Impacts of Native and Non-native plants on Urban Insect Communities: Are Native Plants Better than Non-natives?

by

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Abstract

With continued suburban expansion in the southeastern United States, it is increasingly important to understand urbanization and its impacts on sustainability and natural ecosystems. Expansion of suburbia is often coupled with replacement of native plants by alien ornamental plants such as crepe myrtle, Bradford pear, and Japanese maple. Two projects were conducted for this thesis. The purpose of the first project (Chapter 2) was to conduct an analysis of existing larval Lepidoptera and Symphyta hostplant records in the southeastern United States, comparing their species richness on common native and alien woody plants. We found that, in most cases, native plants support more species of eruciform larvae compared to aliens. Alien congener plant species (those in the same genus as native species) supported more species of larvae than alien, non-congeners. Most of the larvae that feed on alien plants are generalist species. However, most of the specialist species feeding on alien plants use congeners of native plants, providing evidence of a spillover, or false spillover, effect. Results are concordant with those predicted by the Enemy Release Hypothesis, which states that alien plants are more successful in non-native areas due to reduced herbivore attack. With a reduction in primary consumer diversity, secondary consumers such as migratory birds and parasitoid wasps may also be impacted. These results highlight the need for further research into specific interactions between native and non-native plants.

Suburban landscapes have contrived associations of native and non-native plants that may interact with insect communities across multiple trophic levels. The purpose of the second

project (Chapter 3) was to investigate associational interactions (associational resistance or associational susceptibility) between native and non-native plants in urban environments, and how they impact insect communities. In a 2 year field study, abundance and diversity of eruciform larvae and natural enemies, as well as plant damage, were measured in 5 x 5 m plots in which a native red maple (*Acer rubrum*) was interplanted with either other native red maples, non-congeneric non-native crepe myrtles (*Lagerstroemia indica*), non-native congeneric Norway maples (*Acer platanoides*), or placed by themselves in a plot. Tree damage percentage, caterpillar abundance, and caterpillar species richness were all collected on focal red maples and one neighboring plant. Natural enemies were also measured using modified yellow pan traps. Damage rate and caterpillar abundance were similar between all treatment groups during 2014. In 2015, however, caterpillar abundance was greater for red maple surrounded by crepe myrtle than it was for red maples with no neighbors, red maples surrounded by other red maples, and red maples surrounded by Norway maples. Greenstriped mapleworm (*Dryocampa rubicunda*), a native, multivoltine specialist caterpillar, was the most abundant caterpillar found in the study, and its abundance was correlated with damage and total caterpillar abundance. We propose that *D. rubicunda* caterpillars feeding on red maples surrounded by crepe myrtles have an increase in larval and adult survival through a decrease in predation. There were no significant differences in insect natural enemy abundance or family richness due to treatments. We believe that our analysis of natural enemy community composition at the family level is insufficient and that results may differ if identified to a lower taxonomic level. The results indicate that associational interactions between native and non-native plants can greatly influence urban insect herbivore communities and that maximizing use of native plants in urban environments will decrease opportunities for plant pest outbreaks.

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List of Abbreviations

AR	Associational Resistance
AS	Associational Susceptibility
RM/RM	Plots with red maple surrounded by four red maples
RM/CM	Plots with red maple surrounded by crepe myrtle
RM/NM	Plots with red maple surrounded by Norway maple
RM/N	Plots with red maple and no neighbors
RM/DIV	Plots with red maple surrounded by four diverse native trees

Chapter 1

Introduction and Literature Review

Problem Statement

The world's human population is projected to increase from 7.2 billion in 2012 to 9.6 billion in 2050. Consequently, urban and suburban environments have been increasing exponentially world-wide. In the United States and other developed countries, which are considered low-fertility, populations are expected to remain relatively stable (United Nations, 2013). However, this has not halted the suburbanization phenomenon. Between 1950 and 2000, urban populations have shifted from 70% living in central cities, to 60% living in suburban areas located in the outskirts of cities. As a result, the population density in most cities has been cut in half (Rusk 2000), thus increasing human-modified land area substantially. If trends continue as they are, by 2030 urban land coverage will be nearly triple what it was in 2000 (Seto et al. 2012). Plant, vertebrate, and invertebrate diversity changes with levels of urbanization. High levels of urbanization are linked to declines in diversity of all three groups (McKinney 2008). However, in suburban environments (which are generally considered to have moderate levels of urbanization), the general trend is for an increase in plant species richness but a decrease in vertebrate and invertebrate species richness (McIntyre 2000, McKinney 2008). These findings are largely the result of a massive influx of non-native plants into suburban environments.

Since European settlers landed in North America, at least 5000 alien plant species have been introduced into the United States. Hundreds of these species have become invasive and have decimated natural habitats, with the southern states being no exception (Tallamy 2004, Miller et al. 2012). Research suggests that native insect herbivores such as caterpillars suffer reduced population numbers and reduced diversity in areas where alien plants are prevalent (Burghardt and Tallamy 2013, Clem and Held 2015, Liu and Stiling 2006, Tallamy et al. 2008, Vilà et al. 2005). Due to evolutionary separation, many native insects cannot overcome the natural defenses presented by alien plants. Insect species which are able to feed are usually generalists with a wide diet-breadth (Burghardt 2010, Clem and Held 2015). Most alien plants are popular among horticulturists for these reasons alone (Tallamy 2007). Additionally, natural enemies, such as birds and parasitoid wasps, can be affected by decreased populations of these herbivores (Greenstone 2013, Burghardt et al. 2008).

Changes in an insect community can lead to changes in higher trophic levels. Of all the bird species in North America, 61% are primarily insectivorous and 28% are partially insectivorous (Capinera 2010). Ninety-six percent of terrestrial bird species in North America forage partially or entirely for insects when feeding their young during the nesting season (Dickenson 1999). There have been steep declines in many native bird populations in the United States since 1967 (Mass Audubon Committee 2011). Some species previously referred to as “common” have experienced declines as high as 80% (Butcher and Niven 2007). These declines are directly correlated with factors related to increasing human habitation such as cats and window-strikes (Mass Audubon Committee 2011), but are indirectly correlated with the influx of non-native plants (Burghardt et al. 2008, Narango et al. 2015).

Effects of non-native plants on native ecosystems in urban environments are not well studied. For example, the existing literature often does not take into account that most normal suburban ecosystems are composed of mixtures of native and non-native plants. Native plants in these situations may support differing abundances of herbivorous insects through associational interactions with non-native plants. Additionally, there has been very little research on the impacts of native and non-native plants on insect herbivore communities in the southeastern United States. The following literature review has been conducted in order to design projects that will help fill these knowledge gaps. These projects are explained further in Chapters 2 and 3 of this thesis.

Overview of Published Work

1) <u>Native vs. non-native host preference by native insect herbivores</u>

The Enemy Release Hypothesis states that alien species are less susceptible to attack in non-natural ranges due to a lack of natural enemies (Elton 1958, Colautti et al. 2004). As described by Tallamy (2007), native insects have evolved adaptations that allow them to overcome secondary plant compounds and other defenses produced by native plants. Native herbivores did not evolve with non-native plants, making most non-native plants less susceptible to herbivore attack. In fact, non-native plants coupled with disturbed habitat are one of the largest contributing threats to rare and endangered Lepidoptera on the U.S. East Coast (Wagner and Van Driesche 2010). In his book, Tallamy compares the herbivore loads of five species of non-native plants that have been in the U.S. for over 100 years. All of these plants supported approximately 0.02% of the number of herbivores supported in their home range (Tallamy 2007). He estimates that thousands, if not millions of years are required for insects to “catch up” with these plants that have evolved elsewhere. Consequently, horticulturists and landscape designers tend to favor non-native ornamentals (Tallamy 2004).

Tallamy et al. (2008) tested the capabilities of four native herbivorous caterpillars (considered highly polyphagous) to consume and survive on a wide variety of non-native plants. Larvae were much less capable of surviving on non-native plants even when they were congeners to their native hosts (Tallamy et al. 2008). Native plants can harbor as many as five times more specialist Lepidoptera species (Burghardt 2010). This makes sense, considering that generalists can sustain themselves on members of multiple plant families while specialists feed on very few (Bernays and Graham 1988). At a system level, Ballard et al. (2013) compared arthropod communities on native and non-native early successional plants and found that native plants produced as much as five times more arthropods. A review by Liu and Stiling (2006) summarized data on herbivory of 15 plant species in their native and introduced geographic ranges. Consistent with the Enemy Release Hypothesis, there were significantly fewer herbivores and significantly less leaf damage on plants in their non-native ranges. White (2013) explored herbivore preference at the host plant assemblage level. He found that increasing preferred, native host plants could increase caterpillar species richness and abundance by as much as 30-40% in disturbed remnant forest systems in Canada.

Non-native plants support different loads of herbivores, depending on their degree of relatedness to native species. In a field study conducted in suburban landscapes in Delaware, Burghardt and Tallamy (2013) found that non-native congeneric plant species can support more herbivores than non-native non-congeneric species. Cincotta et al. (2009) found that Norway maple (*Acer platanoides*), an invasive, non-native congeneric species, had less leaf damage compared to the native sugar maple (*Acer saccharum*). Additionally, non-native plants do not impact all herbivore guilds equally. Chewing herbivores and immature forms were more impacted by non-native plants than adult forms and those that feed using piercing-sucking mouthparts. Insect eggs were much more common on native plants. Finally, very few insect herbivores that feed internally were found on non-native plants; this appeared to be the feeding guild that was most sensitive to plant origin (Burghardt and Tallamy 2013).

The Enemy Release Hypothesis does not consistently explain the success of non-native plants. Community productivity (Dostál et al. 2013) and the modification of species composition into monocultures (Castagneyrol et al. 2013) can also significantly impact herbivory on exotic plant species. It is important to recognize that herbivore species diversity in areas dominated by native or exotic plants can vary extensively depending on specific situations involving specific plant species (Sax et al. 2005).

2) <u>Associational Resistance and Associational Susceptibility</u>

The relationship between herbivore and plant is a primary topic of basic and applied insect ecology. Historically and still today, there is an emphasis on more thoroughly understanding the relationship between consumer and resource. Among others, Richard Root and colleagues (e.g. Tahvanainen and Root 1972, Root 1973) expanded our perspective on insect-plant relationships to include community-wide factors. Resource Concentration, Associational Resistance (AR), and now Associational Susceptibility (AS) are concepts that evolved from this early work to explain the relative abundance of, and damage caused by, herbivores in the context of their communities. AR and AS describe the outcome of specific plant associations whereby a host plant for a herbivore would experience reduced (AR) or increased (AS) susceptibility or detection by that animal (Atsatt et al. 1976, Barbosa et al. 2009, Plath et al. 2012).

Traits of focal plants, herbivores, and external environmental factors are likely to influence both AR and AS. The literature defines a focal plant as the primary target for the herbivore, and adjacent plants as 'neighbors'. Typical response variables for these studies are herbivore abundance and damage to the focal plant. Barbosa et al. (2009) reviewed current mechanisms and used meta-analysis to identify herbivore and plant traits that may favor either AR or AS. They concluded that when focal plants are surrounded by unpalatable neighbors, AR is more likely, and AS is predicted when the neighbor plants are palatable. Furthermore, AR was more likely in interactions involving mammals, while AS was more likely in interactions involving insect herbivores. Among herbivorous insects, they determined that feeding guild or diet breadth were not significantly influenced by the likelihood of either AS or AR and therefore were not reliable indicators of these effects (Barbosa et al. 2009). Herbivore-induced effects appear to vary on a case-by-case basis. For example, Koricheva et al. (2006) concluded that published studies provide no support for the concept that diversity in tree stands leads to fewer pest and disease outbreaks. Plath et al. (2012) discovered that the tropical plant *Tabebuia rosea* was more susceptible to damage by a specialist Pyralid caterpillar when growing in mixed stands as opposed to monocultures. In contrast, a specialist Chrysomelid beetle had higher abundance, and caused more damage, in *T. rosea* monocultures (Plath et al. 2012). This suggests that insect identity and biology may play a role in determining associational interactions.

Plant associational apparency is another factor that can play a role in associational interactions. Results from a manipulated field study (Castagneyrol et al. 2013) suggest that a decrease in focal tree apparency via host dilution causes AR through a decrease in herbivore damage. The authors stress that tree size (in their case sapling size) plays a major role in determining AR and AS: bigger trees are more attractive to herbivores and smaller trees are less attractive due to decreased apparency, especially in the presence of larger neighboring trees. Franziska et al. (2014) concluded that forest fragmentation and tree diversity interactively affect insect (herbivore) community composition. For slightly fragmented forests, the number of herbivore species decreased and the abundance of herbivores increased with increasing tree diversity. For highly fragmented forests, abundance and species richness of herbivore species were not affected by tree diversity.

Alteration of habitat on differing spatial scales may also have an effect. Smaller spatial scales, such as urban ecosystems, may exhibit stronger effects on herbivores than larger spatial scales (Harvey and Fortuna 2012). Bommarco and Banks (2003) did a meta-analysis on plant diversification experiments, comparing effects of insect populations at different scales. They suggested that vegetational diversification at smaller spatial scales can have enhanced effects on insect herbivore populations. Thus, the occurrence of AR or AS should be most detectable at a smaller spatial scale in which plants are placed in close proximity.

Herbivore damage via associational effects has been shown to decrease with increasing phylogenetic dissimilarity between plants (Barbosa et al. 2009, Giffard et at. 2012, Ness et al. 2011). When neighbor plants are related or even congeners, there may be 'spillover' effects because the focal and neighbor plants share herbivores (Barbosa et al. 2009). If plant neighbors are also non-native plants, there may be further negative consequences on focal, native plants. This concept is not well represented in the literature. Invasive, non-native species can directly compete with native plants, but indirect effects via AR are also predicted for native plants in the presence of invasives. Using path analysis, Atwater et al. (2011) outlined direct and indirect effects of invasive leafy spurge (*Euphorbia esula* Linnaeus) on a native forb (*Balsamorhiza sagitatta* Nuttall). Indirect positive effects via AR on *B. sagitatta* reduced the negative effects of direct competition between the plants by 75%. The Novel Weapons Hypothesis states that unique chemicals produced by non-native plants may confer protection in non-natural systems (Calloway and Meron 2006). Harvey and Fortuna (2012) hypothesized that introduction of new chemicals and volatiles (i.e. the novel weapons) at small scales will influence herbivore interactions with host plants. These changes in chemical complexity could impact host-parasitoid interactions (Harvey and Fortuna 2012). For example, the parasitoid *Diadegma semiclausum* took longer to find its host in the presence of multiple host plants (Gols et al. 2005). Plath et al. (2012) mentions this as a possibility for why specialists choose host plants in mixed stands versus monocultures. Moths that select trees in chemically complex stands could be selected for over those that choose trees in monocultures because the complex stands are more "enemy free." These effects could be either reduced or elevated in environments that consist of non-native plants.

3) Tri-trophic interactions between plants, insects, and birds

The interactions between native and invasive plants, and how they influence the third trophic level, are poorly understood. Trophic cascades work in two directions: bottom-up control and top-down control. Top-down control is where secondary (or tertiary) consumers influence primary consumers such as herbivorous insects, which in turn can influence plants serving as producers. This Ecosystem Exploitation Hypothesis has been observed in a wide variety of systems, from simple agricultural and cold climactic systems, to more complex systems like boreal, temperate, Mediterranean, and tropical ecosystems (Mäntylä et al. 2010). Bottom-up control occurs when producers influence primary consumers, such as herbivores, which then influence secondary consumers. Many studies have tested this form of tri-trophic interaction. Bateman and Ostoja (2012) found that non-native, monotypic *Tamarix* (saltcedar sp.) forests had decreased arthropod abundance, lizard abundance, and mammal diversity compared to areas where forests were mixed with *Tamarix* and native species. Similarly, green frogs (*Rana clamitans*) had reduced foraging success in fields dominated by Japanese Knotweed (*Fallopia japonica*), suggesting that the non-native plant had a detrimental effect on the arthropod community (Maerz et al. 2005). Greenstone (2013) established native and non-native gardens at the National Arboretum: gardens with only native woody and herbaceous plants had greater diversity and abundance of parasitoid wasps than gardens with only non-native plants. Sperber et al. (2004) sampled family-level parasitoid diversity on cacao agroecosystems in Brazil and found that parasitoid richness increased with increasing tree species richness.

