiraling towards disaster.

2.2.2 Colonization and Wasteful Cutting

When colonists first arrived in New England, one of the first known plentiful resources in the area was the forests. However, this resource began to dwindle far earlier than one would expect. Even before the American Revolution, there were many areas, particularly the larger cities, that were running out of wood for various purposes. In *The Northeast's Changing Forest* Lloyd Irland mentions that "in Boston as early as 1637-1638, fuelwood was running seriously short" (Irland 1999, 239). This shortage meant that even during the early days of colonization, wood had to be transported from rural areas to the larger cities to meet the fuel and construction budgets of their inhabitants. The poor felt the effects of this the most, as they struggled more than others to acquire wood for heating through this method.

By the 1690's, lumber was beginning to become a major export of New England. The Broad Arrow Acts, passed in 1691, reserved all large pine trees with a 24 inch or greater in diameter trunk for the King (Irland 1999, 240). This act directly led to the decline of the large pine tree in many of the coastal regions of the area, where the massive trunks could most easily be transported out of the forests and onto ships. For the next century, local timber supplies were increasingly exploited as populations, and therefore lumber and firewood requirements, continued to grow. By 1850, local shipyards in New England began importing lumber from other regions to build ships (Irland 1999, 242). This was truly the peak of forest clearing in the region; after the mid-1800s, there simply was not enough remaining forest left in the region to support the industry. In fact, the forests had been exploited to the brink of devastation. Irland notes that "A search of state board of agriculture reports from the Civil War to the turn of the century will yield a large harvest of essays and speeches decrying forest destruction and urging planting, research, and fire control" (Irland 1999, 244). Without serious changes, the forests of New

England would no longer exist in a matter of decades. A nearly nonexistent timber budget meant that many companies would simply clear as much land as they could afford, leading to wasteful cutting and a loss of timber resources.

It would take until after the Second World War for sawtimber trees (trees large enough to process in a sawmill) in New England to start making a comeback. Once this reforestation and maturation process began, the increase in reclaimed forest acreage, combined with smarter budgeting and utilization of timber resources, meant that the timber inventory in the northeast doubled in the second half of the 20th century (Irland 1999, 248). However, much of this timber was either young or of low quality due to the various diseases and pests the northern forests have endured over the past century. These vulnerabilities, exacerbated in some cases by monoculture forest management practices, rendered much of the forests usable only for firewood, making it difficult to harvest and sell the amount of trees needed to maintain timber productivity.

2.3 Climate Resilience

2.3.1 What is Climate Resilience?

Ecological resilience refers to an ecosystem's ability to survive through and adapt to change. The species and physical conditions of an area constantly influence one another, balancing the ecosystem into a state of equilibrium. However, changing conditions tip the scales, forcing the system to rebalance itself. Ecological resilience measures how large of a disturbance an ecosystem can endure before its behavior changes so much that it effectively shifts into a new, different equilibrium state (Gunderson 2000, 426).

Climate change creates a variety of stressors that disturb ecosystems, including rising temperatures, longer droughts, and harsher storms. Climate resilience refers to an ecosystem's fortitude in the face of these changes. The level of climate resilience largely depends on the species in the ecosystem and their individual abilities to adapt. Various species have different abilities to adapt to the stress of climate change, and each species will influence others in the ecosystem. For example, the mutualistic relationship between pollinators and flowers means a stressor affecting one will also affect the other. Biological interdependence can cause a domino effect that affects the entire ecosystem. All ecosystems have some resilience, as they've evolved to cope with natural fluctuations, but climate change is pushing many past their limits (U.S. Climate Toolkit 2021).

2.3.2 Massachusetts Climate Change

Massachusetts has warmed 3.5°F in the last century, with New England as a whole heating faster than any other region in the continental U.S. The state's geography exposes it to the influences of the Atlantic Ocean, air masses from the interior states, and the jet stream, all of which manifest consequences of global warming. The state is vulnerable to extreme weather at both ends of the spectrum; droughts in 2016, 2017, and 2020 diminished water supplies, while huge rain storms dumped 19" on parts of the state in 2010. As greenhouse gas emissions continue to raise temperatures, heat waves and extreme precipitation events will increase, adding stress to the region's wildlife (Runkle et al. 2022).

2.4 Invasive & Pest Insects

2.4.1 The Asian Longhorned Beetle

The Asian Longhorned Beetle (ALB) is, bar none, the most destructive invasive insect to ever arrive in New England. No other damaging invasive insect is so generous with preferred species of trees, so damaging to the host tree, and so hard to control and eradicate. Where the beetle has taken hold, the forests have already been severely damaged. In 2008, 25,000 trees had to be cut down in the Worcester area to control a beetle outbreak, fundamentally changing the appearance of the landscape (Cartolano 2021). Even as beetle detections wane, all it takes is one infected tree to spell disaster for an entire forest. Without vigilance and early detection, central Massachusetts could see a repeat of 2008, or perhaps even worse.

Unlike many other invasive insects, the beetle is somewhat of a generalist. Although it shows a strong preference for maple trees, the beetle will feed on other species like birch, elm, and willow if no maple trees can be found. Both the larval and adult forms of the beetle feed on the host trees. Generally, an ALB infection is extremely damaging, and leads to the eventual death of the tree after a few years (NYS Dept. of Environmental Conservation). The beetles tend to prefer the upper larger limbs of the tree as opposed to the lower trunk. This behavior manifests on damaged trees as the dead upper branches fall to the forest floor while the rest of the tree appears completely healthy. These branches can pose a safety hazard to those beneath an otherwise healthy-appearing tree.

Adult females of the ALB usually lay about 90 eggs throughout their lifetime. They chew depressions in the bark where they lay their eggs, generally on the same tree that they hatched from or another stressed or infected tree. (U.S. Department of Agriculture, 2020) The larval stage of the beetle lasts 1-2 seasons, where they spend their time boring throughout the host tree and causing damage. They then pupate within the tree for 13-24 days. (U.S. Department of Agriculture, 2020) Generally, around late June the adult beetles emerge. This beetle emerging is one of the most damaging parts of the entire infection; a 3/8 inch hole is bored from where the beetle hatched to the outside of the tree (NYS Dept. of Environmental Conservation). The process usually results in massive damage to the tree, and a pile of sawdust below where the adults emerged. After hatching, the adults may continue to feed on trees for a couple of weeks, then they lay eggs on another host tree and the cycle continues.

2.4.2 Hemlock Wooly Adelgid

The Hemlock Woolly Adelgid (HWA) is an aphid-like insect originally native to eastern Asia. Only 1.5mm in length, HWAs produce two generations each year, with one generation overwintering. They were first found in Massachusetts in 1988, and chose the Eastern Hemlock as their host species in the region. HWA infestation can be found by looking for their white, wooly sacs along the branches. These sacs appear around March, when the winter life cycle matures into adults. The insects spread by wind and animal movement, and trees growing in stressful conditions are especially susceptible. HWAs feed on Hemlock's sap, stealing away the host's carbohydrates and weakening the tree. Once infested, the hemlock's foliage will begin to deteriorate, typically dying within 4-15 years if untreated (Childs 2022).

There are several methods for managing HWA infestation. Hemlocks should be monitored for signs of HWAs in order to catch infestations quickly, before mass spread. Infestations localized to specific branches can be stopped by cutting off the affected branch and destroying it. Tree-wide infestations are usually treated chemically, through sprays or injections. One option is to spray a mixture of horticultural oils on the tree, a lower-risk option than insecticides. However, with large scale infestations, the insecticides imidacloprid and dinotefuran have been shown to kill off HWAs and protect trees for up to five years after application. Both can be applied via trunk injection, which greatly reduces risk of the insecticide affecting other species like pollinators.

2.4.3 Emerald Ash Borer

Emerald Ash Borers (EAB) are metallic, green beetles that feed on Ash trees. Originally native to Eastern Asia, the beetle was first found in Massachusetts in 2012, and primarily attacks the White Ash and Green Ash in the state. Similar to the ALB, the larvae of EABs are the primary threat to hosts, boring into the trunk and destroying the outer layer responsible for transporting water and nutrients around the tree. This causes even old, large Ash trees to die within 3-4 years. The larvae create D-shaped marks under the bark, and emerging adults create D-shaped exit holes in the trunk. Traps can also be set to catch the EAB, but in some cases infestation will go undetected until the tree is cut down (Simisky 2020).

Chemical treatment is effective for EAB infestations, especially if caught early. However, biological control has been effective at reducing EAB populations in the U.S. Several parasitoid wasp species and woodpeckers are major predators of the EAB, acting as a natural mechanism to keep the insect in check. Measures to attract and assist these predators can prevent trees from succumbing to EAB infection.

2.4.4 Spongy Moth

The Spongy Moth was first introduced to Massachusetts in 1869, and primarily affects oak trees. The moth feeds on leaves, and can defoliate large swaths of forest, slowing tree growth. Although a pest, these moths have been around for so long that they have essentially become naturalized. In fact, some defoliation can lead to understory growth, letting in sunlight to shrubs and younger trees normally blocked by the canopy. There is a biological control in the form of the Calosoma Sycophant beetle, which eats spongy moths at multiple life stages. Generally, treatment and prevention is done to protect individual trees, often large oaks (Mass. Audubon, 2022).

2.4.5 Dutch Elm Disease

Dutch Elm Disease (DED) is one of the oldest cases of an invasive threat causing widespread tree damage in the northeast. Although Dutch Elm Disease is not directly caused by insects, the most common way the disease spreads is through a host insect known as the Elm Bark Beetle (*Hylurgopinus rufipes*). This disease is unique compared to many other invasive threats in the northeast, since the bark beetle that most commonly spreads Dutch Elm Disease is actually native to the area. Although all elm trees can be damaged by DED, the American Elm is particularly susceptible to damage. Because the American Elm is additionally the most common elm tree in New England, DED has caused an immense amount of damage to elm trees across the northeast (Brazee 2017).

Usually, DED damage presents first on a single branch on the tree, as an area of yellowed or missing leaves when the rest of the foliage is green. As the disease continues to progress, adjacent branches become diseased, and eventually these branches completely die and lose their bark. In the late stages of the disease, the entire canopy of an affected elm tree can completely die. Because these dead limbs are attractive to the elm bark beetle, adults will usually lay their eggs on diseased trees, where the larva will burrow into the affected wood. These larvae will then carry the spores of DED to other healthy elm trees after hatching as adults (Brazee 2017).

2.5 Insect Sampling

2.5.1 Sampling Plans

Field sampling is important to understanding species behavior and estimating populations. To ensure success, a variety of factors need to be considered decided upon in the sampling plan. First to consider is the species itself; surveyors must decide which species they will be counting, and how precise they will be in taxonomic identification. For example, a survey could investigate butterflies, only monarch butterflies, or even only young male monarch butterflies. The degree of specificity will impact the survey's complexity, as identification requires both time and expertise. The surveyors then account for known species behavior in the sample plan. Insects in particular will be found at different heights, on different plants, or in different light levels depending on their species and even life stage. To get a representative count, these behaviors must be considered. Next, the size and distribution of the sampling units is chosen. In this phase it is important to balance survey accuracy and constraints. Larger survey areas will provide more data, and smaller sampling units will make that data more robust. However, both come with increased costs in supplies and man-power. Small scale pilot studies, where the money and time put into each step in the sampling plan are tracked, are recommended to help find this balance (Southwood, 2000). The last step in devising a sampling plan is to choose sample collection methods. There are several methods, which will vary in effectiveness depending on the site and the species being surveyed.

