Which oaks provide the greatest benefits to insects?

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Introduction

Oaks (*Quercus* spp.) are generally one of the greatest supporters of insect diversity and abundance when planted in their native range and therefore also contribute to overall biodiversity. They are particularly valuable as host plants for caterpillars, the most important animals in transferring energy from plants to terrestrial food webs (Janzen 1988). This revelation has led to a preference for oaks when discussing restoration plantings and managed landscapes; however, there still is little information about which species of oaks are the most beneficial in any given region. As of 2003, the USDA and U.S. Forest Service estimate that there are 92 oak species in the United States and 50 native oaks in Eastern North America. While studies have adequately measured differences in the ability to host caterpillars between tree families and genera (Tallamy and Shropshire 2009), there has been little research regarding the differences in caterpillar productivity between species within a genus, which may be greater than once believed. The focus of this thesis is to explore the differences in insect use of oaks among species in the Northeast U.S., specifically the Delaware valley. The results of this project will be beneficial to land managers, homeowners, restoration ecologists, conservation biologists, and any who aim to naturally support biodiversity.

Background and Context

Species of Oaks in Northeast US

- *Quercus alba* – White Oak, Eastern & Central U.S.
- *Q. coccinea* – Scarlet Oak, Eastern U.S.
- *Q. rubra* – Red Oak, Eastern & Central U.S.
- *Q. bicolor* – Swamp White Oak, North-central & Northeast Forests
- *Q. velutina* – Black Oak, Eastern & Central U.S.
- *Q. palustris* – Pin Oak, Eastern U.S.
- *Q. phellos* – Willow Oak, Eastern & Central U.S.

- *Q. macrocarpa* – Burr Oak, Eastern & Central U.S.
- *Q. arkansana* – Arkansas Oak, Southeast U.S.
- *Q. austrina* – Bluff Oak, Southeast U.S.
- *Q. boyntonni* – Boynton Sand Post Oak, Alabama
- *Q. buckleyi* – Texas Red Oak, Southern Great Plains
- *Q. chapmanii* – Chapman Oak, Southeast U.S.
- *Q. acerifolia* – Maple Leaf Oak, South-central U.S.

A comprehensive list of native oaks can be found in the USDA *Field Guide to Native Oak Species of Eastern North America*.

Problem Statement

This project serves to identify which species of oaks support the greatest abundance of insect herbivores. Although we know that native oaks support more insect herbivores than any other plant genus in North America (Tallamy and Shropshire 2009), little is known regarding which species of oak is best. We can maximize the efficiency and impact of planting beneficial hardwoods if we identify which species perform better in specific regions. In the modern era where land is being consumed through urbanization and climate change threatens plant life around the world, deriving the maximum benefit from the environment and its various ecosystems is of critical importance.

Literature review

Key Concepts, Theories, and Studies

Narango et al. (2017,2018) tested whether landscapes dominated by native or introduced plants affect the lifecycles of insectivorous birds. By monitoring and understanding population fluctuations of birds, the ecological cycles of insects they prey upon can be

inferred. Researchers monitored local plant species compositions and abundance, caterpillar counts, birds foraging, and site occupancy. They determined that the birds in question (Carolina chickadees) preferred native habitats because such habitats supported higher biomass of caterpillars, the primary constituent of nesting diets. The diversity of plants across sites represented over 230 species across 63 different, with an average plant species per site at 29 ± 10. Disregarding plant abundance per site, the plant genera that supported the highest frequency of foraging were native *Quercus* (28%), native *Acer* (16%), native *Carya* (4%), native *Liriodendron* (3%), native *Ulmus* (3%) and native *Pinus* (3%); this study also indicates that native *Quercus* sp. was the most preferred foraging plant group in 61% of bird territories. We can infer from the rates of foraging that those with higher values provided the greatest amount of resources, in this case, a higher abundance of insects.