More evidence links interactions among plants, insects, and birds. In suburban landscapes in Pennsylvania, Burghardt et al. (2008) found that a native understory increased caterpillar and bird abundance and diversity. Furthermore, notable increases in herbivorous insects, insect parasitoids, and birds in the Azores occurred when invasive plants (including grasses, shrubs, and trees) had been removed (Heleno et al. 2010). Similar patterns emerge from herbaceous systems such as grasslands. Two species of grass, Lehmann lovegrass (*Eragrostis lehmanniana*) and buffelgrass (*Cenchrus ciliaris*) are introduced exotics that dominate many Texas grasslands. Overall insect and bird abundance was greater in areas where these exotic grasses were absent compared to land that these grasses dominated (Flanders et al. 2006). Lloyd and Martin (2005) documented impacts of crested wheatgrass (*Agropyron cristatum*) on the reproductive success of a bird, the Chestnut-collared Longspur (*Calcarius ornatus*). Crested wheatgrass is an exotic species that has been planted on millions of hectares of land in the Great Plains region. In many areas, this grass has, ironically, been planted on abandoned farmland as part of a conservation program (Lesica and DeLuca 1996). The bird's reproductive success was lower on lands occupied by crested wheatgrass monocultures than on lands where native grasses dominated the landscape (Lloyd and Martin 2005).

Among bird species in North America, 61% of bird species are primarily insectivorous, 28% are partially insectivorous, and 11% are non-insectivorous (Capinera 2010). Insect protein is especially important during breeding season when 96% of terrestrial bird species depend on insects (either partially or entirely) in order to feed their young (Dickenson 1999). Insects provide an exceptional source of fat and protein for birds, which are essential fuels for rapidly growing chicks. Protein from the integument usually ranges from between 20-80% of an insect's dry weight, and fat usually comprises 2-60% of an insect's dry weight (Capinera 2010). Insect prey selection by birds is highly variable (Kaspari and Joern 1993, Capinera 2010). There are six insect orders that contribute the most to bird diets: Coleoptera, Lepidoptera, Hymenoptera, Hemiptera, Orthoptera, and Diptera (Capinera 2010). This is likely because these six orders are also among the most abundant orders available in terrestrial systems, and birds are opportunistic feeders. Birds also consume other arthropods, other invertebrates, and sometimes vertebrates (Capinera 2010). Two studies support the hypothesis that birds are food limited and implicate insect biomass as an important staple for birds when available. Western Kingbirds (*Tyrannus verticalis* Say) had earlier clutch initiation dates, larger clutch sizes, higher nestling growth rates, shorter time between foraging flights, and shorter time between nestling feedings in areas where insect biomass was high compared to areas where it was low (Blancher and Robertson 1987). A large periodical cicada emergence, albeit ephemeral, influences foraging trips, and increases biomass, survival of nestlings, and subsequent fledgling success of red-winged blackbirds (Strehl and White 1986). Therefore, interactions among native and non-native plants that restrict insect biomass are highly likely to negatively influence populations of birds and other natural enemies.

Neotropical migratory birds (birds that fly thousands of kilometers to spend the winter in Central or South America) have, on average, been declining by 1% every year since 1966 (Butcher and Niven 2007). Eastern forest-obligate birds have also been on the decline (Sauer and Link 2011). It is estimated that some previously common birds have declined, on average, by 68% (Butcher and Niven 2007). Many factors appear to be contributing to these declines. These include habitat destruction, habitat fragmentation, structure and mechanics of human society (e.g. cars, glass windows, smog, etc), invasive species (especially feral and free-ranging domestic cats), and toxic chemicals in the environment (Massachusetts Audubon Committee 2011). However, with over 60% of urban human populations living in expanding suburban outskirts (Rusk 2000), accompanied by a massive decrease in suitable bird habitat, habitat destruction and fragmentation is likely the leading cause for these declines. It is well-known that habitat size directly correlates with the number of species in that habitat. For example, an island will have a smaller diversity of organisms than a continent (Rosenzsweig 1995). One reason for this is that species go extinct faster in a smaller area because there are less niches to be filled (Dobson 1996). This is the basis for the concept of "extinction debt", which is currently a problem across the United States. As more and more land is being converted to suburbia, humans are essentially creating islands of suitable bird habitat throughout the country. Conversion to suburbia is often accompanied by plantings of non-native ornamental plants, which generally have fewer herbivorous insects serving as food for birds and other natural enemies (Tallamy 2007, Burgardt et al. 2010, etc.). Furthermore, if associational resistance to herbivores is a factor when native plants are surrounded by non-natives, there is potential for these suburban islands to be even further impoverished.

Chapter 2

Species Richness of Eruciform Larvae Associated with Native and Alien Plants in the Southeastern United States

Abstract

With continued suburban expansion in the southeastern United States, it is increasingly important to understand urbanization and its impacts on sustainability and natural ecosystems. Expansion of suburbia is often coupled with replacement of native plants by alien ornamental plants such as crepe myrtle, Bradford pear, and Japanese maple. The purpose of this project was to conduct an analysis of existing larval Lepidoptera and Symphyta hostplant records in the southeastern United States, comparing their species richness on common native and alien woody plants. We found that, in most cases, native plants have the capability of supporting more species of eruciform larvae compared to aliens. Alien congener plant species (those in the same genus as native species) supported more species of larvae than alien, non-congeners. Most of the larvae that feed on alien plants are generalist species. However, most of the specialist species feeding on alien plants use congeners of native plants, providing evidence of a spillover, or false spillover effect. These results are concordant with those predicted by the Enemy Release Hypothesis, which states that alien plants are more successful in non-native areas due to reduced herbivore attack. With a reduction in primary consumer diversity, secondary consumers such as migratory birds and parasitoid wasps may also be impacted. These results highlight the need for further research in this area.

Introduction

Between 1950 and 2000, urban populations in the United States have shifted from 70% living in central cities, to 60% living in suburban areas located in the outskirts of cities (Rusk 2003). Even areas like the southeastern United States, which are traditionally considered rural, now consist of vast expanses of suburbia (United Nations 2014). For example, Alabama has about 3,130 km^2 of turfgrass (Milesi et al. 2005), which is more area than was devoted to production of both corn and cotton during 2007 and 2008 (NASS 2008). If these trends continue, by 2030 urban land coverage will nearly triple that of urban land in 2000 (Seto et al. 2012).

Levels of urbanization change plant, vertebrate, and invertebrate species richness. High levels of urbanization (>50% impervious surfaces) result in declines in species richness of all three groups. However, at moderate levels of urbanization (20-50% impervious surfaces), the opposite effect occurs on plant species richness (McKinney 2008). Curiously, urbanization at moderate levels causes increased plant species (due to exotic introductions) but decreased species richness of insects (Mcintyre 2000, McKinney 2008). Urbanization, coupled with introductions of exotic plants, seems to be a major driver of changes in insect diversity. This phenomenon makes landscapes in the intermediate suburban category an interesting area in which to study interactions between plant and insect communities.

Tens of thousands of alien plant species have been introduced into the United States since European settlers landed in North America (Pimentel et al. 2000). The majority were introduced as amenity species for beautification of home landscapes, parks, and other settings. As many as 5000 plant species are thought to have become invasive, decimating natural habitats throughout the land, the southeastern United States is no exception (Miller et al. 2012, Pimentel et al. 2000, Tallamy 2004). Diversity of native insect herbivores, such as caterpillars, is significantly reduced in areas where alien plants are prevalent (Burghardt et al. 2010, Liu and Stiling 2006, Tallamy et al. 2007, Vilà et al. 2005). Alien plants, coupled with disturbed habitat, are one of the largest threats for rare and endangered Lepidoptera (Wagner and Van Driesche 2010). Alternatively, generalist insect herbivores may have an increased capability to feed on alien plants, especially if they have been exposed to aliens for many generations.

Some empirical studies have investigated native and alien plant interactions with indigenous insect herbivores. Tallamy et al. (2010) tested the capabilities of four native herbivorous caterpillars (considered polyphagous) to consume and survive on a wide variety of alien plants. Larvae were less capable of surviving on alien plants, even when the plants had similar biomass to their native hosts. Ballard et al. (2013) compared arthropod communities on native and alien early successional plants and found five times more arthropods on the native plants. Liu and Stiling (2006) summarized data on herbivory of 15 plant species in both their native and introduced geographic ranges. There were significantly fewer herbivores, and significantly less leaf damage, on plants in their non-native range. Burghardt et al. (2010) used common garden techniques to survey native and alien congeners and non-congeners for Lepidoptera diversity in Delaware, USA. Alien congeners of native plants supported more Lepidoptera species than alien non-congeners, and alien plants in general were more likely to host generalist herbivores. In addition, a native understory positively influenced caterpillar and bird diversity in urban lots in the northeastern United States (Burghardt et al. 2008). However, because this study was conducted in the northeastern United States, and at a local scale, the results may not be consistent with other climatic regions. The southeastern United States has a warmer climate with a longer growing season, a larger diversity of ecoregions (Omernik 2010), and is a critical part of both the Atlantic and the Mississippi flyways for migrant birds (National Audubon Society 2014). Additional generations of multivoltine insects and greater diversity of herbivores could hasten adaptation of native herbivores to alien plants.

This study summarizes available host records of eruciform larvae (caterpillars represented by Lepidoptera, and Hymenoptera: Symphyta) for common native and alien woody plants occupying the southeastern United States. The compiled data set was used to answer three questions: 1) Do alien plant species occupying southeastern landscapes support fewer species of eruciform larvae than native species? 2) Do alien congener plants support more species than alien, non-congeners? 3) Do alien plants support more generalist larval species than specialist larval species? Based on previous work (Ballard et al. 2013, Tallamy et al. 2010), we hypothesize that native plants will support more species of eruciform larvae, and more dietary specialists than alien plants. Furthermore, alien congener plant species will support greater species richness of larvae than non-congeners.

Methods

Thirty genera of woody plants were chosen based on occurrence in suburban and urban landscapes of the southeastern United States (Birdwell 2003, Raupp et al. 1985, Stewart et al. 2002, USDA Plants Database), and attractiveness to Lepidoptera (Tallamy and Shropshire 2008). Common native and alien species were chosen (if possible) from within each genus. Native plants were defined as those that were present in the southeastern United States before the influence of European settlers, while alien plants are those introduced from outside of the southeastern United States. Host records of larval Lepidoptera, as well as sawfly larvae (Hymenoptera: Symphyta: Cephidae, Diprionidae, Pamphiliidae, and Tenthredinidae), were recorded from three major resources (Ferguson 1975, Johnson and Lyon 1991, Robinson et al. 2013). Symphyta larvae were recorded in addition to Lepidoptera because of their similar morphology and ecological role in plant communities. The geographic range of eruciform species in the southeastern United States was confirmed based on NAMPG (2013), and Wagner (2005). For the purposes of this study, the southeastern United States consisted of Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, and Tennessee.

Do alien plant species occupying southeastern urban landscapes support fewer species of eruciform larvae than native species? For this first question, plants were categorized as native or alien based on criteria previously stated. The number of eruciform species was then totaled for each plant species. Plant species were then split into categories based on eruciform species richness (i.e. <10, 10-20, 20-30, etc). Recognizing that there were not enough observations in certain classes, which violated the assumptions, a 2x2 table with count groups of ≤10 and >10 was created and analyzed using a Chi-square contingency table analysis (SAS Institute Inc 2014).

Do alien congener plants support more species than alien non-congeners? For this second question, alien plants were further divided into congeners and non-congeners. Congeners are plant species that have at least one native member of the same genus in the southeastern United States, while non-congeners are alien plant species with no native relative. Plant species that were members of these groups were separated into categories (i.e. <5, 5-9, and >10) based on number of larval records. Because more than 20% of the expected counts in each category were less than five, which violates the assumptions of the chi-square contingency table analysis, the categories were split into proportions. These proportions were then analyzed in a chi-square contingency table.

The number of caterpillar species was totaled for the plant species within the 15 genera represented by native and alien congeners. In a similar approach to question one, plant species were split into categories based on eruciform species richness, and analyzed using a Chi-square contingency table analysis (SAS Institute Inc 2014). Then, larval species records from *Acer, Betula, Castanea, Pinus, Prunus, Populus, Quercus, Salix,* and *Ulmus* were plotted using Venn diagrams created by the VENNTURE software program (Martin et al. 2012). We selected these genera based on high eruciform species load, and because they contain both native and alien representatives. Venn diagrams are useful for identifying overlap and unique members among groups. In this study, Venn diagrams were used to identify overlapping and unique host records for larval species feeding on multiple plants within genera. Larval species found feeding on both native and alien congeners were categorized as either generalist or specialist. Generalists and specialists were defined based on the criteria discussed in the following paragraph.

Do alien plants support more generalist larval species than specialist larval species? For this final question, the diet breadths of all larval species recorded from question 1 were examined using the HOSTS database (Robinson et al. 2013) and Johnson and Lyon (1991). The number of plant families on which each insect was capable of feeding was recorded. A Chi-square contingency test (Whitlock and Schluter 2009) was used to compare the diet breadth of caterpillars capable of feeding on native plants versus those feeding on non-native plants. Caterpillars feeding on non-native plants were then split into two categories based on whether they fed on congeners or non-congeners and the same chi-square contingency test was applied for comparison. For both of these tests, four classes of diet breadth were established for comparison (1-5, 6-10, 11-15, and 16+).

Results

Do alien plant species occupying southeastern urban landscapes support fewer species of eruciform larvae than native species? Records were summarized for 30 selected plant genera consisting of 70 species (35 native, 35 alien) common in urban and suburban landscapes (Table 2.1, <u>see supplemental material</u>). Most species were deciduous, however, evergreens were represented by broadleaf species (ex: *Magnolia* and *Ilex*), and needled species (ex: *Pinus* and *Juniperus*). Six genera, *Zelkova, Pistacia, Nandina, Lagerstroemia, Pyrus,* and *Ligustrum*, were only represented by alien plant species in the southeastern United States. All native plants hosted eruciform larvae. No eruciform larvae were listed for *Zelkova, Pistacia, Pyrus,* or *Nandina*, but all other alien genera hosted at least one species of caterpillar or sawfly. In total, native plant species hosted 585 species of eruciform larvae which was significantly greater than the 120 reported on alien plant species (df = 3, $\chi^2 = 35.6$, $P < 0.0001$).

Table 2.1. Woody plant species common in urban landscapes and the reported number of caterpillar and sawfly species that utilize them as larval hosts. For specific eruciform species, see supplemental material.