2.5.2 Insect Trapping

Insect trapping is a reliable way to get data on species diversity and population estimates. In these cases, insects are captured for identification and study, which can be difficult to do otherwise. However, these methods can injure or kill the bugs captured, and usually result in underestimates for populations.

One common trap, developed by ecologists CG Johnson and LR Taylor, is a suction trap. An electric fan pulls in insects, which are then filtered by a gauze cone and collected in a jar. The trap can also be fitted with a disc-release device, which will drop at predefined intervals to separate catches over time. The trap does not damage most bugs. The benefit of this design is that it is standardized, with known trap efficiency, making it easier to calculate for error. These traps can be set up in most habitats, and require little supervision. However, they do require electricity.

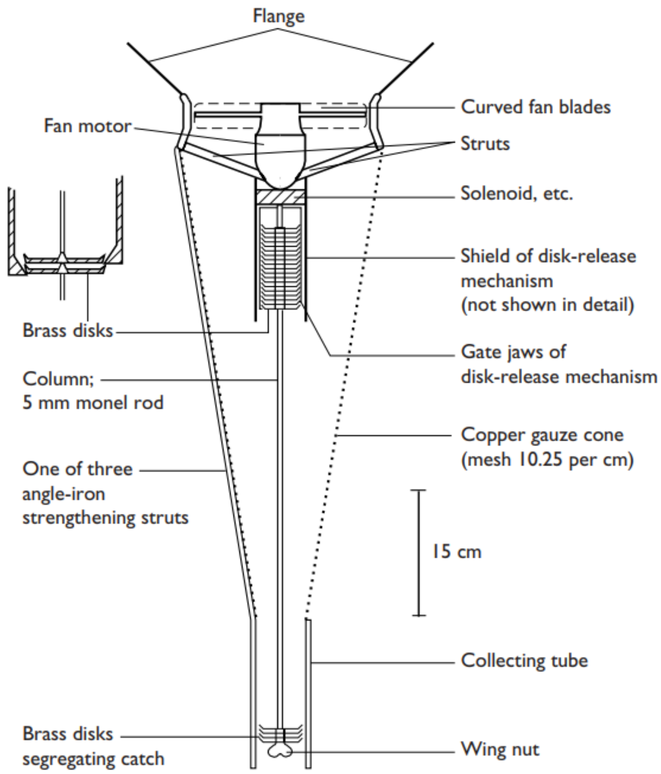

Fig. 4.1 Cross-section of the exposed-cone or Johnson–Taylor suction trap.

Figure 2A: The Johnson-Taylor suction trap described in subsection 2.5.2 (Southwood 2000)

Another easily implemented capture method is light trapping. This method can only be used to study phototactic insects, and must be used at night. A white sheet is hung on a line, and a light is shone on it. Any single, white-bulbed lightsource can be used, though black lights and mercury vapor lights attract more species due to the broader light spectrum. Drawn to the light, insects will land on the sheet. They can then be analyzed right on the sheet, caught in a small net or bottle, or photographed to be identified later. This method requires expertise in visually identifying different species.

Figure 2B: An example of light trapping on moths (NC Parks 2017)

2.6 Tree Species

Rauscher Farm is home to several different kinds of tree. Tree species are typically identified through their foliage; however, in fall and winter, trees can still be distinguished by their bark, trunk shape, and branch characteristics.

Most evergreen trees seen on Rauscher Farm are white pines (*Pinus Strobus*). Evergreens can be identified by their needles, which don't fall off in fall. Their bark is smooth on young trees, becoming rough with age. Mature trees will have vertical bars of bark in scaly layers, the outermost bark gray while exposed inner bark is more tan. Their needles will form bundles of five; white pines are the only tree in the northeast with this feature.

The primary deciduous trees found on the farm are oaks and birches. These types can be further separated into specific species. Black oaks (*Quercus Velutina*) have dark, thin, scaly bark, which can often be seen peeling from the trunk in a vertical strip, and pointed leaves. Red oaks (*Quercus Rubra*) also have pointed leaves, but have thick bark forming long ridges, with a reddish hue in the valleys of the ridges. White oaks (*Quercus Alba*) have thin, scaly bark in light colors, forming thin rectangular scales. They will have round leaves.

Birches can be identified by the horizontal lines of pores in the bark. White birches (*Betula Papyrifera*) are a light, white color, while black birches (*Betula Lenta*) are significantly darker. The wild cherry is often mistaken for black birch, but can be distinguished by their much larger horizontal stripes.

Other, rarer species on the farm include maple, poplar, and sassafras trees. Maples have relatively smooth bark, and their branches will grow with opposite branch arrangement, while all others on the farm have alternating branches. Poplars have deeply ridged bark that form diamond-shaped depressions. Sassafras trees have similar bark to poplar trees; however, sassafras trees have very curvy, angled trunks, while poplars grow very straight.

2.7 Citizen Science

2.7.1 Citizen Science Rubric

Citizen science is defined as “scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions” (OED Online, 2023). Citizen science includes projects such as taking a bird census, or collecting weather data (Simmons 2023). Hosting citizen science events engages the public and allows for professional scientists to collect many data sets, which they may have had great difficulty collecting on their own. Using a rubric for citizen science projects allows for uniform data collection, as well as easy to follow instructions for the participants of the event. Creating a simple to read and follow rubric for any citizen science event is crucial to ensure both its success and accuracy.

2.7.2 Scistarter

SciStarter is a website that hosts a variety of citizen science projects. Their mission is to bring together everyday people and scientists in order to help further research and expand science education. Over 150,000 projects are registered on the site by individual project leaders and research departments. Many researchers are challenged by the man-hours required to collect, organize, and interpret the large amounts of data used in their projects. SciStarter helps these scientists find volunteers to help, as well as providing resources for training and event organization. In return, the public learns more about the scientific process and gets a chance to contribute to real research. This resource can be found at scistarter.org.

3. Methodology

3.1 Project Proposal

In November and December of 2022, the team created a proposal discussing possible project options. This proposal was then presented to the RFMSC at their monthly committee meeting, where members voted on the options and approved their choice. It was especially important to tailor our suggestions to the committee's goals. We also wanted to provide the RFMSC with a variety of options they could explore in the future.

3.1.1 Establishing Goals

As a starting point, the team met with Gloria Parkinson, member of the RFMSC, to discuss the sub committee's goals for the project. We discussed past projects to learn what information was available, as well as ongoing projects on the property. These inquiries were important to understanding what will best supplement the information the committee has in order to advance their goals. The committee has been working on a new adaptive land plan centered around sustainability. The team was tasked with providing insight on the role entomology has in sustainability and climate resiliency on the property. Particularly, insects vulnerable to rising temperatures and the introduction of invasive species. Additionally, our project had to align with their focus on recreation, habitat enhancement, and seasonal events. The team also received a guided tour of the farm from Ms. Parkinson. These activities provided a baseline sense of how the team could best address the needs of the RFMSC.

3.1.2 Evaluating Project Options

During the research phase of the project, the team had several project ideas that could all benefit the RFMSC in some way. Prior to the December 14 meeting with the RFMSC, the team realized that pursuing all these potential deliverables during the project's timeline would be impossible. Additionally, some project ideas drifted considerably away from the original scope of the project, and pursuing these could create scope creep later on. Understanding the particular constraints of the project meant that the team could assess whether a given project idea was even viable under the project's conditions.

The most important constraint present (given the project's outdoor nature) was the weather conditions the team would face. Immediately, this eliminated some project ideas such as insect trapping, since insects would not be active on Rauscher Farm until very late into the project, leaving almost no time for data analysis. Additionally, this entirely eliminated working in grassland areas of the farm, since the grasses would be dead and potentially covered with snow during most of the field work portion of the project. Although a tree survey would still be possible, the team had to go into such an event expecting that tree identification would be much harder given the lack of leaves on deciduous trees during the winter season.

Another constraint present during the project was the aspect of commuting to and from the farm being more difficult than initially expected. This constraint meant that a project would ideally consist of a single event, as opposed to something requiring periodic or even daily visits to the farm by team members. A project that pursued insect trapping would likely involve visiting the farm periodically for a long period of time, making this project option far less appealing to the team.

The feedback received at the December 14 RFMSC meeting was the final piece of evidence used to evaluate project options. Here, the team presented their three main project ideas to gauge the sub committees interest in each of the respective ideas. After this meeting, the team had a much better idea of what the project should focus on, and the team was able to narrow down the focus to the final tree survey that was eventually conducted.

3.1.3 Expert Consultation

Over the course of the project, different experts and WPI faculty were contacted in order to gain more knowledge on the topic at hand. We needed a variety of expertise to inform our methodology, and general background information on tree and insect species. Several WPI faculty were contacted as potential experts, including professors Stephen McCauley, Ali Rangwala, Ingrid Shockey, Elisabeth Stoddard, and Sarah Strauss. Fortunately for the team, we received a response from Professor Stephen McCauley.

Through contacting Professor McCauley, we were able to set up a Zoom meeting, on December 9th, 2022, to discuss and further investigate the citizen science approach. For background, Professor McCauley is an associate professor at WPI, and a co-director of the Melbourne Australia project site.

Professor McCauley gave very helpful insights into how we might approach the citizen science aspect of our project, and provided us with different resources regarding local ecology. We were also informed by him that he had prior experience in citizen science projects in the Worcester area, and that one of the teams that he happened to be advising during fall 2022, was working on a citizen science rubric to host events in the future. (McCauley 2022). This project piqued our interest, as we needed some sort of rubric to provide the participants of the survey in the later months. The citizen science rubric was sent once the project group completed their work.

3.1.4 RFMSC Monthly Meetings

In order to get approval to go forward with the event, a proposal document was created and sent to the RFMSC. The event proposal document can be seen here:
Tree Surveying Event. This included our planned date and time, rain date, and a brief description of what the event would entail. The resources to be developed for the event were also described, and a draft of the advertisement was included. The purpose of the proposal was to give the Subcommittee a summary of what we had planned and establish the scope of the event.

On December 14th, 2022, we met with the RFMSC to propose different ideas for our project. A slide show was presented, discussing our time constraints, the summarized project timeline, and some general background on the purpose of the project. At the end of our presentation, we asked for feedback from the RFMSC, as to what we should include in our project or what we may have missed. The general feedback we received was that our overall project plan seemed feasible, other than the time constraints that some of the project entailed. What was agreed upon most importantly, was that our project should be a hybrid of both the tree survey idea, and the citizen science event. The sum of the committee also provided us with different resources to aid in our project, including camera lenses, books, and surveying tools. It was also brought up that RFMSC could take on the advertising and marketing for the event, which later changed (See § 3.3.7). Other potential IQP projects were also discussed that could benefit the farm in the future (See § 5.5.2).

On February 14th, 2023 we met with the members of the RFMSC to discuss our proposal. Our event was approved, and we talked about the logistics for setting up the event.

This mostly included what materials we will need for the event. For example, our team was given permission to mark our sampling units the day before the event. Additionally, we learned not to use pink flags, as they are currently being used by a railroad survey in the area, and that the farm could provide tape and flagging materials. The Subcommittee will also provide an easel for our instructions poster, and a table to keep all our reference documents. We were asked to edit our advertisements to include a note for participants to wear tick protection, and rescheduled the rain date to April 1st.