T.R.E. Southwood (1961) suggested that the amount of insect species and variation associated with a given individual, species, or genus of tree is correlated with the abundance of that tree in a particular region throughout a period. Therefore, dominant native trees that have been present in the area for a period of geological history will have a greater number of correlated insect species, and trees that were recently introduced will have lower amounts. Southwood compared data from trees in Britain, Sweden, Russia, and Cyprus. In British and European Russian deciduous and coniferous forests, oaks (*Quercus*) had the highest number of insects at 284 and 150, respectively. In Sweden, oaks ranked third in the number of supported Lepidoptera and Coleoptera at 146 species, while in Britain they ranked first at 237 spp. Finally, a comparison of Heteroptera and Homoptera Auchenorrhyncha in Britain and Cyprus found that deciduous oaks (specifically *robur L.* and *petraea* (Matt.) Liebl. hosted 47 insects in Britain and *infectoria* Oliv. hosted 6 in Cyprus. Evergreen oaks (*ilex.* L) hosted no insects in Britain, but *alnifolia* Poech. hosted 2 in Cyprus. In Britain, a more detailed study was performed of common trees and found that oaks (*Q. robur* L. and *Q. petraea* (Matt.)

Liebl.) ranked the highest in total associated insect species (at 284), which a distribution at the order level: 37 Heteroptera, 10 Homoptera, 106 Macro-Lepidoptera, 81 Micro-Lepidoptera, and 50 Coleoptera. The results show on page 6, Figure 1, that the nativeness of a tree (indicative of how long it has been present in an ecosystem), the greater the number of species of insects there are present.

Research Design and Methods

It should stand to reason that trees that support a greater abundance of insects would have a higher representation of insect presence; this will include leaf damage from consumption, the corresponding waste deposits, larval or adult protections (leaf rolling, webs, or mines), egg-laying, and various other activities across the leaf face. These various uses provide an opportunity to quantify the amount of insect use of any particular tree. Study trees will be oak species across regions of Delaware, Pennsylvania, and Maryland from arboretums, conservatories, or preserved forests. These areas include the University of Delaware Botanic Gardens, the Taylor Memorial Arboretum, the Scott Arboretum, the Tyler Arboretum, and the Mt. Cuba Center; while these are the initial sampling sites, more may be visited if we require additional data sources.

To standardize leaf area sampled across species, a 1-meter circle will be filled with leaves of corresponding species, and the total number of leaves required to fill the circle will be counted for each species. This will tell us how many leaves of each species leaf we will need to sample.

Sampling will be through photography rather than a destructive sampling of leaves to preserve the natural progression of herbivory. Sampling will take place throughout the summer season as this is when both insect herbivory and plant growth are at its highest. Repeated samples will be taken, estimated once every two weeks, to record the increasing

damage levels throughout the season. Rather than isolating specific leaves, we will focus on the distribution throughout horizon levels on the trees based on height. The first horizon will represent the base of the trunk, the second horizon will represent the middle portion of the tree, and the third horizon will represent the canopy. While branches will be picked randomly, they must be consistent across species and represent areas of the tree that experience sun for most of the day.

By sampling the maximum number of tree species available, both native and non-native, we will be able to procure a reasonable and educational conclusion on herbivorous preferences. A complete list of trees sampled will be provided in the results section, but there are some prevalent species I anticipate finding due to climate, locale, and horticultural preference. These are *Quercus alba, Q. coccinea, Q. rubra, Q. phellos, Q. bicolor, Q. velutina, Q. macrocarpa, Q. palustris,* and *Q. prinus.*