Plant Genus	Native (N) and Alien (NN) species	Plant Native Region	Number of recorded eruciform species
Acer	*Acer saccharinum* – N -Silver Maple	Central and Eastern U.S.	56
	Acer saccharum - N -Sugar Maple	Central and Eastern U.S.	103
	Acer rubrum – N - Red Maple	Central and Eastern U.S.	109
	Acer palmatum – NN - Japanese Maple	Asia	0
	Acer platanoides – NN - Norway Maple	Europe	11
Betula	*Betula nigra* – N - River Birch	Central and Eastern U.S.	15
	Betula lenta – N - Sweet Birch	Eastern U.S.	18
	Betula pendula – NN - European White Birch	Southern Europe	3
	Betula platyphylla – NN - Japanese White Birch	Asia	0
Castanea	*Castanea dentata* – N - American Chestnut	Eastern U.S.	67
	Castanea pumila – N - American Chinquapin	Eastern U.S.	11
	Castanea sativa – NN - European Chestnut	Europe and Asia	35
	Castanea mollissima – NN - Chinese Chestnut	China and Korea	4
Cercis	*Cercis canadensis* – N - Eastern Redbud	Central and Eastern U.S.A	19
Cornus	*Cornus florida* – N - Flowering Dogwood	Eastern U.S.	24

	Cornus eliptica – NN - Chinese Evergreen Dogwood *Cornus kousa* – NN - Korean Dogwood	China Eastern Asia	0 0
Fagus	*Fagus grandifolia* – N American Beech	Central and Eastern U.S.	80
Ginkgo	*Ginkgo biloba* – NN - Ginkgo Tree	China	4
Ilex	*Ilex opaca* – N - American Holly *Ilex aquifolium* – NN - English Holly	Eastern U.S. Europe, Western Asia, North Africa	9 2
Juniperus	*Juniperus virginiana* - N - Eastern Redcedar *Juniperus chinensis* – NN - Chinese Juniper	Central and Eastern U.S. Northeast Asia	19 3
Lagerstroemia	*Lagerstroemia indica* – NN - Crepe Myrtle	Asia	4
Ligustrum	*Ligustrum vulgare* – NN - European Privet *Ligustrum japonicum* – NN - Japanese Privet *Ligustrum ovalifolium* – NN - Oval-leafed Privet *Ligustrum lucidum* – NN - Glossy Privet	Europe and N. Africa Japan Japan China	9 0 5 0
Liquidambar	*Liquidambar styraciflua* – N - American Sweetgum	Eastern U.S.	32
Liriodendron	*Liriodendron tulipifera* – N - Tulip Poplar	Eastern U.S.	23
Magnolia	*Magnolia grandiflora* – N - Southern Magnolia *Magnolia virginiana* – N - Sweetbay Magnolia *Magnolia stellata* – NN - Star Magnolia *Magnolia liliiflora* – NN - Japanese Magnolia	Southeastern U.S. Eastern U.S. Japan Southwest China	5 13 0 0
Malus	*Malus angustifolia* – N - Southern Crab Apple *Malus floribunda* – NN - Japanese Flowering Crab Apple	Southeastern U.S. East Asia	3 2
Myrica	*Myrica cerifera* – N - Wax Myrtle	Southeastern U.S.	21
Nandina	*Nandina domestica* – NN		

	- Heavenly Bamboo	Asia	0
Pinus	*Pinus taeda* – N - Loblolly Pine *Pinus palustris* – N - Longleaf Pine *Pinus mugo* – NN - Mugho Pine	 Eastern U.S. Southeastern U.S. Europe	 30 16 7
Pistacia	*Pistacia chinensis* – NN - Chinese Pistache	 Western China	 0
Platanus	*Platanus occidentalis* – N American Sycamore	Central and Eastern U.S.	33
Populus	*Populus deltoides* – N - Eastern Cottonwood *Populus nigra* – NN - Lombardy Poplar	 North America Europe and Asia	 31 30
Prunus	*Prunus americana* – N - American Plum *Prunus serotina* – N - Black Cherry *Prunus avium* – NN - Sweet Cherry *Prunus serrulata* – NN -Japanese Cherry	 Throughout U.S.A. Central and Eastern U.S. Europe, North Africa, West Asia East Asia	 42 153 35 3
Pyracantha	*Pyracantha coccinea* – NN - Scarlet Firethorn	 Europe and Asia	 2
Pyrus	*Pyrus calleryana* – NN - Bradford Pear	 China and Vietnam	 0
Quercus	*Quercus alba* – N - White Oak *Quercus falcata* – N - Southern Red Oak *Quercus rubra* – N - Northern Red Oak *Quercus stellata* – N - Post Oak *Quercus palustris* – N - Pin oak *Quercus acutissima* – NN - Sawtooth Oak *Quercus robur* – NN - English Oak	Central and Eastern U.S. Southeastern U.S. Central and Eastern U.S. Southeastern U.S. Eastern U.S. China, Korea, Japan Europe	 135 18 148 25 27 1 10
Rhododendron	*Rhododendron calendulaceum* – N -Plum-leaf azalea *Rhododendron indicum* – NN - Kaempfer azalea	 Eastern U.S. Japan	 4 3

Salix	*Salix discolor* – N - American Willow *Salix nigra* – N - Black Willow *Salix babylonica* – NN - Weeping Willow *Salix caprea* – NN - Goat Willow	Eastern and Northern U.S. Central and Eastern U.S. China Europe and Asia	6 5 12 4
Taxodium	*Taxodium distichum* – N Bald Cypress	Central and Eastern U.S.	17
Ulmus	*Ulmus americana* – N - American Elm *Ulmus rubra* – N - Slippery Elm *Ulmus parvifolia* – NN - Chinese Elm *Ulmus procera* – NN - English Elm	Central and Eastern North America Central and Eastern North America Asia Europe	121 26 5 7
Zelkova	*Zelkova serrata* – NN - Japanese Zelkova	Japan, Korea, China, Taiwan	0
Host data from: Ferguson 1975, Johnson and Lyon 1991, Robinson et al. 2013. Caterpillar range data from: Wagner 2005, and NAMPG 2013. North American plant range data from: USDA 2013.			

Do alien congener plants support more species than alien non-congeners? Fifteen selected genera were chosen to represent native and alien plant congeners. Alien, non-congener species hosted significantly fewer larval species than alien congener species (df = 2, $\chi^2 = 10.64$, $P < 0.01$) (Figure 2.1). Among congeners, native congeners hosted a greater species richness of larval species than alien congeners (df = 3, $\chi^2 = 18.02$, $P = 0.0004$) (Figure 2.2). In fact, the majority (18 out of 24) of alien congeners hosted fewer than ten species of larvae. Native and alien congener species among *Rhododendron, Salix, Populus,* and *Malus* hosted similar numbers of larval species (Table 2.1).

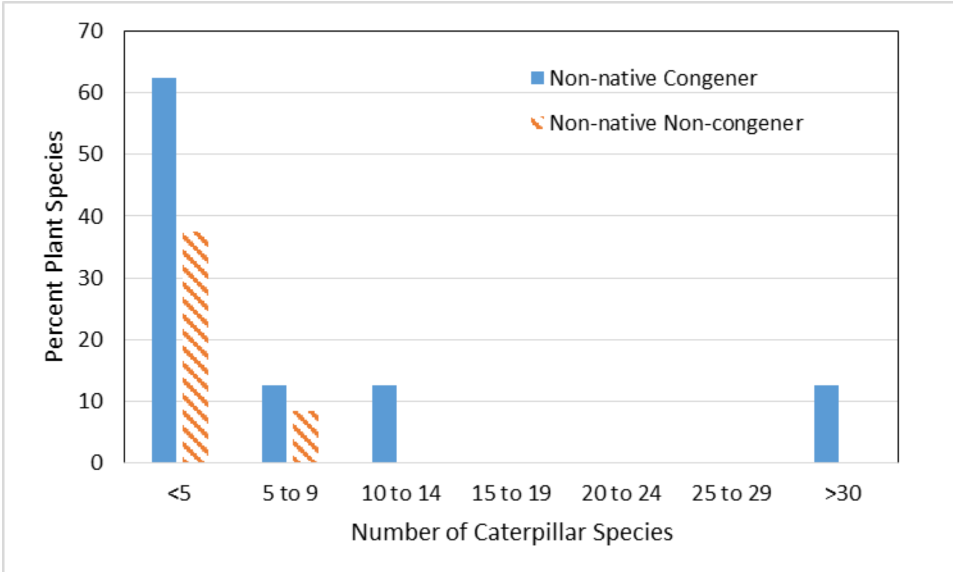

Figure 2.1: Number of larval species feeding on alien congener plant species and alien, non-congener plant species. Percentages of plant species in each category were compared. df = 2, $\chi 2 = 10.64$, $P < 0.01$.

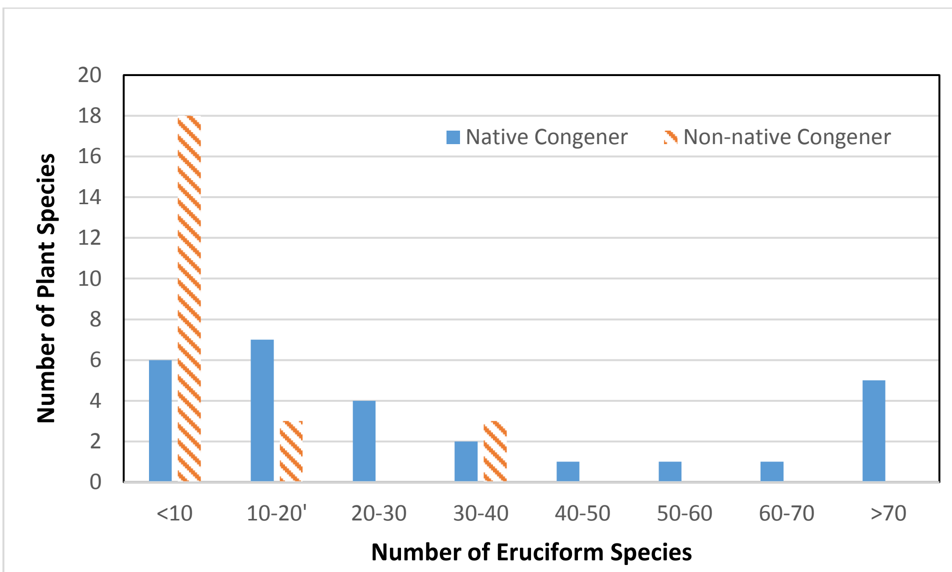

Figure 2.2: Number of Lepidoptera and Symphyta larval species records for native and alien congener plant species df = 3, $\chi^2 = 18.02$, $P = 0.0004$.

When compared using Venn diagrams (Figure 2.3), several larval species that normally feed on native representatives of a genus also are shown as feeding on alien representatives of that genus. For our purposes, specialists were defined as those that feed on three or less plant families, while generalists feed on more than three plant families. This is consistent with the definition provided by Bernays and Graham (1988). Seven species of generalist caterpillars feed on *A. rubrum, A. saccharinum, A. saccharum*, and *A. platanoides* (Figure 2.3A). Approximately half (15) of all species feeding on *Populus nigra* also feed on *P. deltoides* (Figure 2.3B), five of which are specialists (*Catocola amatrix, C. concubens, C. unijuga, Ipimorpha pleonectusa,* and *Raphia frater*). Only two species (*Acronicta clarescens* and *Sunira bicolorago*) feed on all four species of *Prunus* that we investigated (Figure 2.3C). *Acronicta clarescens* is a specialist, but *S. bicolorago* is a generalist. Two generalist caterpillar species (*Anisota stigma* and *Antheraea polyphemus*) feed on all four (two native, two alien) plant species of the genus *Castanea* (Figure 2.3D). No single eruciform species feeds on all seven *Quercus* species (Figure 2.3E). The alien sawtooth oak (*Q. acutissima*) only hosted *Automeris io*, a generalist, which was found feeding on all other oaks except *Q. robur* (alien) and *Q. falcata* (native). Excluding sawtooth oak, only two generalist caterpillar species (*Anisota virginianus* and *Antheraea polyphemus*) feed on all other oaks. Among *Betula* spp., only two species of generalist Saturniid moths (*Antheraea polyphemus* and *Hyalophora cercropia*) were found to feed on all plant species investigated (Figure 2.3F). No single eruciform species fed on all *Ulmus* spp. investigated. However, eight generalists fed on both alien and native members (Figure 2.3G). Among the *Pinus* spp., two specialists (*Exoteleia pinifoliella* and *Prococera robustella*) feed on all investigated members (Figure 2.3H).

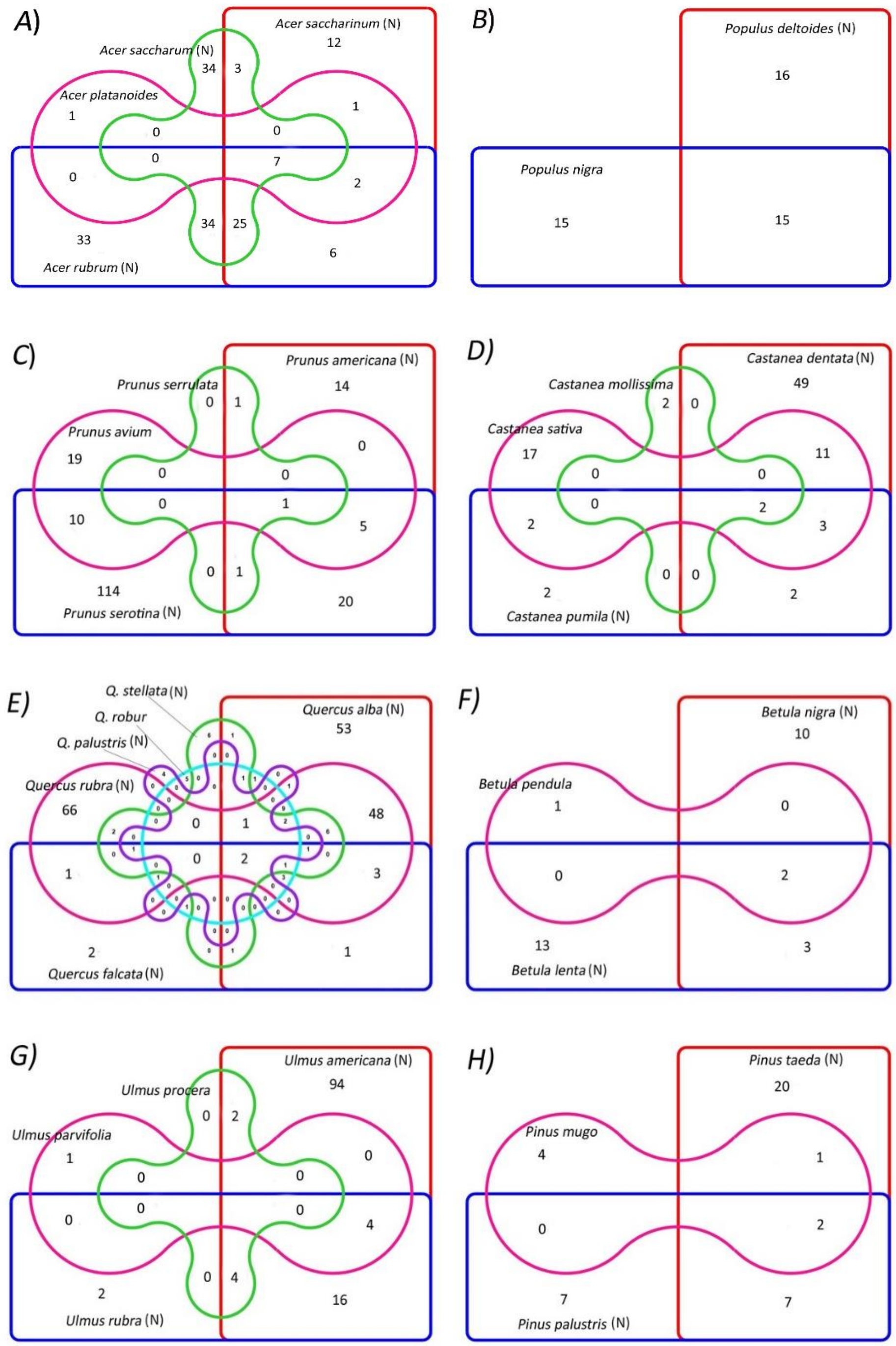

Figure 2.3: Caterpillar species abundance on congeneric plant species (from supplemental data). Each shape distinguishes a different plant species. The numbers in each diagram represent the number of eruciform larval species. Numbers and shapes which overlap correspond to larval species spillover. Native species within a genus is indicated with an (N) following the scientific name. A) *Acer* species, B) *Populus* species, C) *Prunus* species, D) *Castanea* species, E) *Quercus* species, F) *Betula* species, G) *Ulmus* species, H) *Pinus* species

Do alien plants support more generalist larval species than specialist larval species? Native plants hosted significantly more specialized larvae than non-native plants (df = 3, χ^2=14.23, P = 0.0026) (Figure 2.4A-B). The data suggest that non-native, non-congeners supported more species of generalist eruciform larvae compared to non-native congeners (df = 3, χ^2=7.27, P = 0.064) (Figure 2.4C-D).