3.2 Tree Surveying

When investigating potential project areas, we discovered that Rauscher Farm was missing quite a bit of information about the property that would be extremely beneficial in determining how the property was likely going to be stressed by climate change. In particular, it was very unclear exactly which tree species inhabit the forest areas of the farm, as well as how climate change might have already changed the forest before the project. One of the biggest points of concern was invasive insect species, since central Massachusetts has experienced many recent invasive insect outbreaks affecting many different types of trees. Due to these current and future concerns of forest health in a changing climate, our project team decided to conduct a tree survey as a main objective of the project to better prepare Rauscher Farm for the changing climate of the future.

3.2.1 Examining Forest Data

The first step used to complete a tree survey at Rauscher Farm was to review the documents that the farm already had regarding the forest's composition and health. To do this, the existing Rauscher Farm Forest Management Plan was consulted. This gave a rough description of the forest's composition and health, but was lacking in many aspects. As an example, the forest composition in this document was mainly described as "hardwood forest" or "oak/pine forest," giving little insight into the specific species present. Early tree visits to the farm revealed that the forests were much more complex than these short descriptions revealed. The combination of old tree growth along fringe areas where farming did not take place, combined with the large new-growth areas where fields once (relatively recently) existed, meant that describing entire areas of forest in Rauscher Farm with blanket statements made little sense. Additionally, the forest was described as being in "relatively good" health, yet again providing little actual information to the RFMSC when tasked with making forest management decisions. This gap in knowledge in the existing forest data became the clear next step to pursue when working towards how to conduct a tree survey that best suited Rauscher Farm's needs.

3.2.2 Invasive Species and Pests

Early in the project, the project sponsor expressed an interest in the project taking on a focus on insect species on the farm and how these insects relate to climate change. The major difficulty with this approach was that the project ran during the fall and winter seasons, when insect activity on the farm was seriously reduced (and in many cases, completely absent). As a result, a compromise was made where the project would focus on invasive insects as a key aspect of climate change. This allowed for an insect focus while still accounting for how the project timeline would limit the ability of actual insect observation to take place.

This type of focus necessitated that some research would be done on the invasive insects within the region, an investigative task which was largely conducted during November 2022 as necessary background for the tree survey. The early research focused on mainly what insects had already done damage to the region, and what insects are likely to cause damage to the farm in the near future. A key takeaway of this research would be finding out which tree species are most vulnerable to the invasive insects currently present in the region. Knowing these species in advance would allow the team to pick out a better location within the farm for the tree survey, as an area of the farm including these key species would be the most useful to the RFMSC as indicators of potential stress or damage for the forest as a whole. Additionally, this research would allow the farm management to rule out invasive pests that would not be a threat to the farm due to that particular tree species not being present in the Rauscher Farm forest habitat.

3.2.3 Tree Damage

In addition to identifying the range of tree species that are present, a core goal of the tree survey was to get a rough feel for the amount of tree damage and stress that exists in the forests on the farm. In general, a higher amount of tree damage indicates that the forest is in worse health compared to a forest where most trees are generally healthy. Some types of tree damage can be due to overall unhealthy trees having to weather storms, but many other types of tree damage are very specific to invasive insects attacking otherwise healthy trees. Additionally, other climate change factors, such as drought, extreme heat, or even too much rainfall, can cause a tree to become stressed and unhealthy. These damage signs are key to understanding the overall health of the forest, and as a result, a process was put in place for participants to report any potential tree damage that they found during the survey. Instead of focusing on specific damage types, the survey team decided to allow participants to describe tree damage how they felt was best and then include a picture afterwards for the survey team to review. The benefit of this approach was increased simplicity, as for many people describing things like holes in trees or snapped branches is a natural thing without having to follow a specific system of damage surveying. The downside of this approach was this method necessitating pictures for each damaged tree, and as the team later found out the significant number of damaged trees in the survey area meant that many pictures had to be taken by those group members tasked with managing the tree damage photos.

3.2.4 Surveying Methodology

The chosen survey area for the March 18, 2023 tree survey is a triangular area, with approximately 50 yard sides running east-west and north-south. The survey area on the day of the survey will be divided into 6 by 6 yard boxes, with each cell covering roughly 320 square feet. This size was chosen to allow for a reasonable amount of cells in case many participants show up for the survey, yet making the cells large enough to where most of them have at least some trees to identify within them. With this cell size, the survey area will be divided into roughly 30-40 sampling units. Many of the cells around the edge of the survey area will be of odd shapes and sizes, however as long as these are represented in Geographic Information Systems (GIS) to a reasonable degree of accuracy there should not be a problem during data analysis later on. Each unit will be marked using colored tape at the corners. The units will be labeled with a number for their row and a letter for their column, as in the game Battleship. This will make it easy for participants to find their assigned unit. The resulting map will be printed and then laminated, so that units can be tweaked or marked off with an expo marker during the event.

3.2.5 GIS Mapping

Without a good map to back it up, spatial data is nearly useless. There would be no point in conducting a survey using a unit-based approach if these cells could not be later used to pinpoint tree locations on a map. As a result, the importance of having a good map for the survey data soon became apparent, and work on the mapping portion of the project began. Furthering this conclusion was the ability of the survey team to pinpoint each corner of the survey area with relatively high accuracy, making a map of the data natural and relatively accurate.

The first usage of GIS mapping occurred in January 2023, when scouting for potential survey areas on the farm. To get a rough idea of the "lay of the land" on the farm, a GIS layer known as Light Detection And Ranging, or LIDAR, imaging was used. This technology allows one to see very fine terrain detail on the surface, even through trees and other obstructing objects. Using this terrain layer allowed the steep cliff faces on the farm to be identified and ruled out of the areas for survey candidates.

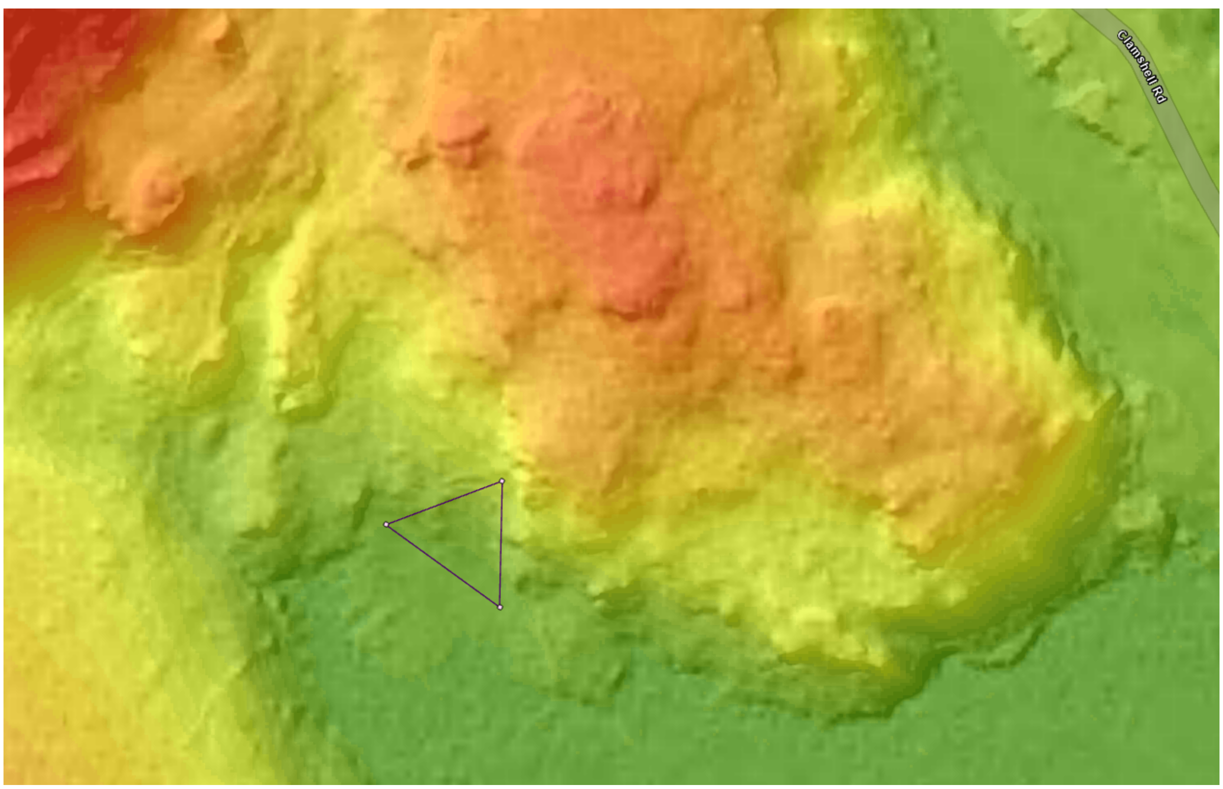

Figure 3A: A LIDAR map of Rauscher Farm, with the survey area marked using GPS

Additionally, areas within a couple feet of elevation as the surface of Clamshell Pond were additionally ruled out, since these areas are likely either marked wetland (off-limits) or could become very muddy during the wet early spring season.

At the February 24, 2023 farm visit, the coordinates for the survey area were collected using a phone GPS system. These were then used, in combination with the known size of survey units, to accurately create a map layer for the tree survey.

Figure 3B: The same area as figure 3A displayed as a satellite image

Each polygon within this layer will represent a single cell from the survey, where originally the tree data would have been placed after the survey. This feature allows for complex analysis of the data, as well as the ability to create maps to display the data collected in a visual manner that may make it easier to understand. In the end, the team opted to forego this method of mapping the survey data for a different graphical approach, however GIS was still utilized to analyze other aspects of the survey area, such as why the farm has such a high average wind speed.