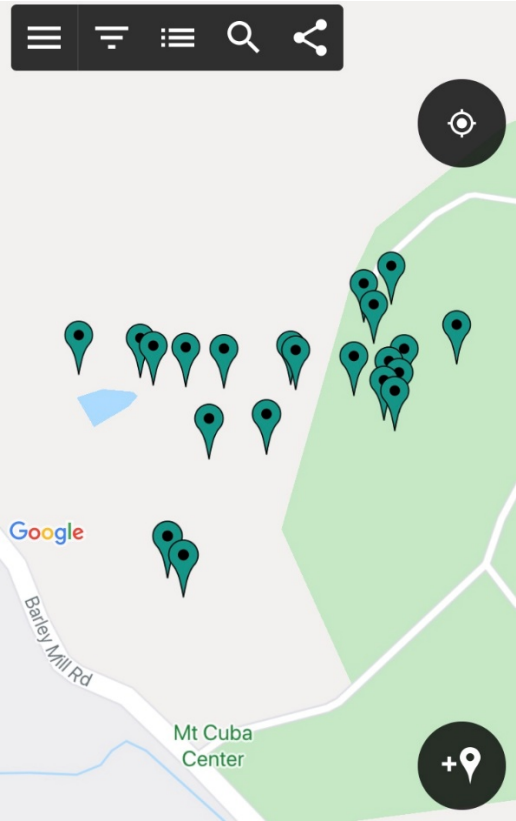
The samples will then be analyzed based on their use to disuse ratios. The photos will be uploaded into a program that will analyze the total leaf area index to gain exact measurements of usage which will allow us to compare the area of the leaf face that has been utilized by insects. Using the ratios we established through our leaf standardization, we will be able to establish which oak species have suffered the most damage across samples.

The design of this research incorporates both qualitative and quantitative data. For quantitative, we require a specific ratio of samples across species in order to gather an accurate representation of usage. The measurement of damage, while quantitative, will be based on qualitative observations and recordings. The presence of insect damage and use across the leaf face will give us a good idea of the total abundance per tree and species.

Results

Mt. Cuba Center

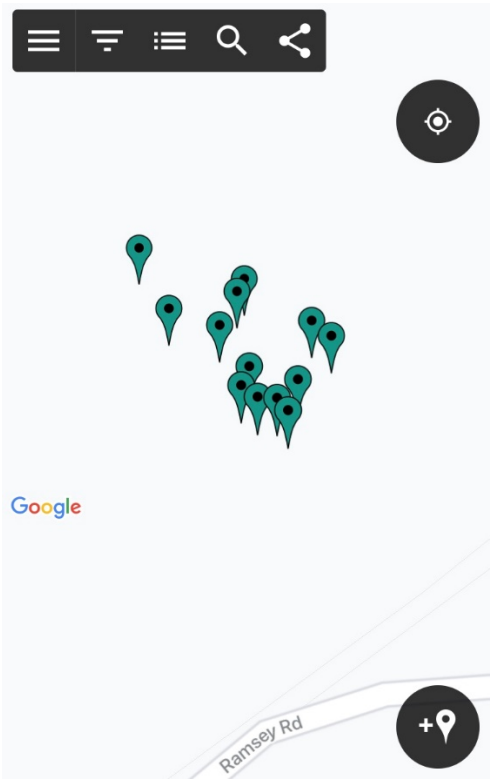
Located in Northern Delaware (Hockessin) in the hills and forests of the Delaware Piedmont, Mt. Cuba Center is a 500+-acre botanical garden composed of forests, fields, and riverbeds. According to their website, “Mt. Cuba Center is home to more than 1,000 species of native plants, many of which are threatened by extinction.” While the majority of the landscape is cultivated and cared for by staff, deeper regions of woodlands are relatively untouched and allowed to reside in natural areas.



Oak Species	Number
White Oak	11
Red Oak	1
Scarlet Oak	5
Swamp White Oak	2
Bur Oak	1
Willow Oak	1

Mt. Cuba Nursery

Located in Northern Delaware (Hockessin) and South of the Mt. Cuba Center, Mt. Cuba's Nursery is an isolated area of land that allows for research and propagation. At the moment, the plot is focused on growing hardwoods in varying densities and therefore provides an ample supply of oaks. Although the oaks grown here are younger (5-8 years), the comparison of age in insect damage will be an addition to our base project.