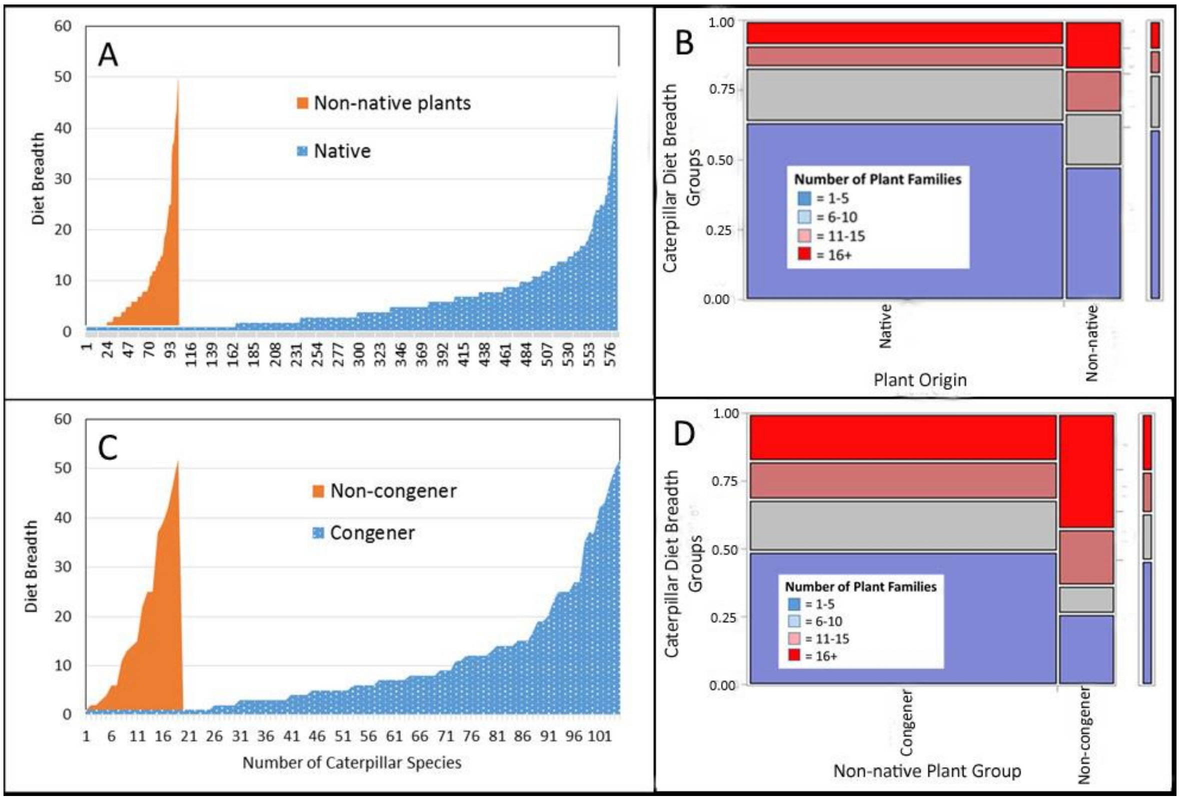

Figure 2.4: Ericiform diet breadth on native vs. alien plants (A-B), and non-native congener vs. non-congener (C-D). Diet breadth is based on number of plant families each eruciform species is known to be capable of consuming. For A-B: df = 3, χ^2 =14.23, P = 0.0026; For C-D: df = 3, χ^2=7.27, P = 0.064

Discussion

Introduction of alien plants in suburban and urban environments impacts the diversity of eruciform communities. In this study, alien plants supported fewer species of larvae than natives, which is consistent with the majority of reports in the literature

(Ballard et al. 2013, Burghardt et al. 2010, Liu and Stiling 2006, Tallamy et al. 2008). Based on host records, plants in the southeastern United States follow similar trends to those in other regions. Host records are based on observations and empirical data, and therefore may be incomplete depending on range of the host plant, level of human utility, and situational context in which the observation was recorded. However, conclusions derived from these data provide general trends. Species-level interactions should be investigated experimentally.

It is likely that, in addition to eruciform larvae, native plants also support a larger diversity of other insect herbivores. One hypothesis to explain this phenomenon is the Enemy Release Hypothesis. This states that due to evolutionary separation, many endemic insects do not have the capability of overcoming natural defenses presented by alien plants (Colautti et al. 2004, Elton 1958, Keane and Crawley 2002). Endemic insects have evolved the ability to overcome secondary plant compounds and other defenses utilized by the native plants with which they share an evolutionary history. Alien plants did not evolve with these native herbivores, making most alien plants less susceptible to herbivore attack.

There appear to be larval species unique to some alien non-congeners such as *Ligustrum* and *Lagerstromia*. However, these are unique in context of this survey because certain native plants were not included. For example, five out of 12 larval records for *Ligustrum* species are seemingly unique to that genus, but only because native members of Oleaceae were not included. These were not included because the focus of this work was on common urban landscape plants and not necessarily an exhaustive survey of the thousands of plant genera represented in the southeastern United States. Most eruciform larvae feeding on alien congeners of native plants, however, also exploit woody natives. Alien *Acer platanoides*, for example, hosts only one caterpillar species that was not recorded on its native congeners (*A. rubrum* and *A. saccharinum*) (Figure 2.3A). The data suggest that even though more generalists feed on alien congeners, alien congeners are more capable of supporting specialists compared to alien non-congeners; this is known as a spillover effect.

Spillover occurs when an insect exploits a plant species that is less-preferred (Price et al. 2011). Figure 2.3 shows that a slight ecological spillover effect with generalist and specialist eruciforms is occurring between native and alien plants. For example, *Acronicta clarescens* exhibits spillover because it feeds on native and non-native representatives of *Prunus* (Figure 2.3C). Many generalist and specialist species, however, cannot sustain themselves entirely by feeding on alien plants (Tallamy et al. 2010). This suggests that "false spillover" may occur. False spillover occurs when an eruciform larva feeds on an alien plant even though the host will not sustain larval development. This would occur in situations where food choices are limited (such as suburban neighborhoods or monotypic plant nurseries). As Figure 2.1 suggests, false spillover is more evident on alien non-congener plants. Thus, an alien congener planted among related native plants may have less impact on diversity of eruciform larvae than an alien non-congener. We are currently testing this hypothesis in a multi-year field experiment in Tallassee, Alabama using *Acer rubrum* and native and alien congeners.

Changes in an herbivore community can detrimentally impact organisms occupying higher trophic levels. For example, an ongoing research project at the National Arboretum (Washington D.C.) with the USDA-ARS is showing that gardens with only native woody and herbaceous plants have greater diversity and abundance of parasitoid wasps than gardens with only alien plants (Greenstone 2013). In an invasive plant context, the diversity of arthropods, lizards, and small mammals in alien, monotypic *Tamarix* (saltcedar spp.) forests is reduced relative to areas where forests were mixed with *Tamarix* and native species (Bateman and Ostoja 2012). Furthermore, there are notable increases in herbivorous insects, insect parasitoids, and birds in observed sites in the Azores where invasive plants had been removed (Heleno et al. 2010). Although results vary on a case-by-case basis, replacement of native plants with aliens will have implications for insect conservation.

Alien invasive plants, coupled with disturbed habitats, are significant contributing threats for rare and endangered Lepidoptera (Wagner and Van Driesche 2010). For example, three state-listed rare butterfly species in Connecticut were lost due to the invasion of *Phragmites*, a common reed (Wagner et al. 2007). In Oregon, the federally endangered *Euproserpinus euterpe* Edwards, a species of Sphingid moth, exhibits decreased larval survival due to accidental oviposition on invasive *Erodium cicutarium* L'Héritier (Tuskes and Emmel 1981). *Pieris virginiensis* Edwards, a declining, state-listed butterfly, oviposits on the invasive *Alliaria petiolata* Cavara (garlic mustard), resulting in decreased larval survival (Bowden 1971). Examples like these can be perceived as false spillover, which can make it difficult to quantify host range and the impacts of alien plants. Alien, non-invasive plants used in urban and suburban settings may be factors in the declines of insect species, but the interactions are poorly understood.

In addition, there is a clear connection between native plants, insect herbivores, and avian abundance, diversity, species richness, biomass, and number of breeding pairs (Burghardt et al. 2008). Many bird species specialize on specific groups of insects (Capinera 2010). For example, based on gut content analysis, the diet of tufted titmice (*Baeolophus bicolor* Linnaeus) consists of 66.6% animal matter (as opposed to plant matter like seeds, berries, etc.), with 38.3% being Lepidoptera. Yellow-billed cuckoos (*Coccyzus americanus* Linnaeus) have diets that consist of 92% animal matter, with 65.6% being Lepidoptera. Red-cockaded woodpeckers (*Picoides borealis* Vieillot) have diets consisting of 88.1% animal matter, with 51.7% being ants. Ruby-throated hummingbirds (*Archilochus colubris* Linnaeus) have diets consisting of 94.3% animal matter, with 43.5% being spiders. Others specialize on Hymenoptera, Orthoptera, Diptera, Coleoptera, and Hemiptera (Capinera 2010). Bird diets change seasonally, but most concentrate on insects during the spring nesting season (Tallamy 2004). When arthropod diversity within a community changes, certain bird species may be driven out. The southeastern U.S. is notable for having two of the four major flyways in the United States (Mississippi and Atlantic), which are used at least temporarily by more than half of all North American bird species. Approximately 40% of the bird species using the Atlantic flyway alone are of conservation concern (National Audubon Society 2014). Lack of food resources in urban and suburban environments may be one of many factors perpetuating the declines of

North American bird species (Tallamy 2007). All of these facts highlight the need for additional research addressing tri-trophic interactions in suburban ecosystems.

Changing plant communities from native to alien has dramatic impacts on insect communities (Burghardt et al. 2010, Liu and Stiling 2006, Tallamy et al. 2007, Vilà et al. 2005). Urban landscapes are contrived plant communities largely based on aesthetic value, and often little thought is placed toward their ecological roles. Competing efforts between pest management and ecological value are constant. Eruciform larvae on newly established trees consume a greater percentage of overall leaf biomass compared to other herbivorous insect guilds, and are therefore more conspicuous. For this reason, they are more likely to evoke a response to control using an insecticide application or other means. This is an opportunity for extension or outreach programs to educate homeowners and landscape professionals on sustainability concepts in urban landscapes. We suggest a need for a long-term paradigm shift in which people choose landscape plants for both aesthetic value and ecological function, as these two are not mutually exclusive.

Chapter 3

Associational Interactions in the Urban Landscape: Are Native Plant Neighbors Better than Non-natives?

Abstract

The relationship between herbivore and plant is a primary topic of basic and applied insect ecology. Historically and still today, there is an emphasis on more thoroughly understanding the relationship between consumer and resource, especially in the context of urban environments. Urban environments are unique in that, among other things, they are occupied by a large number of cultivated non-native plants. While it is well known that most non-native plants support fewer herbivores than do native plants, suburban landscapes with contrived associations of native and non-native plants may interact with insect communities across multiple trophic levels. The purpose of this project was to investigate associational interactions (associational resistance or associational susceptibility) between native and non-native plants used in urban environments and how they impact insect communities. In a 2 year field study, abundance and diversity of eruciform larvae, plant damage, and herbivore natural enemies were measured in 5 x 5m plots in which a native red maple (*Acer rubrum* L.) was interplanted with either other native red maples, non-congeneric non-native crepe myrtles (*Lagerstroemia indica* P.), non-native congeneric Norway maples (*Acer platanoides* L.), or placed by themselves in a plot. Tree damage percentage, caterpillar abundance, and caterpillar species richness were all collected on focal red maples and one neighboring plant. Natural enemies were also measured using modified yellow pan

traps. Damage rate and caterpillar abundance were similar for all treatment groups during 2014. In 2015, however, caterpillar abundance was greater for red maples surrounded by crepe myrtle than it was for the other treatments. Greenstriped mapleworm (*Dryocampa rubicunda*), a native, multivoltine specialist caterpillar, was the most abundant caterpillar in the study, and its presence appeared to correspond with damage and overall caterpillar abundance. We propose that the *D. rubicunda* feeding on red maples surrounded by crepe myrtles have an ecological advantage possibly as a result of an increase in larval and adult survival resulting from decreased predation. There were no significant trends in insect natural enemy abundance or family richness, but we believe our analysis of natural enemy community composition at the family level is not sufficient at such a small experimental scale. Our results suggest that associational interactions between native and non-native plants have a large impact on urban insect herbivore communities. We suggest that maximizing use of native plants in urban environments will decrease the frequency of pest outbreaks while subsequently providing ecological services.

Introduction

Tens of thousands of non-native plant species have been introduced into the United States since European settlers landed in North America (Pimentel et al. 2000). Most have been introduced for ornamental purposes (Miller et al. 2012, Tallamy 2004), for the beautification of residential, public, and commercial landscapes. Previous research suggests that native insect herbivores, such as caterpillars, suffer reduced population numbers and reduced diversity in areas where non-native plants are prevalent as opposed to areas where native plants are prevalent (Liu and Stiling 2006, Tallamy et al. 2010, Vilà et al. 2005). As described by Tallamy (2007), native insects have evolved to overcome secondary plant compounds and other defenses harbored by native plants, but not those of non-native plants. This is consistent with the Enemy Release Hypothesis which states that non-native organisms tend to be more successful in non-native range because they have been liberated from their natural enemies (Liu and Stiling 2006). Non-native plants are damaged less; consequently, horticulturists and landscape designers tend to favor non-native ornamentals (Tallamy 2004), leading to widespread suburban environments mixed with native and non-native cultivated plants.

White (2013) compared host plant abundance to plant species richness at the assemblage level as two parameters for predicting Lepidopteran abundance and diversity. He found that caterpillar diversity, species richness, and abundance were better correlated with host plant abundance than with plant species richness. One factor contributing to the lack of correlation between insect and plant species richness could be the fact that Norway maple (*Acer platanoides* Linnaeus) and European buck-thorn (*Rhamnus cathartica* Linnaeus) both non-native, invasive species, were rampant in the study area (White 2013). These two plants, through associational interactions, could have negatively influenced the insect communities.

Among others, Richard Root and his colleagues (Tahvanainen and Root 1972, Root 1973) expanded our perspective on insect-plant relationships to include community-wide factors. Resource Concentration, Associational Resistance (AR), and now Associational Susceptibility (AS) are concepts that evolved from this early work to explain the relative abundance and damage from herbivores in the context of their communities. AR and AS describe the outcome of specific plant associations whereby a host plant of an herbivore may experience reduced (AR) or increased (AS) susceptibility or detection by that animal (Atsatt et al. 1976, Barbosa et al. 2009, Plath et al. 2012).

Traits of focal plants, herbivores, and external environmental factors are likely to influence both AR and AS. The literature defines a focal plant as the primary target for the herbivore, and adjacent plants as 'neighbors'. Typical response variables for these studies are herbivore abundance and damage to the focal plant. Barbosa et al. (2009) reviewed current mechanisms and used meta-analysis to identify herbivore and plant traits that may favor either AR or AS. They concluded that when focal plants are surrounded by unpalatable neighbors, AR is more likely, and AS is predicted when the neighbor plants are palatable. Furthermore, AR was more likely in interactions involving mammals, while AS was more likely in interactions involving insect herbivores. Among herbivorous insects, they determined that feeding guild or diet breadth were not significantly influential in the likelihood of either AS or AR and therefore were not reliable indicators of these effects (Barbosa et al. 2009). Empirical studies, however, are ambiguous, and the herbivore-induced effects appear to vary on a case-by-case basis. For example, Koricheva et al. (2006) concluded in a review that published studies provide no support for the concept that the diversification of tree species in tree stands leads to fewer pest and disease outbreaks. Plath et al. (2012) discovered that the tropical plant *Tabebuia rosea* de Candolle was more susceptible to damage by a specialist pyralid caterpillar in the presence of mixed stands as opposed to monocultures. In contrast, a specialist chrysomelid beetle had higher abundance, and caused more damage, in *T. rosea* monocultures (Plath et al. 2012). This suggests that insect identity and biology play a role in determining the effects of associational interactions.