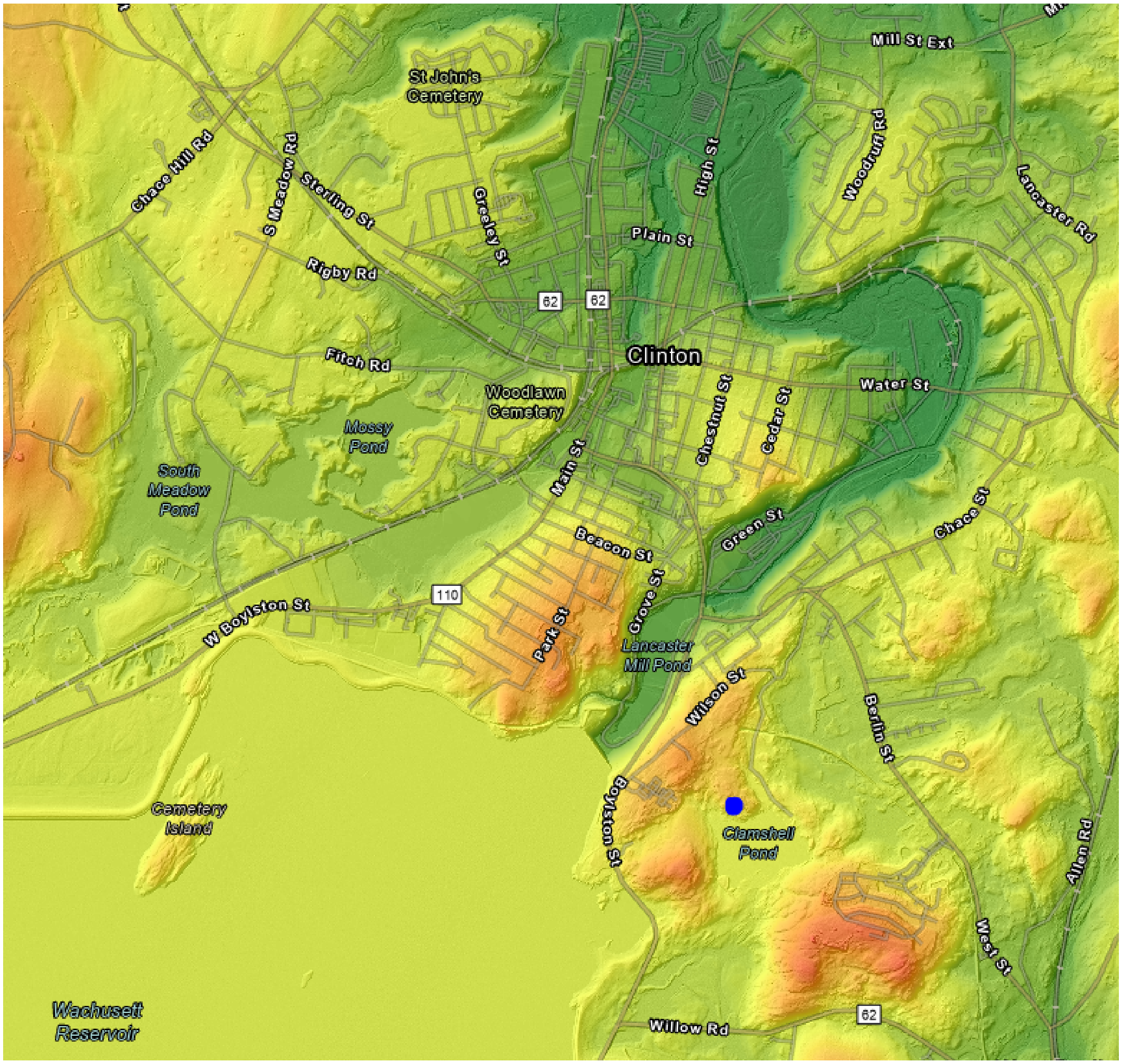

Figure 3C: The town of Clinton on LIDAR imaging. The survey area on Rauscher Farm is marked using a blue dot.

3.3 Event Planning

Much of February 2023 was spent creating materials that would allow the tree survey to function successfully. Several documents were created for usage by participants on the day of the survey, such as the tree identification guide and forms to submit tree responses. Additionally, materials were made to instruct the participants on how to successfully participate in the survey, such as instruction posters. Finally, the team needed tocreate advertising materials to attract potential survey participants and notify them of important information about the event.

3.3.1 Tree Identification Guide

Although seemingly a simple task, the tree identification guide became a very time-consuming product to create due to the timeframe of the tree survey falling during a time where deciduous trees lack leaves. This meant that alternative methods of tree identification had to be pursued, including bark appearance, tree branching patterns, and persistence of dead leaves on the trees. Additionally, the goal was to produce an identification guide using only pictures of actual trees taken from the farm, so this aspect of the project required multiple trips to the farm. Additionally, at least one member of the team had to become relatively proficient in tree identification to both create the identification guide and identify potential new trees that may be in the farm survey area.

The first step to completing this part of the reference material was to collect photos of what tree species were roughly on the farm. The team took tree photos on two separate visits; one of these instances was early on in the project (Nov. 20, 2022), but the pictures were not of high quality and did not showcase a majority of species on the farm. As a result, a second trip was made to the farm on Feb. 1st to take much more detailed and comprehensive tree bark photos to be used specifically for the tree identification guide. Once these photos were taken and stored in a shared photo bank, the team conducted research that would allow them to create a viable winter identification guide. Several online resources were used, which provided the team with both bark identification methods as well as other tricks that could prove useful for winter tree identification. One of these tricks (opposite branching only occurring on maple and ash trees) proved to be very useful for the day of the survey. After this research phase, what was thought to be just an oak and birch forest soon had at least 10 potential tree species identified as candidates to find during the tree survey.

Since the actual survey area was not decided until February 24, the tree identification guide had to be made in a way that covered most of the potential survey areas in advance so that there were no tree species missing from the guide but still present in the survey area. Regardless, on February 24 (when the survey area was scouted), the team still found two species in the survey area that were not present on the identification guide. Another important consideration for the survey guide was ensuring that it was reasonably usable by the average survey participant. As an example, the survey participants should not be expected to have to differentiate between maple species based on the shape of their buds, or attempt to guess between oak tree species and their hybrids. As a result, the team decided to sacrifice some amount of precision in identification in order to make the tree survey a more accessible project to the average farm visitor.

3.3.2 Data Collection

A major challenge during the planning of the tree survey was creating a simple yet effective way for the survey participants to submit responses to the team for later analysis. Although it seems simple to collect data from participants, the addition of images of each tree, as well as knowing exactly where the tree is located, made this aspect of the planning phase quite tricky to figure out.

Initially, a Google Forms approach was taken to data collection. In this method, survey participants would use their phones to submit survey data and images for each tree through a

Google Form.The team decided to limit the amount of questions per response as much as possible without losing too much data, in order to make the survey more easy to complete in the field. Additionally, because the survey response automatically includes the name of the participant that responds, data organization after the survey became much easier, as each response was automatically correlated with a participant without survey participants having to record their name over and over for every tree. The primary questions asked in each survey response included the tree location (cell row-column), tree species, tree trunk diameter (optionally), and a description of damage. Additionally, the survey asked participants to upload a cell phone photo of the tree trunk, the tree canopy, and the tree damage (if the damage is present and the cell phone photo is adequate). Once a survey response is submitted, the response is sent to a Google account, and the photos are stored in specific folders within the Google Drive linked with this account.

The Google Form method had the benefit of automatically linking survey responses to their corresponding tree images (saved within a Google Drive folder), and some data analysis was automatically performed on the responses as well. However, it soon became apparent that a secondary method for data collection would be helpful for the day of the survey, as the phone service in the chosen survey area was not ideal. The RFMSC noted that they would like a paper form to be able to utilize for the survey responses as well. Both of these factors meant that both a digital method as well as a paper method would be needed to effectively complete the tree survey on the day of the event.

The paper form includes the same questions and instructions given in the online version. It was designed to fit on a half sheet of 8.5”x11” paper, so when printed double-sided, each paper can record data for four trees. For participants using paper, a team member photographed each response, and then took the needed photos of the tree. This approach kept the photos labeled and organized and circumvented the need for sharing photos.

3.3.4 Providing Effective Instructions

On the day of the tree survey, instructions were given to participants so that they could effectively participate in the tree survey event. The team planned to use a “teach, then reinforce” method to instruct these participants. First, a team member would verbally instruct newly arriving survey participants on the proper procedure for the tree survey, with the help of a poster describing the tree survey process. This process was then reinforced by other team members, known as “floaters,” whose job was to be a resource for survey participants to get help and ask questions about the tree survey procedure.

Before the survey took place, the team worked on the various materials that would allow this process to take place. Before actually creating the materials, the team created an actual set of instructions that each survey participant would have to follow. This instruction process was then stylized, and a poster was created showcasing these instructions in an easy-to-read format for both the team member and survey participants to reference. Additionally, because the team planned to use a primarily verbal instruction format, team members were tasked with learning the instructions well enough to be able to present them effectively to new survey participants.

3.3.5 Location Choice

The location of the survey was important from both a scientific and logistical perspective. In order to provide useful information, the chosen site had to include a large number of diverse tree species. We also wanted to avoid dangerous areas, like cliffs, to ensure the site was safe for children. Additionally, the site had to allow for a grid, in order to mark the survey units. Based on this criteria, the team chose an area of forest surrounded by two stone walls. Due to their origin from the time when the farm was active, the two walls were perpendicular, with one running north to south and the other east to west. This finding meant that the walls could be used as references while making our grid and analyzing our results.

Although the diversity of the tree species and the ability to leverage the pre-existing stone walls as the boundary for the survey area were the primary considerations that led to choosing this survey area, there were additional considerations that needed to be addressed before the day of the survey due to this choice of location. Firstly, the survey area was a considerable distance from the parking lot (~0.25 miles), so the materials brought to the actual survey area had to be relatively minimized to make setup and cleanup easier. Second, the lower area of the survey region was located in an area adjacent to wetland habitat, which meant that in our case (the survey was taking place during peak mud season) there was likely to be mud to navigate at least in close proximity to the survey area. The weather not only necessitated waterproof shoes for the day of the survey, but meant that the trail now traveled through the survey area, as the old trail location was extremely muddy. Accounting for this meant making the survey area markings unobtrusive enough to allow regular farm visitors to pass through without too much trouble. Finally, because part of the survey area was on a steep rocky slope, plans had to be made to allow for any volunteers not comfortable in climbing over rocks to have a separate survey area on safer terrain.

3.3.6 Sampling Unit Materials

Keeping track of the location of the trees surveyed was important. The team needed this information so that the impact of geography could be studied. Participants needed to reliably know which sampling unit they were in at any time. To accomplish this, a grid was made using brightly colored plastic flagging tape.

Figure 3D: The flagging tape grid on set-up day (March 17)

The tape was marked at six yard intervals, which became the corners of each unit. We planned to hang the tape from trees on the perimeter of the site, running north to south and east to west, forming 6 yard squares. Signs were attached to denote cell location; on the tapes running east to west, signs with letters A-F labeled the column, and on the tapes running north to south, numbers labeled the row. These labels made each unit identifiable based on a letter-number code. The labels were made waterproof with tape, as we were unsure what the weather conditions would be.

3.3.7 Advertising Materials

Citizen science requires community participation to work, making advertising for the event vital to its success. Two flyers and a webpage were designed to spread awareness for the tree survey. The first flyer was designed to mimic the style of Rauscher Farm's past event flyers. It was posted on the Rauscher Farm website, as well as at the entrance to the farm. The second flier, designed in the style of club advertisements, was posted on bulletin boards across the WPI campus to inform students about the event. Both fliers provide essential information such as the date, time, and location of the event.

Both flyers also provided links (via QR code) to a Google Site created for the event. It was important to have a website because it was capable of hosting more information than the flyers could. Supplementary information included things such as digital versions of our educational materials, driving directions, and an RSVP survey.

3.4 Hosting the Event

3.4.1 Set-Up

On March 17, the team ventured to the farm to set up the survey area for the next day. Because the survey area grid had already been constructed, this process was designed to be as simple as possible, but difficulties were still encountered. The first problem the team encountered was the area of mud at the southern edge of the survey area. This mud was sufficiently deep that the team decided to move the survey area slightly up the hill compared to what was originally planned. The second major issue was that the hill's incline, combined with the stretchiness in general of the ribbon used to create the survey area, created a situation where some cells were being stretched into different shapes and sizes, ruining the alignment of the grid. The final visibility of cells was remedied by adding additional labels to some of the cells to show exactly where they started and ended, as creating perfectly square surveying cells by this point was deemed unfeasible.

The final issue encountered on set-up day could have been entirely avoided. The survey grid was designed to be hung up with a specific side being the front and another side being the back, however the team somehow got the orientation of the grid confused and ended up hanging the back of the grid at the front and vice versa. This meant that some sections of the survey area were far too long, and others were far too short. The team ended up fixing this problem by creating new survey cells in the missing sections in the field using some extra ribbon they had brought.