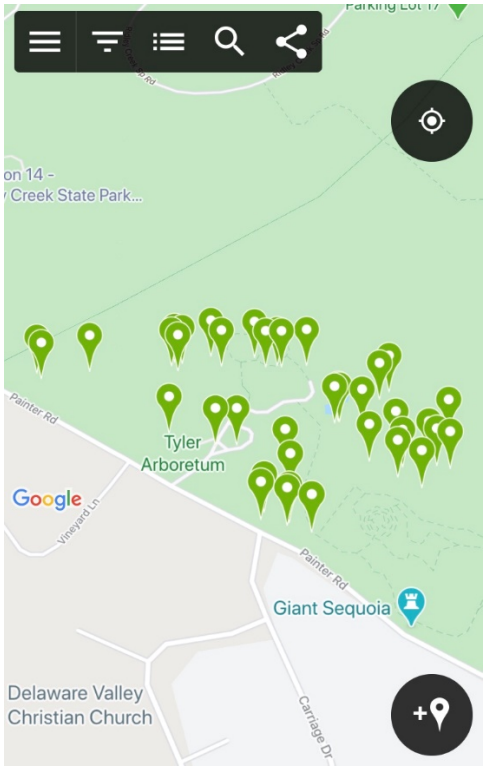


Oak Species	Number
White Oak	1
Swamp White Oak	2

Oaks from this location were not properly identified and need to be checked against a representative sample before confirming numbers.

Tyler Arboretum

Located in Southeast Pennsylvania (Media), Tyler Arboretum is a 650+-acre park that hosts a variety of habitats such as meadows, lush forests, edge habitat, and riverbeds. Founded in 1681, it is one of the oldest public gardens in the United States and, as such, has oaks that are equally as old (two specimens of white oak).

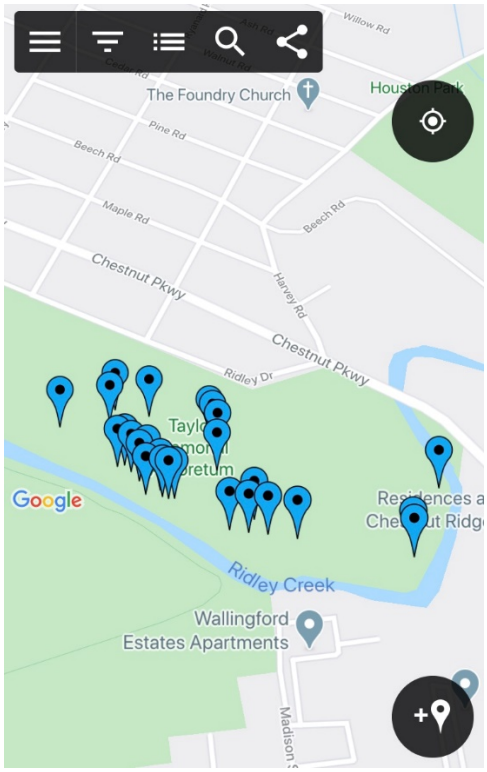


Oak Species	Number
Scarlet Oak	4
Sawtooth Oak	4
Willow Oak	6
Red Oak	6
Bur Oak	3
White Oak	11
Swamp White Oak	2

Pin Oak	1

Taylor Arboretum

Located in Southeast Pennsylvania, Taylor Arboretum is a 30+-acre reserve composed of deep forests and riverside habitats. Associated with Widener University, the gardens host a variety of native plants with the addition of some exotic beds.

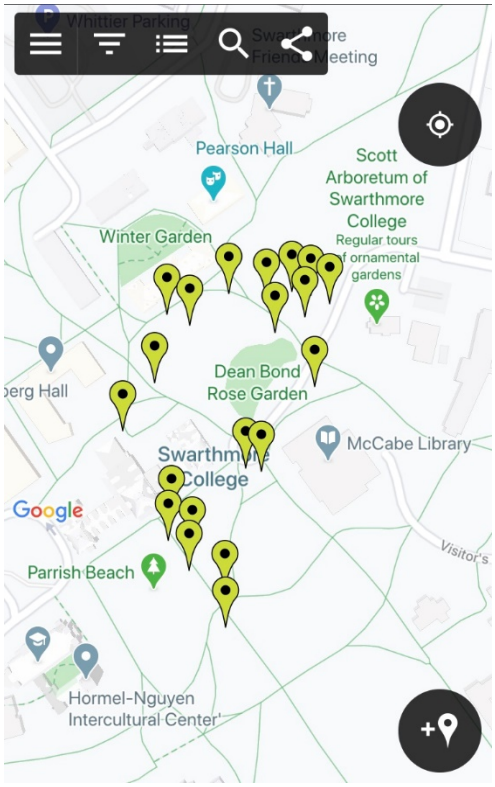


Oak Species	**Number**
Bur Oak	1
Water Oak	3
Chestnut Oak	1
Willow Oak	4
Swamp White Oak	2
White Oak	2