Plant apparency is another variable that can play a role in dealing with associational interactions. A manipulated field study (Castagneyrol et al. 2013) suggested that a decrease in focal tree apparency via host dilution causes AR through a decrease in herbivore damage. The authors stress that tree size (in this case sapling size) plays a major role in determining AR and AS. Bigger trees are more attractive to herbivores, and smaller trees are less attractive due to lower associational apparency in the presence of larger neighboring trees. Franziska et al. (2014) concluded that forest fragmentation and tree diversity interactively affect insect (herbivore) community composition. For slightly fragmented forests, the number of herbivore species was lower, and the abundance of herbivores increased with increasing tree diversity. For highly fragmented forests, abundance and species richness of herbivore species were not affected by tree diversity (Franziska et al. 2014).

On smaller spatial scales, such as urban ecosystems, there may be stronger effects on herbivores than on larger spatial scales (Harvey and Fortuna 2012). Bommarco and Banks (2003) did a meta-analysis of plant diversification experiments, comparing effects on insect populations at different scales. They suggested that vegetational diversification at smaller spatial scales can have a greater negative effect on insect herbivore populations compared to effects at intermediate scales. Thus, the occurrence of AR or AS should be most detectable at a smaller spatial scale in which plants are placed in close proximity.

Maintaining or enhancing the presence of insect herbivores is often overlooked as an important factor in habitat restoration and ecosystem enhancement (White 2013). Herbivores are an essential component of almost every terrestrial ecosystem, providing food for organisms like birds, mammals, lizards, and predacious/parasitoid insects that occupy higher trophic levels (Burghardt et al. 2008, Greenstone 2013, Heleno et al. 2010). Therefore, alteration of the number of host plants can indirectly influence the third trophic level. For example, Sperber et al. (2004) sampled family-level parasitoid diversity on cacao agroecosystems in Brazil and found that parasitoid richness increased with increasing tree species richness. Greenstone (2013) has established native and non-native gardens at the U.S. National Arboretum. Gardens with only native woody and herbaceous plants had greater diversity and abundance of parasitoid wasps than gardens with strictly non-native plants (Greenstone 2013). Roland and Taylor (1997) demonstrated that changes in landscape structure can alter the foraging efficiency of parasitoids. They investigated the ability of four species of tachinid (Diptera) parasitoids to attack forest tent caterpillar (*Malacosoma disstria* Hübner) in fragmented and unfragmented areas. They found that three of the flies had reduced foraging efficiency when forests were fragmented and increased efficiency in contiguous forests, while one species exhibited the opposite pattern. Narango et al. (2015) concluded that changes in plant structure and origin in landscapes can alter bird foraging effort. They concluded that chickadees spend more time foraging for insects on native plants than non-native plants. In suburban landscapes in Pennsylvania, Burghardt et al. (2008) concluded that a native understory positively influences caterpillar and bird abundance and diversity. Furthermore, notable increases in herbivorous insects, insect parasitoids, and birds in the Azores occurred where all invasive plants including grasses, shrubs, and trees had been removed (Heleno et al. 2010). With fewer natural enemies, ecosystem stability may decrease, leading to an increase in frequency or severity of pest outbreaks. From an insect conservation perspective, it is reported that invasive, non-native plants, coupled with disturbed habitat, are one of the largest contributing threats for rare and endangered Lepidoptera on the U.S. east coast (Wagner and Van Driesche 2010). The conclusion that can be derived from the above research is that the most important way to conserve natural enemies is to conserve the native host plants upon which their prey feed (White 2013, Tallamy 2004). However, the associational effects of native, non-native mixures of plants on natural enemies remain largely unexplored.

The overall purpose of this project was to investigate the associational interactions (associational resistance or associational susceptibility) between native and non-native plants in urban environments, and determine how they impact insect communities. The first objective was to investigate caterpillar community response to native and non-native plant assemblages. The second objective was to evaluate caterpillar community response to native trees surrounded by non-native trees that are phylogenetically dissimilar (non-congeners – crepe myrtle) or similar (congeners – Norway maple). The final objective was to investigate how natural enemies could be impacted by these associational interactions. If non-natives in urban landscapes can impact herbivore and natural enemy communities, then sentinel or token natives interspersed into a virtual sea of non-natives may have little overall impact in providing ecosystem services. These results can provide context with which urban ecologists, the general public, and urban planners could develop urban plantings that positively impact resources for declining North American birds and other insectivorous organisms.

Methods

Study Plants

Non-native plants were defined as those with no known origin in the southeastern United States, and non-native congener plants were defined as plant species not native to North America but sharing the same genus as a native plant. Native members of the genus *Acer* host a plethora of caterpillar species (Tallamy and Shropshire 2008, Clem and Held 2015) and the genus includes both native and non-native species used in urban plantings. Therefore, *Acer rubrum* Linnaeus 'Frank Jr Redpointe' (red maple) was selected as the focal native species for this experiment. The two non-native species that were chosen as treatment plants were *Lagerstroemia indica* Persoon 'Tuscarora' (crepe myrtle) as the non-congener and *Acer platanoides* Linnaeus 'Princeton Gold' (Norway maple) as the congener.

Both crepe myrtle and Norway maple were among the first trees imported into the United States for ornamental purposes. Crepe myrtle was first introduced into Charleston, South Carolina around 1787, and immediately became popular due to its beautiful blooms and ability to thrive in the South's warm, humid climate (Cothran 2004).

Norway maple was first introduced into the United States in 1756, and became immensely popular further north (Nowak and Rowntree, 1990). Today, maple (*Acer* sp.), and crepe myrtle (*Lagerstroemia*) are the two most common genera of street trees used in the southeastern United States (Stewart et al. 2002). Auburn, Alabama hosts thousands of crepe myrtles which are planted on street corners, street medians, grassy lawns, and, in many cases, are interspersed with red maples. Norway maple, however, is rare in the south (Cincotta et al. 2009). Both crepe myrtle and Norway maple are now reported to be invasive, growing voluntarily in different regions of the U.S. (UGA CISEH 2010, Nowak and Rowntree 1990). Cincotta et al. (2009) conducted a study investigating herbivory rates on Norway maple versus native sugar maple (*Acer saccharum* Marshall): they found that Norway maple had less leaf damage compared to sugar maple, which is concordant with the Enemy Release Hypothesis. Other than this, very little work has been done investigating the effects that these plants can have on urban insect communities.

Acer rubrum and *A. platanoides* were donated by a wholesale plant distributor in Willamette Valley, Oregon, while *L. indica* were donated by a nursery in Mobile, Alabama. *Acer rubrum* and *A. platanoides* were obtained as 1.8m, 2yr old bare-root whip forms, while *L. indica* were obtained as multi-trunked potted forms – the forms normally used in landscapes. Crepe mytle trees flower through spring and summer but the flowers do not produce nectar (Kim et al. 1994) that may influence recruitment of adult Lepidoptera. Flowers, therefore, were not removed during the course of this experiment. Because the red maple-red maple plots could be considered a monoculture, a fifth treatment group was added in 2015. Neighbors in these plots are all different species of native trees (sycamore – *Platanus occidentalis* Linnaeus, sweetbay magnolia – *Magnolia virginiana* Linnaeus, pin oak – *Quercus palustris* Münchh, and river birch – *Betula nigra* Linnaeus). These trees were obtained from a nursery in Mathews, Alabama.

As a note, a second set of treatment groups using red oak (*Quercus rubra* Linnaeus) as the native focal tree, English oak (*Quercus robur* Linnaeus) as the non-native congener, and Bradford pear (*Pyrus calleryana* Decaisne) as the non-native non-congener were planned, but the red oaks did not survive initial planting. Consequently, all *Quercus* treatment groups had to be abandoned. The experiment and results presented here only include data from red maple treatments.

Study Area and Plot Design

The experiment was conducted using a common garden technique planted at Auburn University's E.V. Smith Research Farm in Tallassee, Alabama. Tallassee lies in the Level III Southeastern Plains ecoregion which historically was dominated by longleaf pine and is geologically separated into Tertiary-age sands, silts, and clays (USEPA 2000). Simulated landscapes, consisting of 5 x 5m gardens, were established in March 2014. They were located 10 m from the nearest woodland border and 15 m between adjacent plots. Each plot contained a central focal tree surrounded by four treatment trees, or "neighbors." Treatment trees were located in the four corners of each plot, 3.5 m from the focal tree (Figure 3.1). Seven replicates were established, each containing four randomly ordered treatment plots. The treatments were: 1. native tree (*A. rubrum*) surrounded by four non-native non-congeners (*L. indica*)(Supplemental Image 1.6 – see photographic appendix); 2. native tree with no neighbors (Image 1.7); 3. native tree surrounded by four native trees of the same species (*A. rubrum*)(Image 1.8); and 4. native tree surrounded by four non-native congeners (*A. platanoides*)(Image 1.9). The fifth treatment group (added in 2015) consisted of a native tree surrounded by four native trees (one each of *Platanus occidentalis*, *Magnolia virginiana*, *Quercus palustris*, and *Betula nigra*)(Image 1.10).

Figure 3.1**:** Typical layout of each 5 x 5 m plot. The focal tree in the center is a red maple while the neighboring trees are either red maple, Norway maple, or crepe myrtle. There are also plots with a single focal tree that has no neighbors.

The seven replicates were placed on two sites approximately 0.4 km apart. The first site contained replicates 1-4 and the second site contained replicates 5-7 (Images 2.2-2.5). The second site was freshly tilled before plots were established. Each plot was initially mowed and treated with herbicide (Cornerstone® Plus, glyphosate, Winfield Solutions LLC, St. Paul, MN) and a pre-emergent (Preen®, trifluralin, Lebanon Seaboard Corp., Lebanon, PA). Exposed ground was covered with longleaf pine straw (Swift Straw Co., Atlanta GA) to prevent weed growth. Holes were dug using a tractor auger. Trees arrived on March 28, 2014 and were immediately placed in temporary pots containing Premier General Purpose Growing Medium (Pro-mix® BX)(Image 1.1). Trees were then planted in their respective localities between the dates of March 30-April 3. Each tree was given 68 g (1/3 cup) of nitrogen fertilizer (18-8-12 Field Grown Nursery Blend, Regal Chemistry Co. Alparetta, GA) during April and August of both years. All remaining trees were planted into 56.8L individual pots and maintained as replacement plants. Deer guards (122 cm white corrugated tubing for maples, and 122 x 30 cm white corrugated sheeting for crepe myrtles; Item Nos. HG348 and CG4812, A.M. Leonard, Piqua, OH) were installed soon after planting due to the threat of deer rubbing (Image 1.4). Each tree was also staked for stability using 1.52 m green metal plant stakes, and tagged with a code to designate replicate, plot, and tree. The first number represented the replicate (1-7), the second number represented the plot (1-8), and the third number represented the specific tree (1-5). The focal tree was always number 1, and the neighboring trees were designated 2-5. Once plots were established, a simple survey of the surrounding vegetation was conducted in order to understand the makeup the surrounding plant community. Plants included in this survey were those that were present along the outer borders of the wooded landscape.

Canopy Area Measurement

At the end of both seasons, average canopy area (m^2) and tree height (m) of *A. rubrum*, *A. platanoides*, and *L. indica* were calculated from digital images (Nikon® D5000). A measuring stick was placed in each photo as a reference point, and a side view of the canopies were measured using the manual tracing tool in the ImageJ software program (http://imagej.nih.gov/ij/). A one-way ANOVA followed by a Student's T-test was conducted on the areas of the focal red maples in order to test for significant differences in size between the treatments. The same procedure was conducted on the other tree species in order to estimate variables of size and focal tree associational apparency.

Caterpillar Surveys and Damage Assessments

Percent foliar damage (0-100% scale) on each focal tree and one neighbor tree was assessed once a month, coincident with caterpillar surveys. Neighbor trees were surveyed rotationally; for the first plot on the first data collection day, neighboring tree 112 was surveyed, following neighbor tree 123 for plot two, etc. On the second data collection day, neighboring tree 113 was surveyed on plot one, followed by neighboring tree 124 on plot two, etc. Leaf damage (a total of defoliation and skeletonization by all eruciform larvae present) was a visual estimate from two independent observers to the nearest 5%. Trees with damage, but less than 5%, could be rated as 1%. Estimates from both observers were then averaged per sample providing one value per tree. Each percentage was converted to a decimal value and ARCSIN transformed. A standardized number (0.05) was then added to each transformed value in order to make the values large enough to analyze.

Caterpillar surveys were conducted bi-monthly from June through September 2014, and May through September 2015. Each focal tree and one neighboring tree were surveyed in every plot. Neighboring trees were surveyed systematically, as described in the previous paragraph; the purpose of this was to provide context for caterpillar spillover. Surveys consisted of counting all larvae on 30 leaves in each of four cardinal directions on every tree. Leaves were not chosen randomly, but selected by the primary investigator (PI) based on factors that might indicate caterpillar presence (i.e. chewed leaves, leaf ties, etc). Leaves were surveyed from the base of the canopy to the top of the canopy of each tree. Caterpillar species (Wagner 2005), or morphospecies richness and abundance were recorded. Representative caterpillars were extracted and reared in the lab for species identification when possible. If an emergence of caterpillars such as *Dryocampa rubicunda* was observed, all caterpillars were recorded even if not on censused leaves. Additionally, if caterpillars were spotted on branches, but not on leaves, they were also recorded. The PI did all caterpillar surveys to avoid bias. Data from both bi-monthly samples were combined and analyzed by month. A repeated measures MANOVA (JMP Software, SAS Institute 2015) was used to test for differences in main effects and interactions. A one-way analysis of variance (ANOVA) (SAS Institute 2015) followed by a Student's t-test was then applied to individual years by treatment. P-values lower than 0.05 were considered significant.

A sampling-effort estimate for caterpillars was conducted on August 10 and October 5, 2015, coincident with the scheduled monthly caterpillar survey. For each sample, five randomly chosen red maple neighbor trees, each from a different plot, were compared to five neighbor maple trees in the same plot sampled as part of the monthly survey. On each tree, all leaves were counted, and all encountered larvae during the leaf count recorded. The number of larvae encountered as part of the routine sample, and the number encountered during the total survey were averaged separately. The routine larva samples were then expressed as a percentage of the total larva sample. This provided an estimated percentage of the true number of caterpillars that were present.

Natural Enemy Surveys

Natural enemies were surveyed using a modification of a method commonly used for pollinator surveys (Tuell and Isaacs 2010). Yellow plastic pan traps were elevated on 1.5 m PVC stands placed in the middle of each plot, approximately 0.6m from the base of the focal tree (Image 2). Two 0.35L yellow sunshine plastic bowls (Festive Occasion®, East Providence, RI) were used for each trap: the first bowl was glued and nailed to a PVC joiner, and the second bowl was filled with 200mL (295mL soap/7.6L water) of lemon-scented soapy water (Joy® liquid detergent, Procter & Gamble, Cincinnati, OH) and placed into the first bowl. Two liter bottle heads were placed cap-end down on the PVC and used to stabilize each trap (Image 1.11). A 0.3m rebar stick was hammered into the ground, and the PVC tube was placed on top of it. Traps were left in the field for approximately 24 hours every 2 weeks, coincident with scheduled caterpillar surveys. In the lab, trap captures were sorted and natural enemies were identified to family level and counted. Families were identified using the keys from Goulet and Huber (1993), and Gilson et al. (1997).

Most parasitoid families consist of a large variety of species that attack a large variety of insects. It is impossible, for the most part, to separate those that are Lepidoptera specific from those that attack insects in other orders like Hemiptera, Coleoptera, and Orthoptera without identifying them to a lower taxonomic level. For the purposes of this project, all of the parasitoid families that are known to attack herbivores were included. The sub-categories that were analyzed included generalist predator abundance, muscoid abundance (combined Sarcophagidae and Tachinidae), Ichneumonidae abundance, Scelionidae abundance, parasitoid abundance, family richness, Shannon-Weiner diversity, evenness. Additionally, all natural enemy abundance, family richness, Shannon-Weiner diversity, and evenness were analyzed. All of these categories were analyzed in the same way as the caterpillar data, with a repeated-measures MANOVA, followed by a one-way ANOVA for individual years.

Figure 3.2**:** A pan trap located next to a severely defoliated red maple (*Acer rubrum*). This maple would be considered to be approximately 70% defoliated.