3.4.2 The Event

On the day of the event (March 18), the team gathered an hour before the proposed survey start time to allow adequate time to set up. Half of the team then carried materials to the survey area, while the other half waited for members of the RFMSC to arrive before heading into the forest. Once at the survey area, the team set up the poster and table, organized documents, and went over the roles that each team member would be filling that day. Before any survey participants arrived, a friend of one of the team members was instructed on the survey methodology and began the survey. The team used this as a type of “dry run” to ensure that the rest of the survey participants would be able to follow the instructions that the team had created (See § Appendix B for event pictures).

All of the volunteer survey participants for the day arrived in a single group, meaning that the instructions were only presented one time. The benefit of this was that the survey participants came in a manageable number as well as at a predictable time, however this result meant that the team members assigned to be floaters ended up doing considerably more work than those presenting instructions. This inequality was addressed by the team members left with nothing to do already beginning data analysis while the survey was still taking place. Since an overwhelming number of participants used paper forms, this early analysis involved a large amount of work transferring these responses into a spreadsheet.

At the end of the day, the team realized that having the data from an additional column on the eastern edge of the survey area would be very helpful. As a result, the team strung up some additional ribbons that created one extra column of survey cells. Since no other survey volunteers arrived later in the day, a team member elected to survey this last column while the rest of the team tore down the rest of the survey area and packed up. Due to the ribbon design of the survey area, it could be easily torn down in a matter of minutes, and this allowed the team to be fully packed up and leaving the survey area within 30 minutes of the end of the survey.

4. Results

4.1 Tree Species & Damage Counts

4.1.1 Tree Species Found

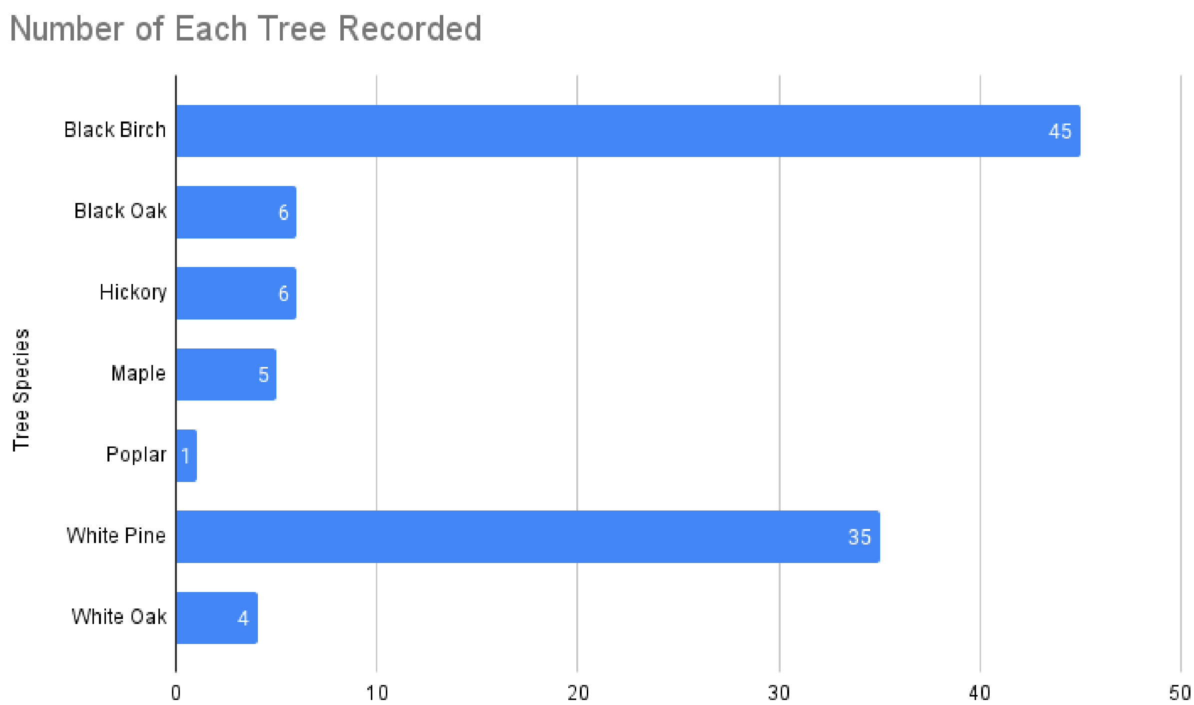

Figure 4A: Graph shows amount of each tree species counted during the survey

From Figure 4A, it is shown that there were 45 black birches, 6 black oak, 6 hickory, 5 maple, 1 poplar, 35 white pine, and 4 white oak. The total number of trees surveyed amounted to 102 total.

4.1.2 Overall Damage to Area

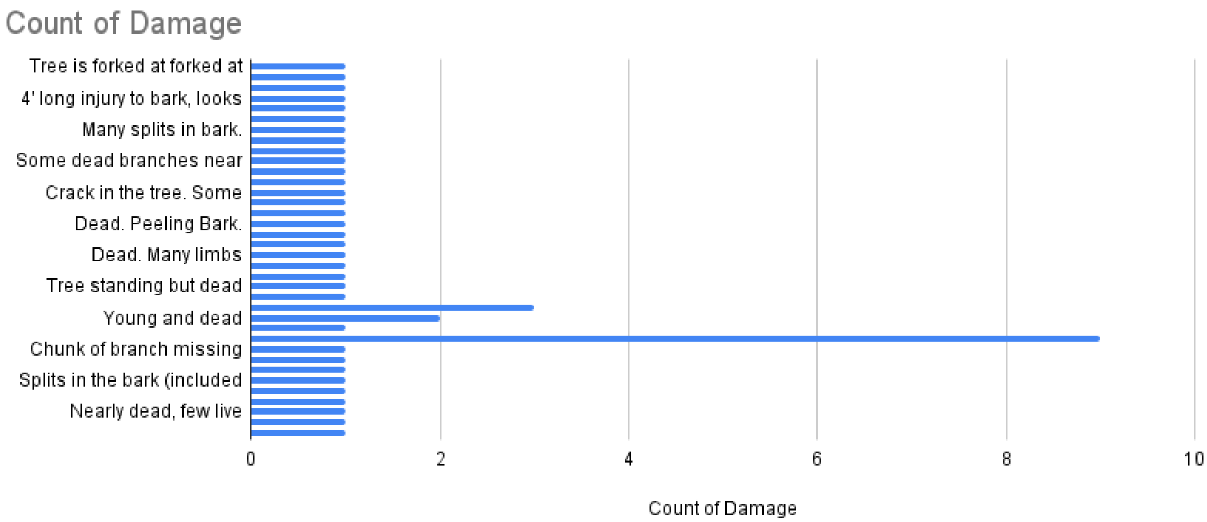

Figure 4B: Chart shows the different categories of damage from the trees surveyed.

From Figure 4B, the amount of trees with damage is shown using a bar graph. Using the COUNTA function in the spreadsheet, there are 47 total trees with some sort of damage. The IFERROR function was used to check if the damage category explicitly said “dead”, which then gave a number in a separate column, and then the SUM function was used to find the total, which was 24 total dead trees.

4.2 Observed Trends

4.2.1 Species-Damage Correlation

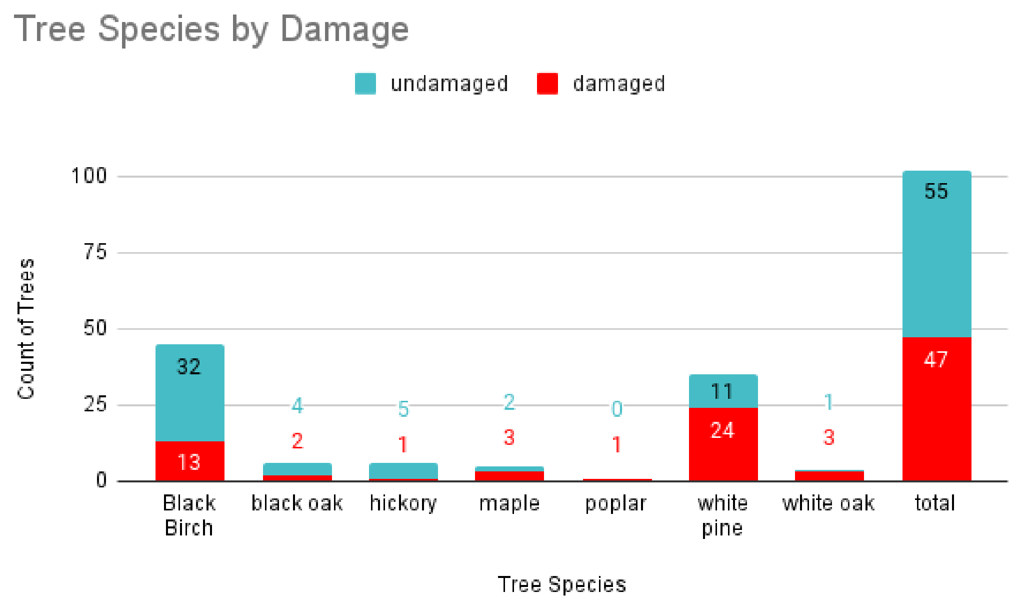

Figure 4C: Graph shows the tree species by damage, the blue representing the undamaged trees, and the red the damaged trees.

Species	Damage Rate
Black Birch	28.9%
Black Oak	33.3%
Hickory	16.7%
Maple	60%
Poplar	100%
White Pine	68.6%
White Oak	75%

Figure 4D: Table shows the damage rate by tree species

From the tree survey data that was gathered, the tree species displaying the highest rate of damage would seem to be the poplar. This data point may be disregarded, as there was only one poplar tree recorded for the whole survey. Among the other species, white oak had the second highest rate of damage, being 75%. Next was white pine, with a damage rate of 68.6%. The third highest rate of damage was the maple, with a 60% rate of damage. For all the other tree species surveyed, there was a damage rate of 33.3% or less.

4.2.2 Species-Location Correlation

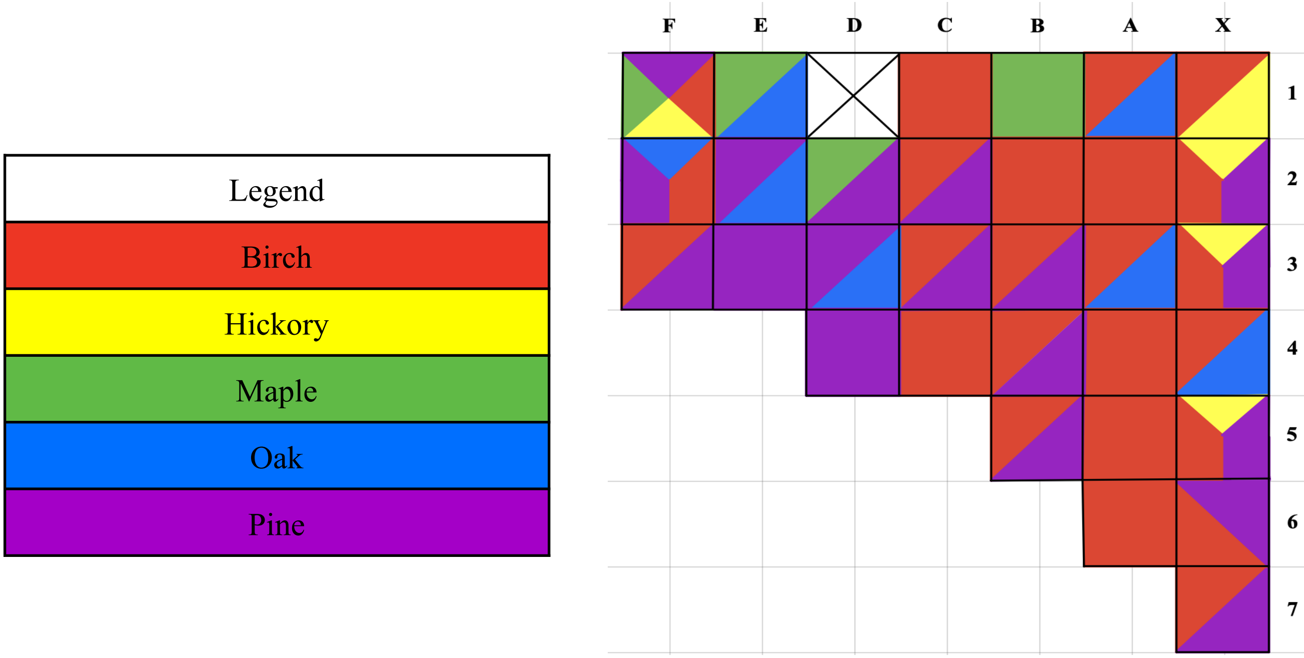

Figure 4E: Graph shows the tree species recorded in each section

From Figure 4E, the tree species recorded in each area are represented by different colors. When examining the graph, it is clear that there is a higher population of younger trees, like pine and birch, towards the center of the graph. If the outer edges of the graph are examined, there are harder tree species present, like maple and hickory. This could be due to the fact that the area surveyed used to be farmland. The trees in the center are predominantly new growth, while the trees on the outer edge were closer to the rock wall, so they have been alive for much longer.