Pin/Hybrid Oak	5
Sawtooth Oak	1
Scarlet Oak	1
Red Oak	2

Scott Arboretum of Swarthmore

Located in Southeast Pennsylvania (Swarthmore), Scott Arboretum is coterminous with Swarthmore College, a 357-acre mixture of lecture halls and greenery. This arboretum focuses more on propagating plants that will survive in the local climate, rather than focusing on planting purely natives. The grounds are split into various gardens: Crum Woods is a 200-acre woodland trail, Dean Bond Rose Garden hosts over 650 roses, James R. Frorer Holly Collection has over 350 types of hollies, and the Pinetum contains pines, firs, spruces, and conifers. The majority of the samples came from the Main Green and Crum Woods.



Oak Species	Number
Bur Oak	3
Red Oak	2
Sawtooth Oak	2
White Oak	3
Spanish Oak	1
Willow Oak	1
Scarlet Oak	1
Swamp White Oak	6

Adkins Arboretum

Located in East Maryland, Adkins Arboretum is a 400-acre park within Tuckahoe State Park composed of woodlands, meadows, wetlands, and tended gardens. The arboretum hosts a variety of plants, including a “living collection” of more than 600 native plant species.

University of Delaware Botanic Gardens

Located in Northeast Delaware on the University of Delaware South Campus, the UD Botanic Gardens is a 15-acre area composed of eleven different garden habitats. The gardens pride themselves on their vast collection of plants, both exotic and native, that support the education, aesthetic design, and ecological impact of the University.

The results of this study are not currently represented in this paper. Sampling will continue through the Summer season, professional comparisons must be made, and leaf area must be

further analyzed. This paper is acting as an intermediate report on the status of this project. A finalized version of this report is set to be assembled during the 2020 semesters.

Practical Considerations

This research focuses entirely on the damage that has occurred to the leaf face, which will give us a representation of herbivory that occurs on the tree. However, there are a variety of other scenarios in which insects utilize the entirety of the plant: wood borers disregard the leaves and tunnel directly into the cambium of the tree; certain life stages of insects such as cicadas drop to the forest floor and remain near the base of the tree or even reside within the roots; gall insects, while they may be present on the leaf surface, often attack branches or bark. While this project is unable to represent the totality of usage, it will demonstrate a significant portion of cases.

The project also encounters certain limitations represented by external factors. Ideally, we would be able to control for environmental factors across sampling sites such as biotic composition, regional climate and topography, and random sampling. While most locations are similar in climate and biotic composition, there are variables across each site that may alter the results of this study. We have attempted to remove as many errors as possible by using a large sample size.

Implications and contributions to knowledge

This project will determine which species of oaks are the most beneficial to insects in the Mid-Atlantic deciduous forest. The results will be useful in conservation, restoration, landscaping, and land management, as well as in future research. By understanding which oaks provide the most resources in this region, we can begin assisting animal diversity by planting the oaks that provide the greatest number of benefits. These results may also supply

a basis for future research that may observe specific abiotic or biotic factors outside of species.

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Research schedule

Research phase	**Objectives**	**Deadline**
Confirmation of visits	Reach out to established sites and ensure we can still sample	6/1
Scouting	Initial visitation to sites to scout available samples and identify specimens	6/8
Complete preparations	Standardize leaves, create horizons, identify species	6/15
Begin sampling	Initial sampling of specimens	6/21
Continue season sampling	Repeated sampling from sites throughout the season	Continue until end of August/temperatures alter; sampling will continue through the semester if more data is required
Organization and analysis of data	Organize cumulative data, analyze use patterns, and compare between species	NA