Results

Surrounding Vegetation Survey

The more common species found growing adjacent to the field plots are presented in Table 3.1. *Pinus taeda* was especially prevalent around the first three replicates. Non-native invasive plants that were present included *Ligustrum* sp. (privet), and *Phyllostachys aurea* (golden bamboo). Replicates 5, 6, and 7 were located behind a pecan grove (*Carya illinoensis*). *Acer rubrum* was an established plant mixed in with the surrounding vegetation before the study began. *Platanus occidentalis*, *Magnolia* *virginiana*, and *Quercus* spp., plant species used in the diversity plot analysis, were also present. A volunteer crepe myrtle, whose origin is unknown, was observed to be growing near replicate 7 in 2015.

Acer rubrum	*Juniperus virginiana*	*Quercus falcata*
Albizia julibrissin	*Ligustrum* spp.	*Quercus incana*
Alnus spp.	*Liquidambar styraciflua*	*Quercus nigra*
Callicarpa americana	*Liriodendron tulipifera*	*Quercus phellos*
Carya illinoensis	*Magnolia virginiana*	*Sambucus canadensis*
Castanea mollissima	*Melia azedarach*	*Sassafras albidum*
Celtis occidentalis	*Phyllostachys aurea*	*Tilia americana*
Cephalanthus occidentalis	*Pinus taeda*	*Triadica sebifera*
Cornus florida	*Platanus occidentalis*	*Ulmus rubra*
Juglans nigra	*Prunus serotina*	*Vitis rotundifolia*

Table 3.1: Common woody plant species observed near the two sites.

Tree Canopy Area

The estimated average canopy area of the three tree species was variable. Norway maples had an average estimated canopy area of 0.993m^2. Average crepe myrtle canopy area, 25.4 m^2, is approximately 25 times larger than the Norway maples. Red maples had an average canopy area of 11.7 m^2, about half the size of crepe myrtles (Figure 3.3A). Only the focal red maples from the treatment group which had red maple surrounded by diverse native plants (RM/DIV) were significantly smaller compared to the focal maples of the other treatments (df = 4, $P < 0.01$) (Figure 3.3B). This is presumably because they were planted a year after the other trees; they were growing in pots during the time that the other maples were in the ground.

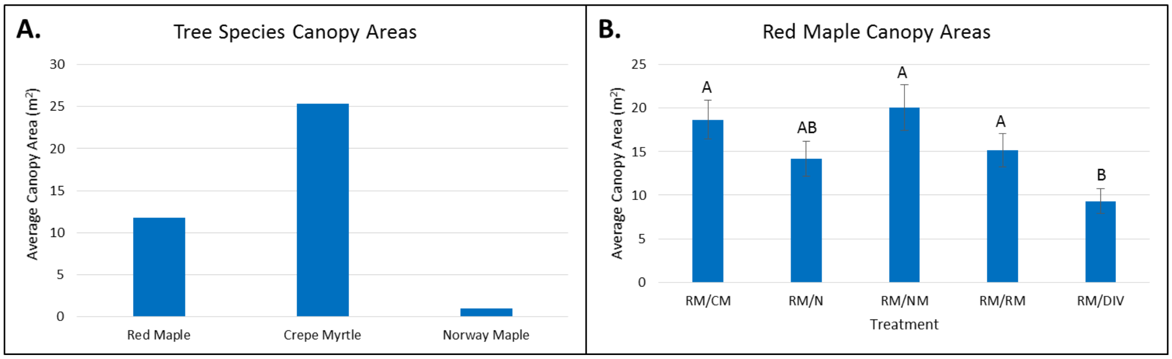

Figure 3.3: Average estimated canopy areas of experimental trees on October 5, 2015. 1A: Average canopy areas of the three tree species red maple (*Acer rubrum*), crepe myrtle (*Lagerstroemia indica*), and Norway maple (*Acer platanoides*). 1B: Average area of focal red maples among treatment groups. RM/CM = red maple with crepe myrtle neighbors, RM/N = red maple with no neighbors, RM/NM = red maple with Norway maple neighbors, RM/RM = red maple with red maple neighbors, RM/DIV = red maples with four different native neighbors (*Platanus occidentalis*, *Betula nigra*, *Magnolia virginiana*, and *Quercus palustris*).

Caterpillars Observed

Overall, red maples supported more species and a greater abundance of caterpillars than both crepe myrtle and Norway maple (Figure 3.4). During the entire study, only four species including *Orgyia leucostigma* Smith (Lymantriidae)(Image 3.31), *Choristoneura rosaceaena* Harris (Tortricidae)(Image 3.71), *Thyridopteryx ephemeraeformis* Haworth (Psychidae)(Image 3.61), and an unknown 1st instar looping caterpillar were found feeding on crepe myrtle. These three species are highly polyphagous (Table 3.2), and the unknown looper was observed to be feeding on red maple, river birch, and pin oak, inferring that it too is a generalist.

Ten species of caterpillar were observed feeding on Norway maple: *O. leucostigma, C. rosaceana, T. ephemeraeformis, Schizura ipomoeae* Doubleday

(Notodontidae)(Image 3.51), *Spodoptera ornithogallii* Guenée (Noctuidae)(Image 3.410), *Heterocampa guttivata* Walker (Notodontidae)(Image 3.52), *Palthis angulalis* Hübner (Noctuidae)(Image 3.46), *Iridopsis ephyraria* Walker (Geometridae)(Image 3.12), *Morrisonia confusa* Hübner (Noctuidae)(Image 3.45), and *Episimus tyrius* Heinrich (Tortricidae)(Image 3.73). Of these, *E. tyrius* was the only specialist on maple and it was only recorded once on Norway maple. Almost all of the caterpillars found on crepe myrtle and Norway maple were also found feeding on red maple (Table 3.2), which hosted a total of 17 morphospecies of caterpillars. The most common species feeding on red maple were maple specialists including *Dryocampa rubicunda* Fabricius (Saturniidae)(Images 3.71-3.76), *Parallelia bistriaris* Hodges (Noctuidae)(Images 3.47-3.49), *Hypena baltimoralis* Guenée (Noctuidae)(Images 3.42-3.43), and *E. tyrius*. Red maple also hosted additional generalist species like *Acronicta americana* Harris (Noctuidae)(3.41), *Acharia stimulea* Clemens (Limacodidae)(Image 3.17), *Platynota rostrana* Walker (Tortricidae) and *Antheraea polyphemus* Cramer (Saturniidae)(Image 3.79). Several other caterpillars, mostly leaf-tiers, were likely present, but were difficult if not impossible to identify in the field. For example, *C. rosaceana* and *P. rostrana* were very difficult to differentiate unless they were reared in the lab. These were lumped into the category "green leaf-tier with black head and pronotum." *Episimus tyrius* was easy to differentiate as 4^{th}-5^{th} instars because of their bright red coloration, but earlier instars were light brown and indistinguishable from other young leaf-tiers. In this case, all of the young brown leaf-tiers with tan heads were lumped as *E. tyrius*. *Palthis angulalis* was easy to distinguish from *E. tyrius* because of their dark brown coloration. Caterpillars that clearly appeared different, but were never identified were photographed and given morphospecies designation.

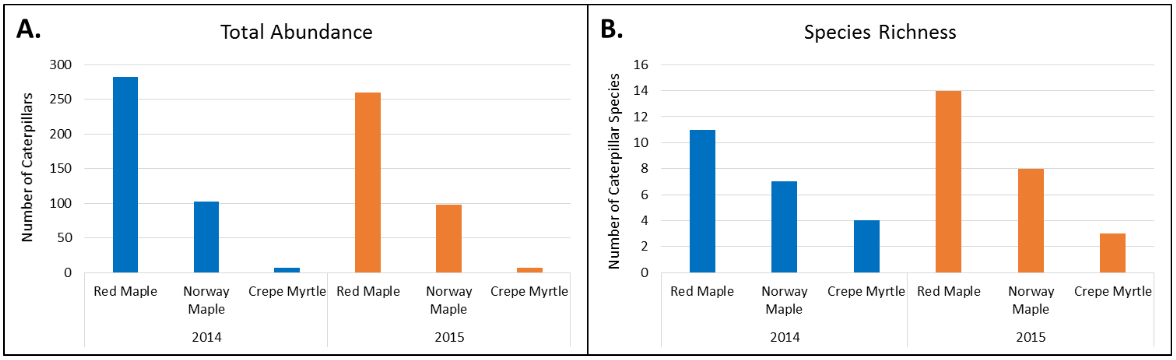

Figure 3.4: Caterpillar abundance and species richness on the three plant species that were investigated.

Family	**Species**	**Known Diet Breadth**	**Hosts from this study**
Geometridae	***Ennomos magnaria***	**12**	**RM**
Geometridae	***Iridopsis ephyraria***	**12**	**RM**
Limacodidae	***Acharia stimulea***	**20**	**RM**
Lymantriidae	***Orgyia leucostigma***	**52**	**RM, CM, NM**
Noctuidae	***Acronicta americana***	**15**	**RM**
Noctuidae	***Hypena baltimoralis***	**1**	**RM**
Noctuidae	***Morrisonia confusa***	**14**	**RM, NM**
Noctuidae	***Palthis angulalis***	**11**	**RM**
Noctuidae	***Parallelia bistriaris***	**3**	**RM**
Noctuidae	***Spodoptera ornithogallii***	**24**	**RM, NM**
Notodontidae	***Heterocampa guttivatta***	**15**	**NM**
Notodontidae	***Schizura ipomoeae***	**14**	**RM, NM**
Psychidae	***Thyridopteryx ephemeraeformis***	**50**	**RM, CM, NM**
Saturniidae	***Antheraea polyphemus***	**25**	**RM**
Saturniidae	***Dryocampa rubicunda***	**5**	**RM**
Tortricidae	***Choristoneura rosaceana***	**27**	**RM, CM, NM**
Tortricidae	***Episimus tyrius***	**2**	**RM, NM**
Tortricidae	***Platynota rostrana***	**24**	**RM**

Table 3.2: Caterpillar species observed feeding on trees during the course of this experiment. Diet breadth refers to the number of plant families reported to host these caterpillars. RM = red maple (*Acer rubrum*), CM = crepe myrtle (*Lagerstroemia indica*), and NM = Norway maple (*Acer platanoides*).

Unsurprisingly, other insects were regularly observed on the plants, but were not included in the survey. For crepe myrtles, there were glassy-winged sharpshooters

(*Homalodisca vitripennis* Germar)(Image 4.14), crepe myrtle aphids (*Tinocallis kahawaluokalani* Kirkaldy)(Image 4.13), and Japanese beetles (*Popillia japonica* Newman), which are all either invasive or highly polyphagous insects. Painted maple aphids (*Drepanaphis acerifoliae* Thomas), tree crickets (Oecanthinae), red-headed bush crickets (*Phyllopalpus pulchellus* Uhler), and various grasshoppers and katydids were occasionally observed in red maple canopies. One caterpillar species that was observed on red maple, crepe myrtle, sweetbay magnolia, and pin oak, but not included in the survey, was observed emerging from large scaly eggmasses (hundreds of individuals) throughout the summer (Image 3.412). These larvae never produced larger larvae, nor did they feed on the plant on which they were found when reared in the lab. For these reasons, this species, perhaps a grass-specialist *Spodoptera* sp., was excluded from the data. On a few rare occasions, yellow-striped armyworm (*Spodoptera ornithogalii*) was observed feeding on the lower canopy of red maples and Norway maples. They were observed on two red maples during September of 2015, and once on a Norway maple in September of 2014 and another in 2015. It is unknown whether *S. ornithogalii* were the mysterious emerging, and subsequently disappearing, caterpillars. Several predators, including various leaf-tying spiders (see Images 4.11 and 4.12), ladybird beetles (*coccinella septempunctata* Linnaeus, *Brachiacantha ursina* Fabricius, and *Harmonia axyridis* Pallas)(Images 4.4-4.6), Carolina mantids (*Stagmomantis carolina* Johansson)(Images 4.1-4.2), paper wasps (Vespidae - *Polistes*)(Image 3.77), potter wasps (Eumeninae)(Image 4.10), hover-fly larvae (Syrphidae)(Image 4.3), and green anoles (*Anolis carolinensis* Voigt)(Image 4.7) were common on all trees.

Sampling Effort

Approximately 63% of the true abundance of caterpillars on each red maple were recorded, and approximately 70% of the species were recorded (Figure 3.5). It can therefore be concluded that approximately 30-40% of the caterpillars on any given tree were not recorded.

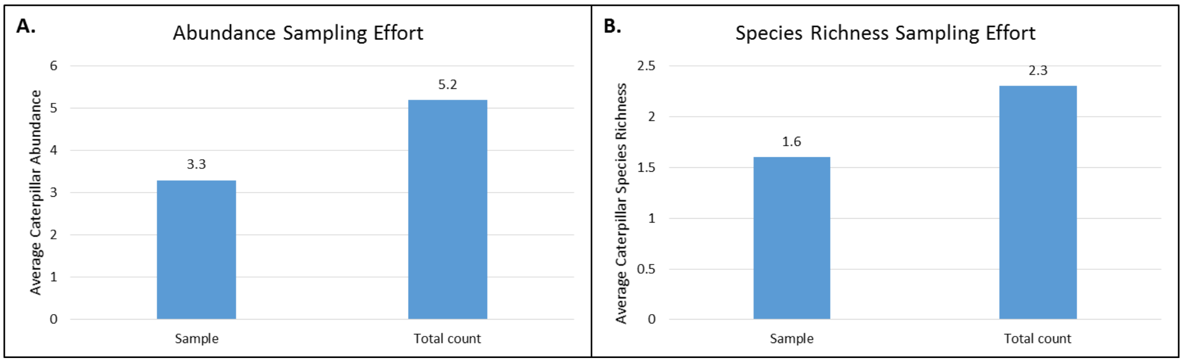

Figure 3.5: Sampling Effort Estimation. The left bar for each graph represents the average caterpillars counted during a normal sampling period on ten neighboring red maples. The right bar for each graph represents the total caterpillars that were counted during a total search of 10 neighboring red maples.

Damage Analysis and Caterpillar Abundance

Data from damage assessments in 2014 yielded different results than that of 2015 [$F(3,46) = 5.35$, $P = 0.003$]. There were no significant differences in damage to the focal red maples in the treatment plots [$F(3,108) = 1.22$, $P = 0.3$] in 2014, but there were significant differences in 2015 [$F(3,126) = 10.78$, $P < 0.0001$]. Red maples that had crepe myrtle neighbors (RM/CM) were subject to more than twice as much damage (df = 3, $P < 0.001$) (Figure 3.6A) compared to focal red maples from other treatments. All other damage levels in other treatments were not significantly different from one another. Data from caterpillar abundance were also different between 2014 and 2015 (Figure 3.6B) [$F(1,46) = 5.09$, $P = 0.029$]. The year by treatment interaction, however, was not significant [F(3,46) = 1.73, *P* = 0.17] unless the Norway maple treatment was excluded from the analysis [F(2,36) = 3.46, *P* = 0.042]. In total, 3,133 caterpillars were recorded on focal red maples during 2014 and 2015. There was no significance between the treatment groups in 2014 [F(3,108) = 0.72, *P* = 0.54], but there was in 2015 [F(3,126) = 3.57, *P* = 0.016]. In 2015, nearly twice as many caterpillars were found on RM/CM maples compared to maples with either no neighbors (RM/N) (df = 3, *P* = 0.007) or red maple neighbors (RM/RM) (df = 3, *P* = 0.005). Red maples with Norway maple neighbors (RM/NM) were not significantly different than the other treatments.

Caterpillar Species Richness

Caterpillar species richness between treatment groups also differed between years [F(1,46) = 3.21, *P* = 0.032] (Figure 3.6C). There were significant differences between treatment groups in 2014 [F(3,108) = 3.8, *P* = 0.012], and marginal differences in 2015 [F(3,126) = 2.22, *P* = 0.09]. On average, there was about one additional caterpillar species found on the RM/RM maples compared to RM/CM maples (df = 3, *P* = 0.0303) or RM/NM maples (df = 3, *P* = 0.0013) in 2014. In 2015, however, the data showed the opposite. There was an average of about one additional caterpillar species found on the RM/CM maples compared to RM/RM maples (df = 3, *P* = 0.0124). A season-wide Shannon-Weiner diversity analysis was performed by pooling together all caterpillars and analyzing them on a year by plot basis, but there was no significant difference between neighbor treatments in either year.