Looking at the bottom diagonal of the graph, it is much like the center of the graph, where there are only younger tree species present (pine and birch). The scarcity of older trees along this margin of the survey zone may be due to the close proximity of the marshes to the area that was surveyed.

4.2.3 Damage-Location Correlation

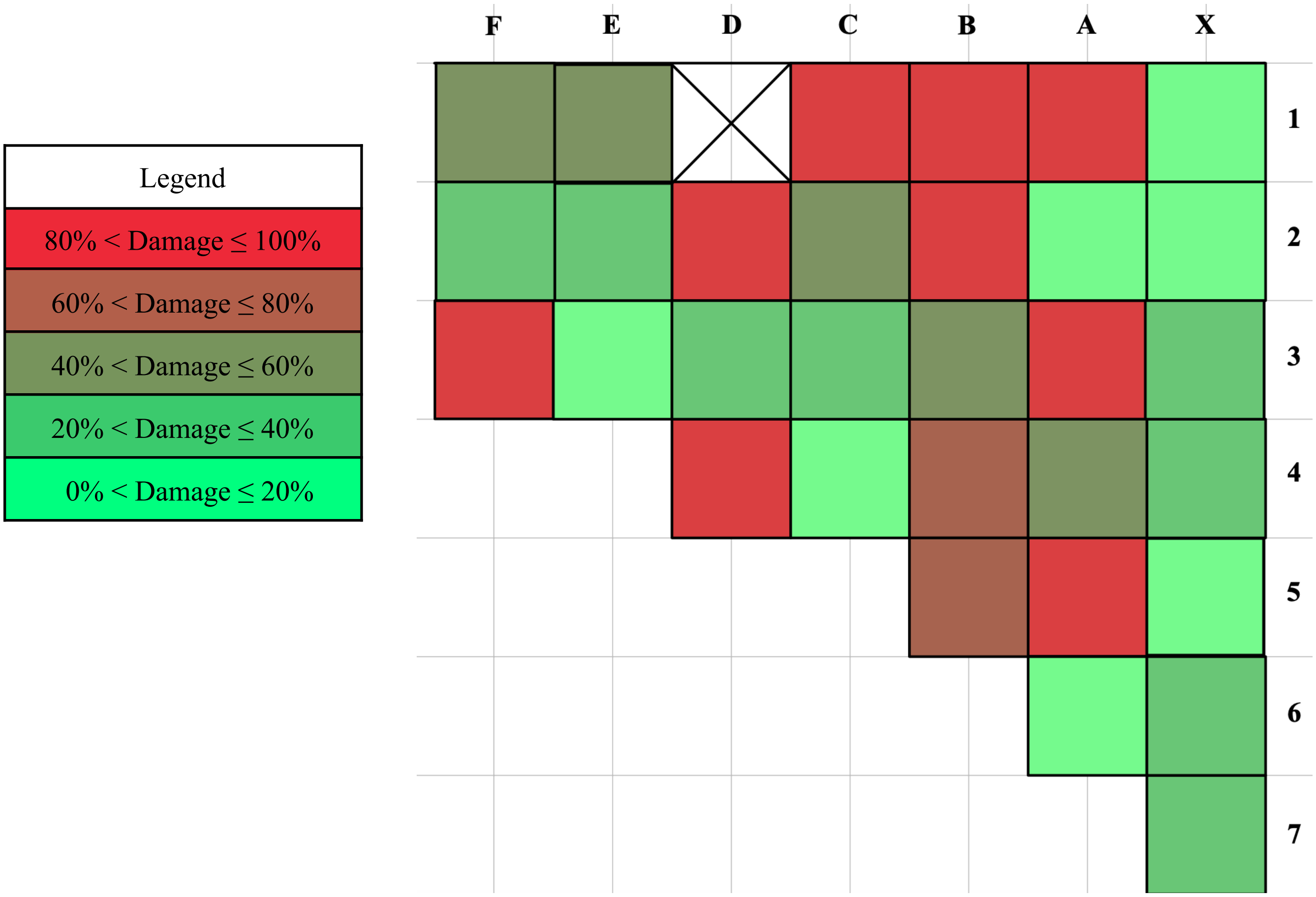

Figure 4F: Graph shows the percent damage of each section

From Figure 4F, the percent damage is represented by a color gradient from least to most observed damage. When examining the graph, there is a higher red gradient towards the center, where most of the younger trees reside. On the outer edge of the survey area, there is the highest density of healthy trees. Variations in health may also be due to the age and species of the trees.

As discussed in Section 4.2.2, there is a presence of harder tree species towards the outer edge, such as maple and hickory. Towards the center, there are softer and younger trees, such as pine and birch, which could be contributing to the higher rate of damage.

4.3 Public Engagement

In total, including the members of the group, there were 6 total participants that surveyed the trees. General comments heard from non-IQP participants, was that the citizen science form was very simple to follow, and there were little to no complaints. The consensus was that they were happy to be involved, and the procedure was very well thought out and planned.

From participants that used that paper form, the procedure was followed for the most part, but the main issue was some participants didn't use a new section of the form for each tree that they recorded. This inconsistency of participant documentation practices created some confusion once the data was entered, but in general, participants separated their descriptions of each tree within the form.

For those that used the Google form, the text input was okay, but the overall feedback that was received was that the photo upload time was kind of long. That may have been due to the fact that the survey was taking place in the middle of a forest. What was helpful about the Google form, was that the participant had to submit a new response for each tree recorded, so there was no confusion as to whether the data was accurate or not.

5. Discussion

5.1 Expected Results

While designing the tree survey, the team had a rough expectation of the results that the survey would produce based on knowledge gained from past visits to the farm. Additionally, both the background research done by the team as well as knowledge of the farm's past land use patterns contributed to a general understanding of the Rauscher Farm forest before compiling any results from the survey itself. Stating these expected results is important, as doing so allows the team to understand both where the information gained from the survey increased the overall knowledge of the RFMSC, as well as find where the survey only revealed information that was already known about the forest.

5.1.1 Expected Species

Based on information gathered from both the forest management plan already available to Rauscher Farm, as well as the visual observations of team members from past farm visits, the survey team already had a rough idea of what species would be present in the survey. This prediction was further compounded by the research needed to create the tree identification guide, where a rough survey needed to be conducted just to decide what species to include on the guide itself. Based on both of these preliminary sources, the team was expecting birch and pine to be far and away the most common tree species, conjectures which ended up being correct. Additionally, the forest management guide called the forest itself an “oak/hardwood forest,” meaning that the team expected a reasonable number of oak trees to be present in the survey area. Based on these early assumptions directly correlating with the collected survey results, the survey did not provide any additional data on the most common tree species found on the farm. However, some metrics the team could not predict in advance were the distribution of these common species within the survey area or the types and numbers of the less common tree species found on the farm. These metrics are much harder to roughly predict, and the data collected from the tree survey provides much more insight into the significance of these particular statistics than the team could infer through other methods.

5.1.2 Expected Damage

Earlier observations of the forest during farm visits already revealed some common patterns of tree damage across the property. One example is the team's observation of the large swath of fallen pine branches at the forest's entrance, where the strong winds from the field damage the softer limbs of the pine trees found at the edge of the forest. Because Rauscher Farm sits at a relatively higher elevation than its surroundings, the wind speed tends to be higher than in other nearby areas, meaning that the team expected to find evidence of damage from past wind storms within the survey area, particularly on the older trees. Another type of damage that the team would not be surprised to find was signs of beaver activity. The chosen survey area sits fairly close to a (formerly active) beaver lodge, and signs of this past beaver activity can be seen in several places along the shore of Clamshell Pond. As a result, it would not be surprising for there to be some beaver damage present on a few of the trees in the survey area.

The insect damage that the team expected to find during the tree survey was entirely dependent on which tree species were found in the survey area. As the background section explains, some tree species in New England have been so severely decimated by invasive insects that it is nearly impossible to find a tree in the area that does not suffer from an infection. Some common examples of these trees include elm and ash trees. Elm trees in the area suffer from

Dutch Elm Disease (DED), which is so widespread that very few adult elm specimens are left in New England that do not have some type of visible DED infection. Ash trees suffer from a similar fate due to the Emerald Ash Borer, and consequently the team assumed that any ash trees present within the survey area would be highly likely to have ash borer damage.

Compared to the tree species present on the farm, damage types were far more difficult to predict in advance. The team expected to learn significantly more from the types of tree damage observed during the survey than from simply the types and numbers of trees found within the survey area. As an example, one of the key goals of the tree survey was to create a system that could search for signs of insect damage from newly introduced invasive insect species. Even if this particular tree survey failed to find any evidence of insect damage, a similar survey could be repeated in the future using the materials that had already been created to detect new insect damage as it forms. As this future damage survey repeatability was a key aspect of the survey that the team chose to preserve, significant effort was put into making sure that the tree damage found now could be accurately sorted and analyzed, so that a future party wishing to use the materials for their own survey could do the same.

5.2 Unanticipated Results

5.2.1 Uncommon Species

The survey results revealed that although many of the expected less common tree species in the farm did show up, some did not, and other species thought to be uncommon were actually relatively plentiful within the area of the tree survey. Black cherry is an example of a tree species that was found elsewhere on the farm but did not occur within the survey area; Although the survey site was found to be relatively diverse, an accurately identified black cherry specimen was not found on the day of the survey. On the contrary, the tree survey event did discover a tree species that was not found prior to the survey date. This tree species, sassafras, was actually found multiple times within the survey area even though it had not been discovered anywhere else on the farm. Other (thought to be) uncommon species were confirmed to be relatively uncommon within the survey area, verifying the team's initial analysis. Some examples of these uncommon species included white birch, poplar, and hickory. Surprisingly, maple trees, thought to be uncommon, were found relatively often within the survey area (compared to other uncommon species). Although this could lead to the potentially incorrect conclusion that maple trees are actually relatively common within the farm forest, the more likely explanation is that there are pockets within the farm where relatively uncommon species for the farm as a whole become locally common. This finding could become very helpful in the future for identifying areas where invasive insect damage searches would be most effective; as an example, the survey area would be an effective place to look for Asian Longhorned Beetle damage since it has a high concentration of maple trees (which the beetles prefer) relative to the rest of the forest.

5.2.2 Observed Damage

Compared to what the team expected, the actual damage that was found during the tree survey was significantly different. Beaver damage, which the team assumed would be present, was not found anywhere within the survey area. Although present on occasion, insect damage was quite rare as well. Neither elm nor ash trees were found during the survey, suggesting that the insect damage that was found probably occurred more so from generalist species as opposed to specific invasive pests that posed a large threat to the forest. Instead of widespread insect damage, what the survey did find was multiple examples of woodpecker damage, which makes sense given the concentration of completely dead young pines within the survey area as well as the high number of birds in general present at Rauscher Farm. One predicted damage type that did present itself was wind damage; the oldest oak trees within the survey area had many broken limbs attributable to past wind damage, and many of the smaller dying or dead pines were already partially or fully blown over from previous storms.

An overwhelming number of the pine trees found during the survey exhibited some form of damage. In fact, almost every young pine found within the survey area either suffered from significant needle loss or was already completely dead. Even though the exact reason for this mass young pine die off is unknown, there are a couple potential explanations. The most likely explanation is that these pines, probably 5-10 years old, are now being overshadowed by the taller deciduous trees above them during the summer months. This source of shade means that the trees do not receive sufficient sunlight and cannot survive. Another possible explanation is that recent droughts have starved these younger trees (with shallow roots due to bedrock just below the surface) of water, however this hypothesis is not supported by the fact that the young pines near a wetland area are just as damaged as those higher up within the survey area. Regardless of the actual reason, the tree survey demonstrates that Rauscher Farm currently does not lack a supply of dying or dead trees for native birds and insects to use as food and shelter. As these trees die, they continue to feed the soil, meaning that the soil quality found within Rauscher Farm will continue to sustain itself into the future. Regardless, finding the exact cause of these dying young pine trees in the future could be very helpful in determining if it is a natural transitional process as opposed to an indicator of poor forest health.

5.3 Tree Distributions

5.3.1 Variation in Conditions

Within the selected survey area, the team found that the distribution of particular tree species directly correlated with the different habitat conditions present there. As an example, the team noted that most of the maple trees were found in areas that bordered the wetland habitat found in many areas around Clamshell Pond. This distribution suggests that maple trees either prefer wetter soil habitats, or are simply more tolerant of them than most of the other species found in the survey area. As described in subsection 2.3.2, New England is trending towards a wetter climate, meaning that these wetland areas are likely to grow in the coming decades. Consequently, the tree distribution of Rauscher Farm is likely to trend towards those that fare better in a wetter forest habitat.

5.3.2 Human-Created Variation

Not all of the differences in tree distribution are due to environmental factors. As explained in subsection 2.1.1, Rauscher Farm was once an area of active farmland. In fact, the rock walls bordering the survey area were likely created during this time to serve as field borders, as was common across most of New England in the past. The tree distributions found during the survey illustrate the legacy of historical patterns of land use in multiple ways. The terrain directly bordering the rock walls at the edge of the survey area tended to have a higher concentration of trees in general, and in particular almost every fully mature tree found during the survey was bordering a rock wall. Some of these mature trees were probably left standing since they were close to the borders of the field anyways and did not need to be cut down, serving as an explanation for some of the massive (and very old) oaks around the rock walls within the survey area. This selective cutting means that although the forests of Rauscher Farm were once farmland, there are still many examples of mature trees scattered throughout the farm that predate the change in land use of the property.

5.3.3 Forest Subtypes

Evidence of a change in dominant species from one side of the survey area to the other end indicates that the survey area lies along a transition zone between forest types. Specifically, most of the black birch trees found during the survey were distributed towards the eastern end of the survey area, with the western end containing more oak and maple trees. Physically being at the survey area makes this localized clustering of certain tree types even more obvious, as when walking in from the west the forest almost entirely consists of black birch trees. Past the survey area, the forest transitions to a more varied forest subtype with oak and maple trees becoming more plentiful. Knowing where these forest subtypes exist could assist the RFMSC in the future with the information needed to focus their efforts on particular areas of the forest. As an example, if Asian Longhorned Beetles are found within the town of Clinton in the future, a potential survey for the insect could focus on the areas of the farm where the maple trees that they prefer are more likely to be found.

5.4 Methodology Assessment

5.4.1 Effective Aspects of the Survey

Although there were some difficulties with data submission, in general the day of the survey progressed smoothly enough to deem it a success. In particular, the survey provided accurate data regarding the distribution of trees within the survey area, which later became a key part of the team's data analysis. The tree identification guide was relatively effective, and every tree species found on the day of the survey was represented on the guide. A paper response option proved to be preferred by the survey participants, and in retrospect the team likely could have stuck with paper as the only survey response option with equal success. The team chose to allow participants to describe tree damage in their own words through an open-ended survey question, which ended up working well as every participant provided more than enough detail in their damage descriptions to the team. Finally, the survey area that was chosen proved to be easy enough to navigate for every survey participant, which was a key concern that shaped exactly how and where the survey area was constructed.

The ease in setting up and breaking down the survey area was another successful aspect of the tree survey. The team's design of a survey area marking system that could be built in advance meant that most of the setup actually occurred at home instead of at the farm. The team appreciated this method, as spending time outside during late winter in New England can be less than comfortable. In total, the team was able to set up the survey area in a couple of hours, and tear it down in less than half an hour. Given the size of the survey area and the varied terrain that it sat upon, such rapidity, ease, and efficiency speak well of the care and advance planning that went into the survey's overall design.

On the day of the survey, the team instructed survey volunteers orally on how to participate in the survey. This strategy proved to be effective since the number of survey participants was relatively small, but for a much larger group it could have been more difficult. The use of "floaters" to walk around and help survey participants/take pictures could have suffered similarly if a much larger group attended the survey.

5.4.2 Survey Difficulties

Not every aspect of the survey was a success. The biggest failure on the day of the survey was the digital (Google Forms) method of submission available for survey participants. Due to the questionable cell phone service on Rauscher Farm, survey results usually took quite a long time to submit, and adding images to the form submission made this time even longer. At the end of the survey, one of the team members used the digital submission method to submit some data, and found that the digital submission method was far inferior to just writing down tree observations.

Another difficulty the team encountered was tree misidentification. Because of the difficulty of deciduous tree identification in the wintertime, misidentification was expected to happen to a degree, but certain species seemed to be chronically misidentified on the day of the survey. An important example was the sassafras tree, since the IQP team identified at least three specimens of this tree on the survey setup day, yet none of them were recorded by survey participants less than 24 hours later. Consequently, sassafras trees could not be used during data analysis, even though they seemed to correlate alongside maple trees in their distribution. One solution could be to assign more floaters to help with tree identification, as much of this misidentification could have been addressed if there were more people experienced in identification present to help the survey participants. Another obvious solution for future surveys would be to conduct them when leaves were present on the trees, as having leaves on tree specimens makes tree identification at least an order of magnitude easier, especially for beginners.

Finally, a major mistake during the setup of the survey area meant that the team had to improvise some aspects of the designed survey area. As mentioned earlier, when hanging up the survey area lines, the front and back of the grid were reversed within the survey area. Given the triangular shape of the survey area, this mistake led to some of the survey columns being far too short and others being far too long. On setup day, the team improvised to counteract this error, but it still made the survey cells slightly harder to differentiate for the survey participants. If a similar survey grid was used in the future, the team recommends clearly labeling which side of the grid goes towards the front of the survey area and vice versa.

5.4.3 Miscellaneous Difficulties

From the outset of the project work begun in October 2022, the team had great difficulty in reaching out to, and subsequently connecting with experts to assist with various aspects of the project. This lack of experts meant that the team would have to perform much more research on certain aspects of the project. This research ended up being heavily focused on learning winter tree identification, so that both the tree identification guide could be created as well as floaters having the knowledge available to help survey participants with identification in the field. Another challenge the team encountered was that transportation to the farm became quite limited during certain parts of the project. Some team members were not able to visit the farm as much as they would have ideally been able to during these times. A final, overarching issue was the simple fact that the IQP was originally planned to focus on insects, but the winter timeframe of the project ended up making an insect focus nearly impossible. As a result, much of the time from November 2022 until February 2023 was spent simply finding a way to design a relevant project that was possible to complete during the winter.

5.5 Recommendations to the RFMSC

5.5.1 Tree Management

Based on the survey results, the team can confidently say that no immediate threats to the Rauscher Farm forests were found by the tree survey. All of the tree damage found within the survey area is typical for this type of young forest, and many of the damage signs (ex. Woodpecker holes) actually signify that the forest is in good health and has the capability to maintain healthy soil conditions. The fact that multiple forest subtypes were found within such a small area additionally means that the forests will be productive in harboring a large amount of biodiversity within a small region of forest. Finally, a core goal of the project was to seek out the possibility of invasive insects being present in the farm, and the team is happy to report that no evidence of their presence was found. A team member even found ash trees (outside of the survey area) that appeared to be healthy, which is actually quite rare given how widespread and damaging the Emerald Ash Borer tends to be for this species of tree. Although it might be beneficial to cut down some dead trees on the property that pose a threat to farm visitors (which could be important given the windy nature of the farm), the actual number of these trees that were found was quite low and most of them would be safe to allow to fall naturally.

5.5.2 Future Monitoring and Surveys

The team recommends that the RFMSC takes a proactive approach to monitoring and managing the farm in future years. In particular, the lack of invasive insects now might not always be the case, and keeping a constant lookout for new invasive pests will give the RFMSC the most time to react to and eliminate the threat. One way to monitor for invasive pests could be to conduct a similar type of tree survey in the future, where the deliverables generated by this project could be very helpful. Additionally, general education for farm visitors on identifying the damage these insects cause would help maximize the odds that an insect infestation will be found as early as possible.

The team is unsure at the current time whether the mass die off of young pines that was found is a normal thing within this type of young forest, but this is an issue which the RFMSC may want to investigate in the future. A future project could potentially research the health of young pines on the property, and in the meantime it would be worthwhile to monitor the forest to see if this pine die off has spread more widely or is just an isolated event. Additionally, the team found that the survey area had quite thin soil, so increased tree stress monitoring efforts during times of drought would be a good idea. Finally, the RFMSC may want to invest effort into developing a long-term forest surveying plan, as the survey results make it clear that having large-scale, periodical forest surveys in the future would be the best way to ensure the forest stays healthy for future generations.

6. Conclusion

Just six months ago, the Rauscher Farm IQP team sat before Gloria Parkinson, the sponsor of the project we would soon undertake. Nobody on the team had even seen the farm yet in person; attempting to tackle a project that would have a lasting impact on the future of the farm seemed completely out of reach to the team at the time. However, with targeted research, careful planning, and hours of field work and observation, the team was able to provide the RFMSC both the results of a methodical tree survey conducted on the farm, as well as many materials that would make conducting a similar tree survey in the future far easier. In the future, the RFMSC will have the means to conduct citizen science tree surveys and similar events without having to create all of the materials from scratch.