Two species (*Dryocampa rubicunda* and *Episimus tyrius*) made up the majority (47% and 33%, respectively) of caterpillars counted in the survey. *Dryocampa rubicunda* was present for the duration of the surveys, while *E. tyrius* was mainly present from June to mid-September (Figure 3.7). *Dryocampa rubicunda* abundance between the treatment groups was not significantly different in 2014 [$F(3,108) = 0.88$, $P = 0.45$], but it was in 2015 [$F(3,126) = 4.01$, $P = 0.01$]. *Dryocampa rubicunda* was nearly five times as abundant on the RM/CM maples compared to the RM/N (df = 3, $P = 0.0017$) and the RM/RM maples (df = 3, $P = 0.0080$) in 2015 (Figure 3.6D). There were no significant trends observed with *E. tyrius* in either 2014 [$F(3,108) = 0.58$, $P = 0.63$] or 2015 [$F(3,126) = 0.31$, $P = 0.82$]. There were also no significant trends when *D. rubicunda* was excluded from the analysis in both 2014 [$F(3,108) = 0.26$, $P = 0.9$] and 2015 [$F(3,126) = 0.62$, $P = 0.6$].

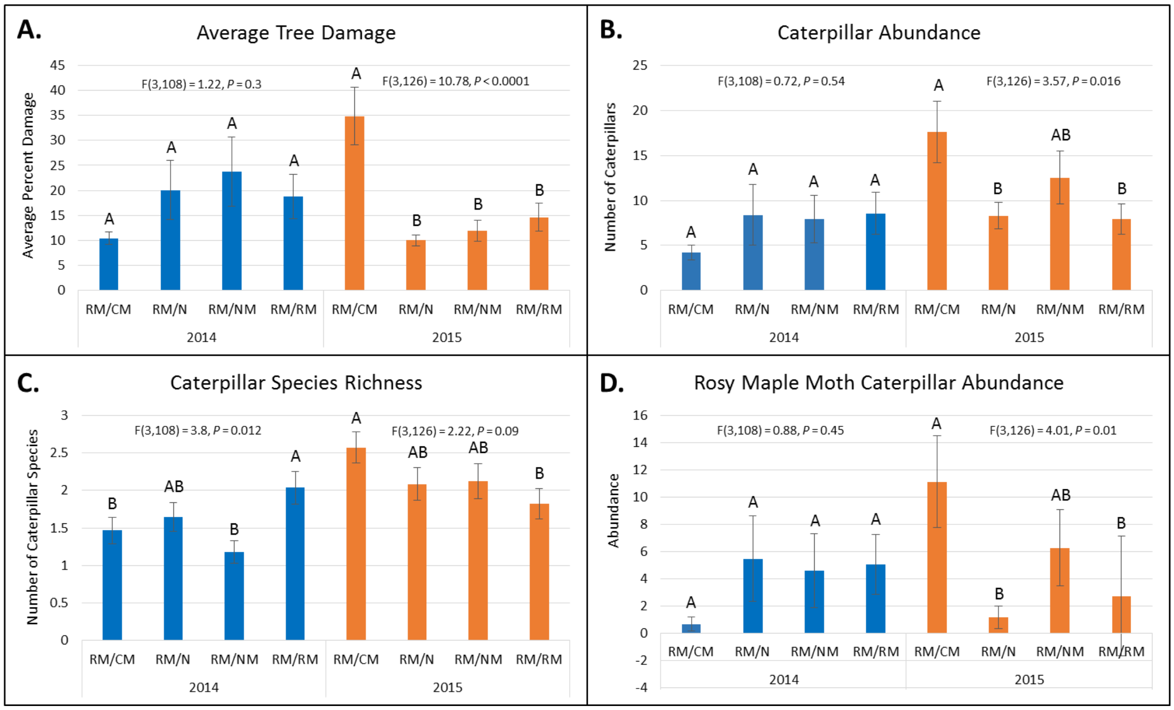

Figure 3.6: One-way analysis of variance on different years for each variable. Error bars represent the standard error of the mean. Letters represent significant differences in the data. F and P values refer to the ANOVA tests run on the individual years. Variables include: Herbivore damage (A), caterpillar abundance (B), caterpillar species richness (C), and *D. rubicunda* abundance (D) on focal red maples among different treatment groups. RM/CM = red maple with crepe myrtle neighbors, RM/N = red maple with no neighbors, RM/NM = red maple with Norway maple neighbors, RM/RM = red maple with red maple neighbors.

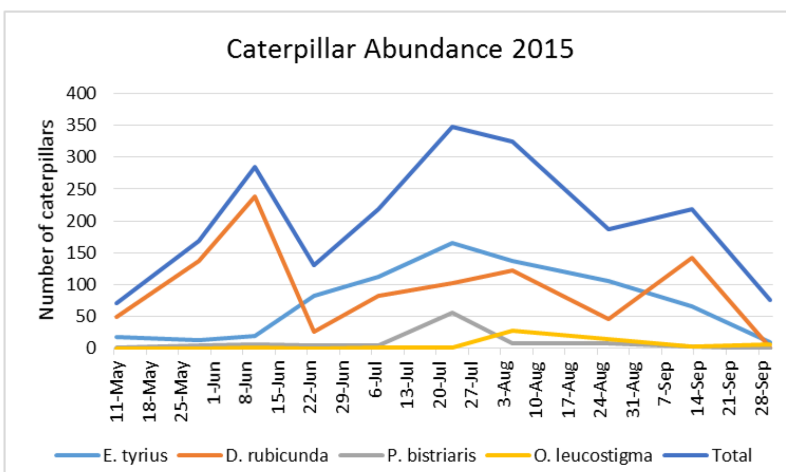

Figure 3.7: Histogram of caterpillar abundance on red maples during 2015.

Focal Maples compared to Neighbor Maples

Caterpillar abundance, richness, damage, and *D. rubicunda* abundance were compared between focal red maples and neighboring maples (Nbor) (Figure 3.8). There were no significant differences in the variables between the neighboring red maples and the RM/RM focal red maples between years. In 2014, the neighboring red maples had greater species richness compared to RM/CM, RM/N, and RM/NM maples (Figure 3.8C).

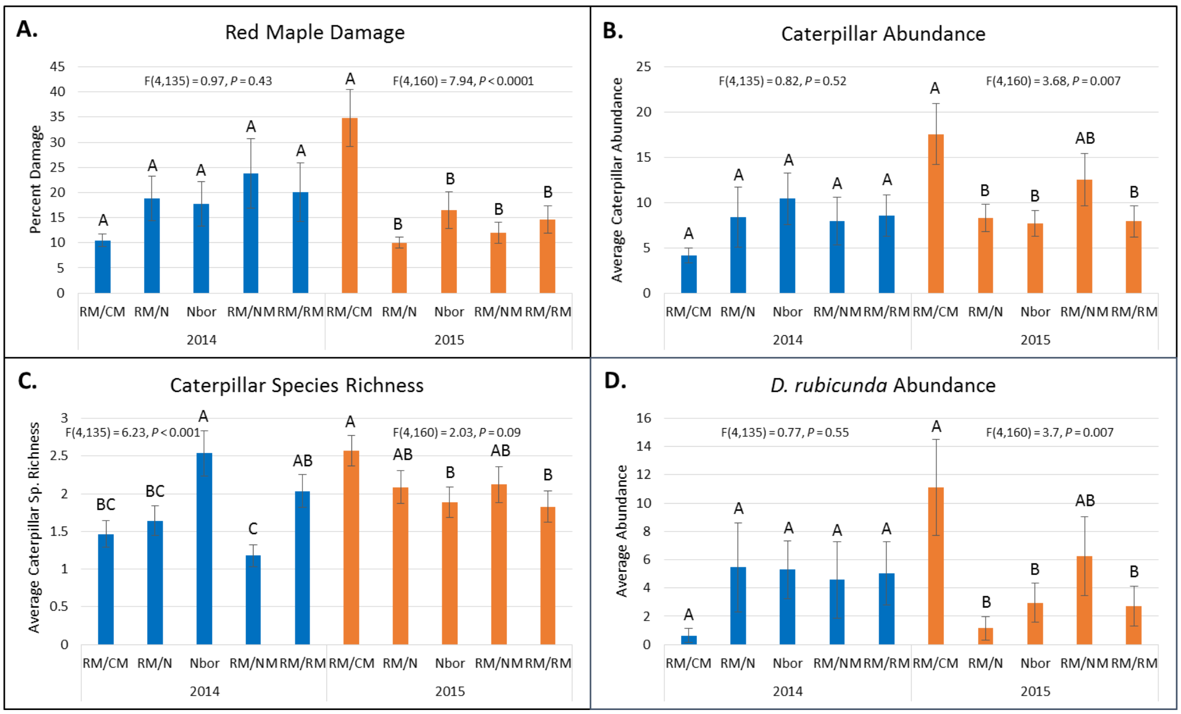

Figure 3.8: Comparison of neighboring maples to focal maples in different treatment plots. One-way analysis of variance was conducted on different years for each variable. Error bars represent the standard error of the mean. Letters represent significant differences in the data. F and P values refer to the ANOVA tests run on the individual years. Variables include: Herbivore damage (A), overall caterpillar abundance (B), caterpillar species richness (C), and *D. rubicunda* abundance (D) on focal red maples among different treatment groups. RM/CM = red maple with crepe myrtle neighbors, RM/N = red maple with no neighbors, Nbor = neighboring red maple, RM/NM = red maple with Norway maple neighbors, RM/RM = red maple with red maple neighbors.

Diversity Plots

New treatment plots were established in May of 2015 containing a treatment where red maples were surrounded by four different native trees including *Platanus occidentalis*, *Betula nigra*, *Magnolia virginiana*, and *Quercus palustris*. A one-way ANOVA was individually conducted on the treatment groups in each year. Red maples surrounded by diverse native trees (RM/DIV) had similar damage, caterpillar abundance, caterpillar species richness, and *D. rubicunda* abundance compared to the RM/N, RM/NM, and RM/RM maples (Figure 3.9). They also had similar *D. rubicunda* abundance compared to the RM/CM maples.

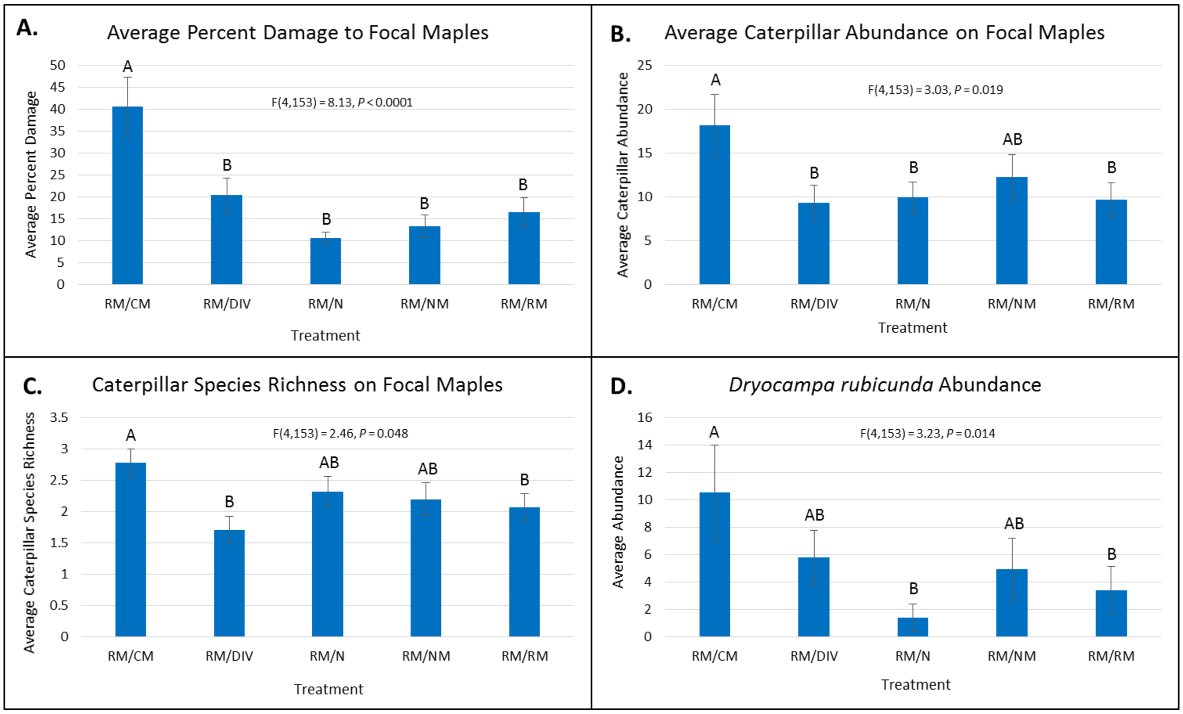

Figure 3.9: Comparison of red maples surrounded by four different species of native plants to other treatment plots in 2015. Error bars represent the standard error of the mean. Letters represent significant differences in the data. F and P values refer to the ANOVA test. Variables include: Herbivore damage (A), overall caterpillar abundance (B), caterpillar species richness (C), and *D. rubicunda* abundance (D) on focal red maples among different treatment groups. RM/CM = red maple with crepe myrtle neighbors, RM/DIV = red maple with diverse neighbors, RM/N = red maple with no neighbors, RM/NM = red maple with Norway maple neighbors, RM/RM = red maple with red maple neighbors.

Natural Enemy Survey

In total, 2,252 insect natural enemies were collected in the pan traps during 2014 and 2015. These natural enemies were split into two categories based on life history traits: predators and parasitoids. Only 171 predators were collected, while 2086 parasitoids were collected. The predator category included the families Anthocoridae (minute pirate bugs), Coccinellidae (ladybird beetles), Nyssonidae (Sphecoid wasps), Reduviidae (Assassin bugs), Sphecidae (thread-waisted wasps), and Vespidae (Paper wasps). The most abundant natural enemies that were included in the parasitoid category were Sarcophagidae (25%)(Image 5.10) and Tachinidae (9%)(Image 5.11), and several Hymenopteran families including Aphelinidae (15%)(Image 5.3), Encyrtidae (7%)(Image 5.5), Ichneumonidae (14%)(Image 5.9), Mymaridae (10%)(Image 5.4), Scelionidae (24%)(Image 5.1), and Trichogrammatidae (11%)(Image 5.2). Less common families Hymenopteran families included Bethylidae, Braconidae (Image 5.7), Ceraphronidae (Image 5.6), Chalicididae (Image 5.8), Eulophidae, Eupelmidae, Eurytomidae, Platygastridae, and Pteromalidae. Sarcophagids were not analyzed separately because there is a chance that some of them were not parasitoids; they were, however, included in the overall count. In all of the categories (predator abundance, muscoid abundance, Ichneumonidae abundance, Scelionidae abundance, parasitoid abundance, family richness, Shannon-Weiner diversity, evenness, abundance without Sarcophagidae, and all natural enemy abundance, richness, and Shannon-Weiner diversity), there was no significant interaction between year and treatment group (Figure 3.10). In 2014, RM/CM plots had significantly greater natural enemy family evenness compared to RM/NM plots (Figure 3.10C) (df = 3, P = 0.014).