Many of these same materials may also prove useful outside of the perspective of a future tree survey as well. Consider that the tree survey guide actually contains nearly every tree species present on the property, since it was created before the survey area was fully identified. This comprehensiveness makes the guide usable as an all-purpose guide for winter tree identification on Rauscher Farm; providing this guide to general farm visitors could be an exciting opportunity for both future farm visitors and the RFMSC. Additionally, the instructions provided to survey participants on the day of the tree survey could be similarly adapted in the future to produce an informational flier to offer to farm visitors. Any future visitor to the farm could then act as a potential survey participant, helping to identify and call attention to invasive insect damage in the forests as early as possible.

The survey area sits in a critical area for monitoring the spread of invasive insects in the state. In particular, Rauscher Farm sits mere miles away from the northern extent of the Asian Longhorned Beetle quarantine area in this part of Massachusetts. Although no ALB damage was found during the March 2023 survey event, future surveys of maple trees in this area may mean the difference between ALB spreading past the quarantine area or being fully eradicated. One does not even need to look past the borders of Rauscher Farm to see the consequences of the unimpeded spread of invasive insects, as not a single specimen of the once pervasive elm tree was observed in the team's survey, an extirpation presumably attributable to the spread of Dutch Elm Disease throughout the region a century ago. In the future, the spotted lanternfly may pose an additional threat to the farm as the spread of this pest continues to increase.

Perhaps most importantly, the team's research provides a baseline data point documenting the state of Rauscher Farm forests in the present day. In the not-so-distant past, the forests of Rauscher Farm did not exist at all. Research into past land use patterns in New England reveals that almost every forest in the entire state was once clearcut for either lumber, farmland, or both. Some forests have even been completely felled several times in just the past few centuries. The results of this project's tree survey highlight this past land use in every possible way. The youngest trees were found in areas that were once open farmland just decades ago, while older trees are found along rock walls where they were left to grow during the field clearing process. Physical evidence was even found during the tree survey which vividly revealed the land's past usage. For example, a rusted farm implement was found within the survey area itself on the northeast corner of the survey area. Since this exact spot was likely once a corner of a field, the tool was even left in exactly the location where one might expect to find it.

As the climate of New England continues to change, the forests of New England will continue to evolve. In just a few decades, the forests of Rauscher Farm will have changed to reflect the ever-changing conditions that trees within the forest face. Wetter and less snowy winters may mean that the wetland habitats on the farm have continued to grow. Completely new invasive insects will be introduced, and already familiar invasive species may spread further north as winters continue to trend warmer. The forest itself may be a completely different composition just because it has continued to mature. Whatever ends up happening to the forest in the future, the work of this IQP will provide a benchmark of what the forest once was, an account of how it had already changed, and advance warning of what change might continue to occur in the future. Not all change is bad, but the first step to identifying potentially harmful change is knowing that change has even occurred in the first place. Many years from now, the work of this project will continue to support effective analysis and provide useful methods to guide how that change is measured.

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U.S. Department Of Agriculture. (2020, June 22). *Asian longhorned beetle - about.* USDA Animal and Plant Health Inspection Service. Retrieved December 5, 2022, from https://www.aphis.usda.gov/aphis/resources/pests-diseases/asian-longhorned-beetle/About-ALB

This report from the USDA explains the damage caused by the invasive asian longhorned beetle. It includes information on hosts affected and the beetle's lifecycle.

Van Driesche, R. G., LaForest, J. H., Bargeron, C. T., Reardon, R. C., & Herlihy, M. (2013). *Forest Pest insects in North America: A photographic guide.* USDA Forest Service, Morgantown, WV.

This guide provides photographs and descriptions of various pest insects in North America. The information on species life cycles, host species, and regions affected help identify which pests are a danger to certain areas.

Williams, M. (2002). *Deforesting the Earth: From Prehistory to Global Crisis* (1st ed.). Chicago : University of Chicago Press.

This book provides a history of forestry methods, as well as explaining the logic behind those methods and their importance.

Appendices

Appendix A: Tree Survey Resources

A1: Event advertisement for use by RFMSC. Distributed on site, social media, and newspaper.

A2: Event advertisement for use on WPI campus. Was printed as a flyer and hung up on bulletin boards in academic buildings.

Tree Identification Guide

Thank you for participating in the first Rauscher Farm tree survey event! This guide will help you identify the trees in the forest around you.

If you have any questions, or find a tree not described here, please find a volunteer to help you.

White Pine

- ❏ Needles grow in bunches of 5
- ❏ Bark is smooth in young trees, &forms vertical bars when older
- ❏ The outermost layer of bark is gray, and tan deeper in

White Oak

- ❏ Light colored, thin, scaly bark
- ❏ Rounded leaves
- ❏ Vertical strips of bark “peeling” away from the trunk

Black Oak

- ❏ Dark , thin, scaly bark
- ❏ Pointed leaves
- ❏ Vertical strips of bark “peeling” from the trunk

Red Oak

- ❑ Thick, long ridges in the bark
- ❑ Pointed Leaves
- ❑ In the valleys of the ridges, deeper into the tree, tree is a reddish color

Hickory

- ❑ Bark forms scales like white oak
- ❑ However, the bark forms long vertical strips that criss-cross over each other
- ❑ Thicker bark than a white oak

White Birch

- ❑ Light, white color
- ❑ Horizontal lines indented in bark

Black Birch

- ❑ Dark, black color
- ❑ Horizontal lines indented in bark

Wild Cherry

- ❏ Longer horizontal stripes
- ❏ Black Birch look-alike
- ❏ Trunks grow very straight
- ❏ Found near Clamshell Pond

Sassafras

- ❏ Bark forms similar ridges diamond pattern to poplar trees
- ❏ However, the trunk will have curves or grow at an angle

Maple

- ❏ Branches grow in pairs, opposite one another
- ❏ Often have green moss on them
- ❏ Bark is smooth in young trees, and cracks in older trees

Poplar

- ❏ Bark is ridged, forming a diamond pattern
- ❏ Trunks grow very straight
- ❏ Grow near Clamshell Pond

A3: Identification guidelines and tips booklet given to volunteers at event.

<table>
<tr><td></td><td>Which cell is the tree located in?</td><td>How many trees are in this cell?</td></tr>
<tr><td colspan="2">1. Look through your Tree ID Guide. What species is the tree?</td><td>2. Does the tree have any visible damage? If so, describe it here.</td></tr>
<tr><td colspan="3">3. Find a survey leader. They will take a photo of your worksheet and photos of the tree damage for you. After that, you may move on to the next tree in in the cell.</td></tr>
</table>

A4: Survey form distributed to participants.

Appendix B: Event Photographs

B1: Setting up the grid on 3/17 (Credit: Gloria Parkinson)

B2: Home base on the day of the survey (3/18) (Credit: Gloria Parkinson)

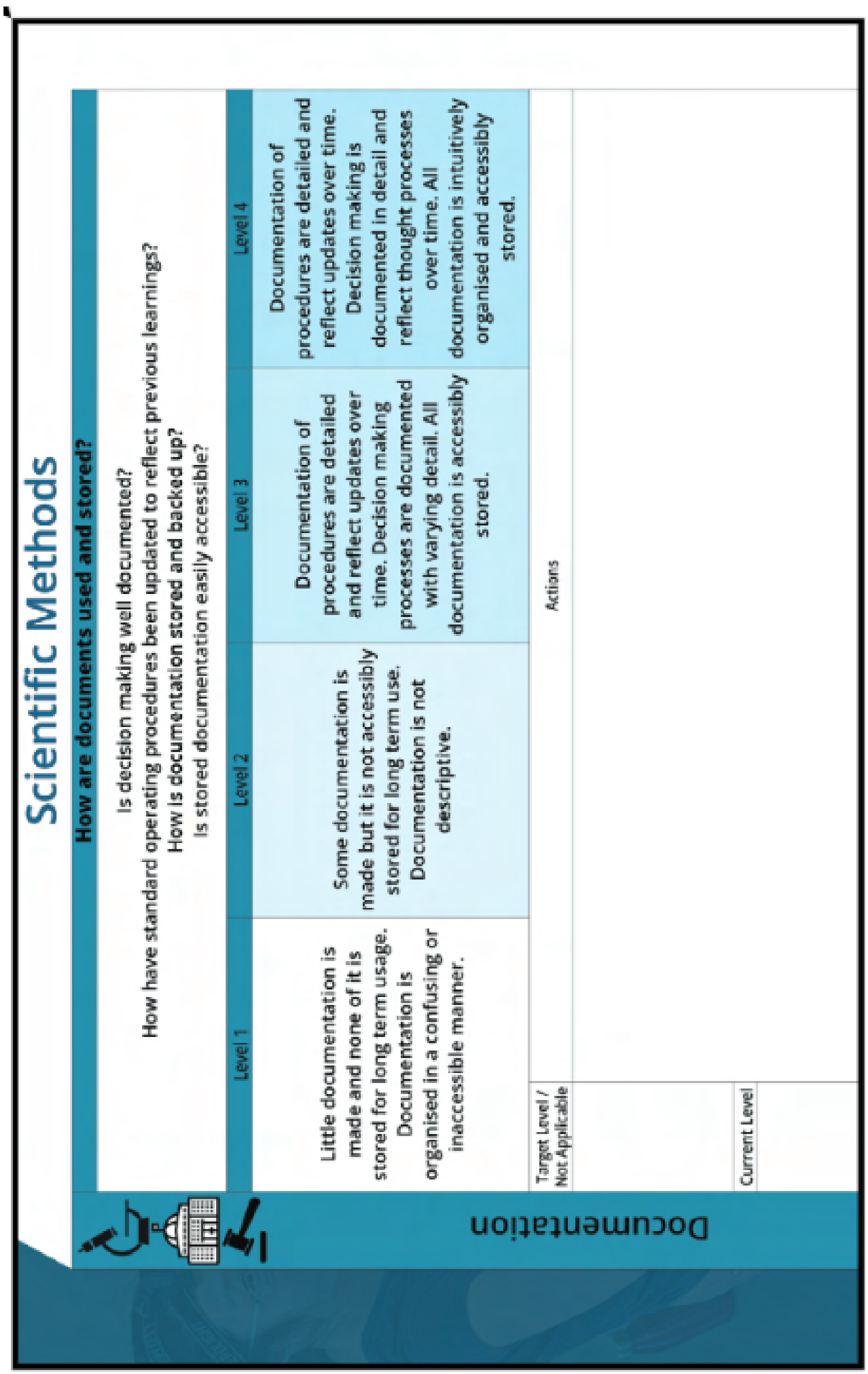
B3: Presenting the instructions (Credit: Gloria Parkinson)

B4: The survey process (Credit: Gloria Parkinson)

B5: Tree damage photographs (Credit: Gloria Parkinson)

B6: Data analysis in the field (Credit: Gloria Parkinson)

Appendix C: Citizen Science Rubric



Scientific Methods

Documentation

How are documents used and stored?

Is decision making well documented?
How have standard operating procedures been updated to reflect previous learnings?
How is documentation stored and backed up?
Is stored documentation easily accessible?

Level 1	Level 2	Level 3	Level 4
Little documentation is made and none of it is stored for long term usage. Documentation is organised in a confusing or inaccessible manner.	Some documentation is made but it is not accessibly stored for long term use. Documentation is not descriptive.	Documentation of procedures are detailed and reflect updates over time. Decision making processes are documented with varying detail. All documentation is accessibly stored.	Documentation of procedures are detailed and reflect updates over time. Decision making is documented in detail and reflect thought processes over time. All documentation is intuitively organised and accessibly stored.

Target Level / Not Applicable	Actions
Current Level	

C1: Citizen science guidelines grading rubric (Ralph et al. 2022)