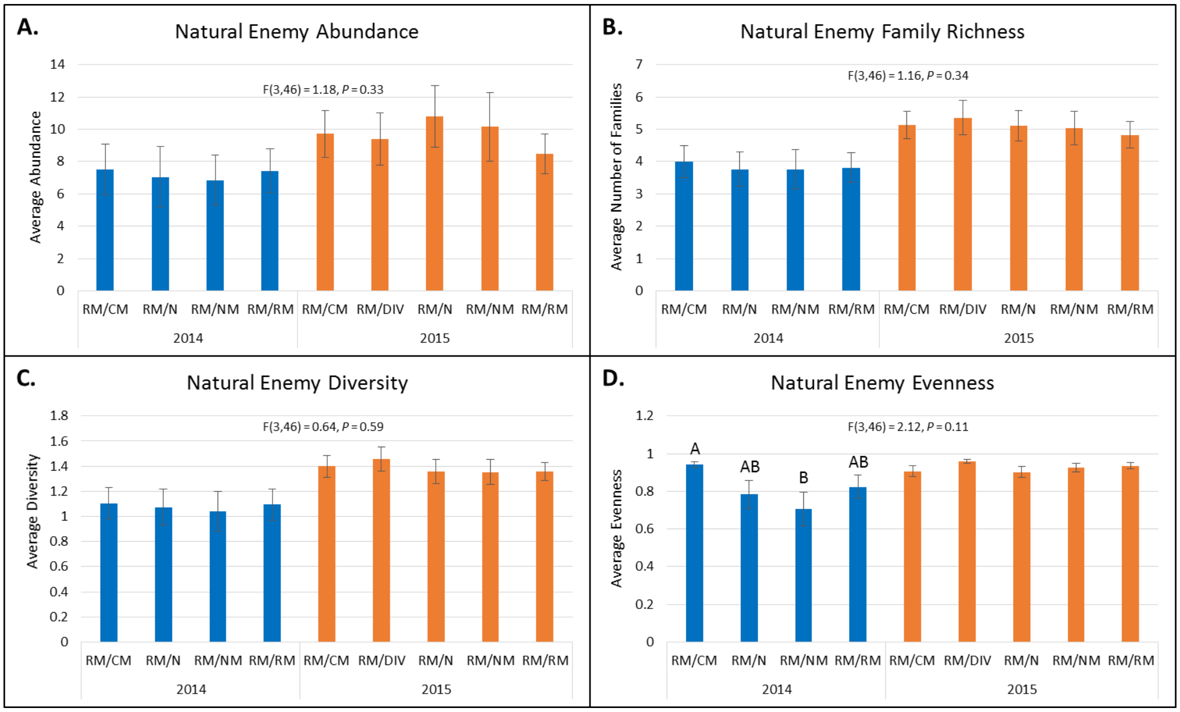

Figure 3.10: Natural enemy comparisons between treatment groups. One-way analysis of variance was conducted on different years for each variable. Error bars represent the standard error of the mean. Letters represent significant differences in the data. F and P values refer to the MANOVA test that was used to compare treatment by year interactions. Variables include: natural enemy abundance (A), natural enemy family richness (B), natural enemy Shannon-Weiner diversity (C), and natural enemy family evenness (D) on focal red maples among different treatment groups. RM/CM = red maple with crepe myrtle neighbors, RM/N = red maple with no neighbors, Nbor = neighboring red maple, RM/NM = red maple with Norway maple neighbors, RM/RM = red maple with red maple neighbors.

Discussion

Associational interactions between native and non-native trees are clearly affecting caterpillar populations in this experiment. Most previous studies have investigated associational responses of one herbivore species feeding upon herbaceous plants. In contrast, very few studies have investigated caterpillar community responses to associational interactions between urban trees, and none, to our knowledge, have investigated this in the context of plant origin. The native, non-native plant complex is unique because most non-native plants are not suitable hosts for the majority of herbivore species in the community. The concepts presented here, therefore, are very important for urban ecologists and landscape professionals to understand in order to predict pest invasion and outbreak.

Our original hypothesis was that associational resistance would occur when native host plants (like red maples) are surrounded by non-host plants (like crepe myrtle). On the contrary, these data infer that associational susceptibility is occurring. Non-native plants create what seems to be a trap effect, causing a greater abundance of herbivores on the focal native. One initial hypothesis is that the species richness of caterpillars was greater on RM/CM maples during 2015 because of greater plant species richness. Raupp et al. (2001) compared the influences of plant species richness or density on pest diversity and abundance in urban landscapes. They noted that pest species richness was most influenced by the number of plant species in a landscape, and that pest abundance is moreso a function of plant density. This makes sense because the majority of insect herbivores are specialized on native plants. However, red maples with no tree neighbors had similar caterpillar diversity to RM/CM plots. Thus, there is little evidence that simple plant diversity was responsible for the greater species richness of caterpillars when red maples were surrounded by crepe myrtle. This provides a rationale for why we added a fifth treatment group with a native red maple surrounded by four diverse native trees in 2015. Data from these plots in future years will give context for the plant diversity variable.

Caterpillar abundance and foliar damage was mostly due to the presence of *Dryocampa rubicunda* (green-striped mapleworm), the most common caterpillar observed in the study. It is a multivoltine specialist that prefers to feed on *Acer*, but occasionally feeds on *Quercus*, *Fagus*, *Platanus*, and *Juglans* species (HOSTS 2015). Female *D. rubicunda* moths that oviposit on trees surrounded by non-hosts may have an ecological advantage based on habitat complexity or the influence of natural enemies and birds. Offspring of moths that oviposit in complex plant communities could have a higher probability of survival. A tropical tree (*Tabebuia rosea*) was more susceptible to damage by a specialist Pyralid caterpillar (*Eulepte gastralis*) in the presence of mixed stands containing non-hosts as opposed to monocultures (Plath et al. 2012). Parasitoids may have increased foraging efficiency when plant communities are simple (i.e. less diverse), and decreased foraging efficiency in plant communities that are more complex (Gols et al. 2005). Furthermore, we expected that native plant plots would support greater abundance and diversity of parasitoids (Greenstone 2013). In our study, however, there were no differences in natural enemy abundance or diversity between treatments. Previous studies suggest that parasitoid communities, especially when assessed at the family level, are much more accurately investigated at larger spatial scales (Roland and Taylor 1997, Sperber et al. 2004). There may be trends in parasitoid and predator diversity that were undetected, but could be revealed if specimens captured in traps were identified to a lower taxonomic level. Bird predation could also be a factor. Narango et al. (2015) concluded that chickadees spend more time foraging for insects on native trees than non-native trees, inferring that birds learn to forage on plants that have more prey items. The greater abundance of *D. rubicunda* on red maples planted with crepe myrtle may be influenced by reduced bird foraging in those plots. Birds could be foraging less on plots occupied by crepe myrtle because of a simple learned behavior combined with a decrease in visual apparency. This hypothesis could be tested by directly assessing caterpillar survival or bird attacks on sentinel larvae in each plot.

Interestingly, there was a significant year by treatment interaction in the model indicating that abundance on RM/CM maples was greater in 2015 than in 2014. The greater abundance of *D. rubicunda* on red maples surrounded by crepe myrtles may be explained by the behavior of adult females. *Dryocampa rubicunda* will drop off of trees and overwinter underground as pupae, remaining present year-round (USDAFS 1971). Female silkworm moths (Saturniidae) tend to utilize the strategy of dispersing as little as possible in order to avoid predation and conserve food reserves. They emit attractant pheromones that bring in wide-ranging males (Tuskes et al. 1996). The extent to which *D. rubicunda* exhibits this behavior is unknown but, if similar to other Saturniids, female moths may stay close to the host rather than dispersing away from the plots. This hypothesis assumes that there is an accumulation of individuals over both years. The first year (2014) was not significant perhaps because pioneering females were discovering the plots. In 2015, however, the crepe myrtles may have been acting as a biological fence, making it difficult to, or seemingly less advantageous for, moths to disperse. Red maples surrounded by red maple neighbors may have encouraged dispersal to adjacent plants that were hosts. Dispersal to adjacent hosts would dilute the relative abundance of *D. rubicunda* on the focal red maple when surrounded by red maple. The red maple neighbors from the RM/RM plots hosted similar population levels of *D. rubicunda* compared to the RM/RM focal trees and the RM/N trees (Figure 3.8D). Moths emerging from pupation in these plots could disperse to and even beyond those same or related hosts. This suggests that there was little associational interaction between red maples and that resource concentration was not occurring in these plots.

Species richness of caterpillars differed between the two years. In 2014, there were significantly fewer caterpillar species on RM/CM and RM/NM maples compared to RM/RM maples. This suggests that associational resistance is occurring, presumably because the non-host plants (crepe myrtle) make it difficult for ovipositing moths to find their hosts. In 2015, however, there were significantly fewer caterpillar species on the RM/RM focal maples compared to the RM/CM maples, suggesting that associational susceptibility is occurring. These differences could also be explained by our hypotheses. Perhaps it was difficult for female moths of many different species to initially find the host in the presence of the non-natives, but once they did, they did not leave. The ultimate effects, then, may have been occurring in 2015.

Whether effects that were caused by crepe myrtles are also caused by native, non-hosts is inconclusive. Data from red maples surrounded by diverse natives in 2015 show that the damage, abundance of caterpillars, and the caterpillar species richness of the RM/DIV maples were significantly less than the red maples surrounded by crepe myrtle (Figure 3.9). Abundance of *D. rubicunda* was not significantly different on any of the other treatment trees including the RM/CM maples (Figure 3.9D). The presence of native non-hosts may have the same effect as non-native non-hosts. However, it would not be valid to compare the data from these plots to the data from plots established in 2014, especially because data from the older plots show that the establishment year provided different results from the second year. Additionally, the red maples planted in May of 2015 were smaller on average (Figure 3.3B), but were the same age and came from the same stock as the trees planted in 2014. Data from a third year may provide more enlightening results.

The Norway maples did not develop in a way that is typical for this species when used in landscapes further north. Some of the Norway maples did not survive to the end of 2015, and the ones that did exhibited very poor foliage mass (approximately 1/10 the size of the red maples, and 1/25 the size of crepe myrtles). In fact, in 2015 there was uneven replication because two of the RM/NM plots were left out of the analysis due to tree death (JMP controls for this in the ANOVA analysis). Results indicate that overall caterpillar abundance, caterpillar species richness, and *D. rubicunda* abundance were intermediate on these plots and not significantly different from either RM/CM or RM/RM. This implies that a very limited amount of spillover could have been occurring despite the very small leaf mass. If the plants were larger, and more typical of the ones further north, the plots may have yielded similar results, but probably less severe results than the RM/CM plots. Considering the poor performance of Norway maple, it may have been a better choice to select Japanese maple (*Acer palmatum* Thunberg) as a congeneric non-native. Japanese maple is used much more frequently in urban landscapes in the southeast and likely would have survived better.

There was no apparent response of the natural enemies to the crepe myrtle blooms, either, although a large amount of Ichneumonid wasps were one time observed swarming a crepe myrtle. Since crape myrtle blooms do not produce nectar (Kim et al. 1994), the wasps may have been attracted to honeydew from the crepe myrtle aphids (*Tinocallis kahawaluokalani*). Another potential confounding factor could be the fact that some of the micro-Lepidoptera species were never recognized. As mentioned before, it is nearly impossible to identify these in the field, so some were lumped together as morphospecies. If all caterpillar species were identified, abundance would have been unaffected and there would have been slight changes in caterpillar species richness. The overall conclusions would likely be the same.

Chapter 4

General Conclusions, Implications, and Applications for Future Study

Associational interactions between native and non-native plants are clearly affecting caterpillar populations within this experiment. Most previous studies have investigated single insect species responses to interactions between herbaceous perennials. In contrast, very few studies have investigated caterpillar community responses to associational interactions between urban trees, and none, to our knowledge, have investigated this in the context of plant origin. The native, non-native plant complex is unique because most non-native plants are non-hosts for the majority of herbivore species in the community. The concepts presented here, therefore, are very important for urban ecologists and landscape professionals to understand in order to predict insect outbreak.

The results have both ecological and economic importance. When natives are removed and replaced with non-natives that provide fewer ecological services, the ecosystem is weakened. This is comparable to a game of Jenga®. When blocks are removed from the Jenga tower, the tower gets weaker. In an urban ecosystem, native plants represent the normally-shaped blocks in this game, whereas non-native plants represent odd, triangular shaped blocks that may fit into the tower, but not as well as squared blocks. They provide some ecosystem services, but not nearly as many as do the natives. When enough of these odd-shaped blocks are added, the system as a whole can become unbalanced, creating conditions that are optimal for pest outbreak. This was observed in the RM/CM plots when crepe myrtles appear to disrupt the balance of the system, allowing *Dryocampa rubicunda* to completely defoliate entire red maples multiple times throughout a season. This simple interaction can be amplified when dealing with true urban landscapes existing on even larger scales, with many complex barriers in addition to widespread use of non-native plants. This research suggests that the optimal condition for suppressing pest outbreaks in the landscape is to maximize the number of native plantings. In this era of expanding human development and continued modification and destruction of natural environments, it is the responsibility of landscape professionals and homeowners alike to promote sustainable urban ecosystems by provisioning urban and suburban areas with native plants. It is essential that people acknowledge ecological function of landscape plant choices as equally important as aesthetic value.

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Photographic Appendix

Part 1: Plot Photos and Installation Process

Image 1.1: Original trees before they were placed in the ground. Crepe myrtles (top) came as multi-trunk forms while all other trees came in whip form, bundled into groups of 10.

Image 1.2: A hole after being dug using a tractor auger.

Image 1.3: Example plot after trees were first placed in the ground.

Image 1.4: Trees were given deer guards, grass was mowed, followed by herbicide and pine straw application.

Image 1.5: Final appearance of each plot at the beginning of 2014.

Image 1.6: RM/CM plot on June 23, 2015.

Image 1.7: RM/N plot on June 23, 2015

Image 1.8: RM/RM plot on June 23, 2015

Image 1.9: RM/NM plot on June 23, 2015

Image 1.10: RM/DIV plot on June 23, 2015

Image 1.11: Pan trap used for natural enemy surveys

Part 2: Maps

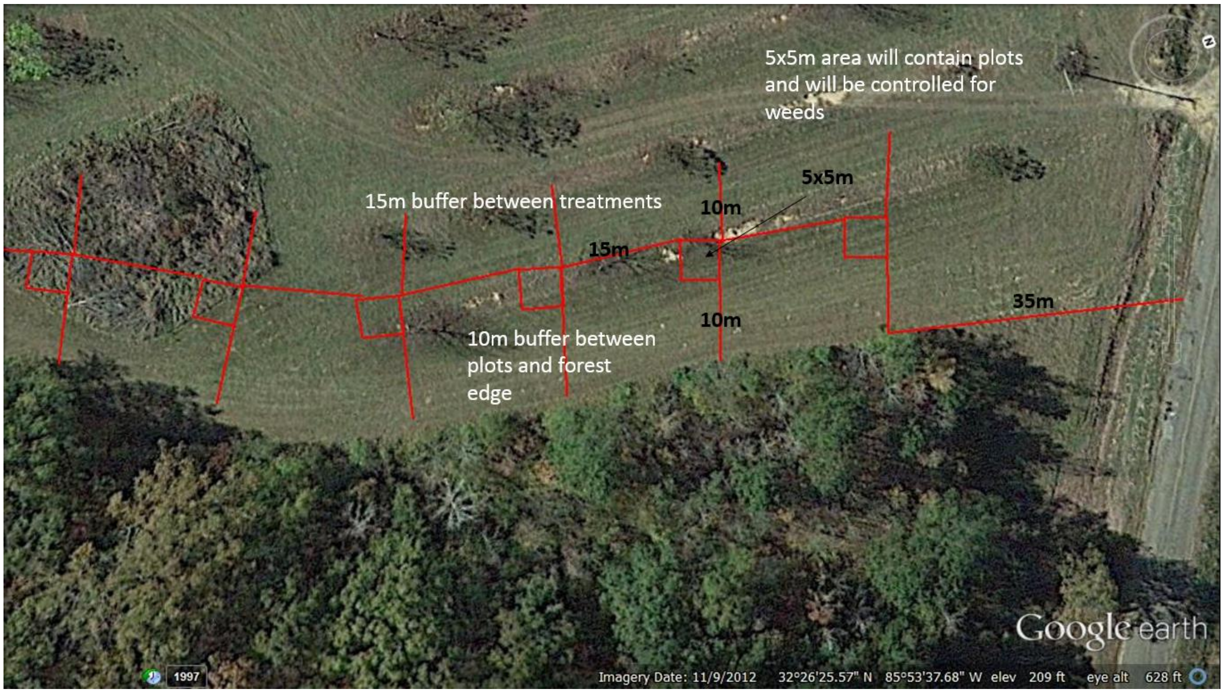

Image 2.1: General plot layout along woodline

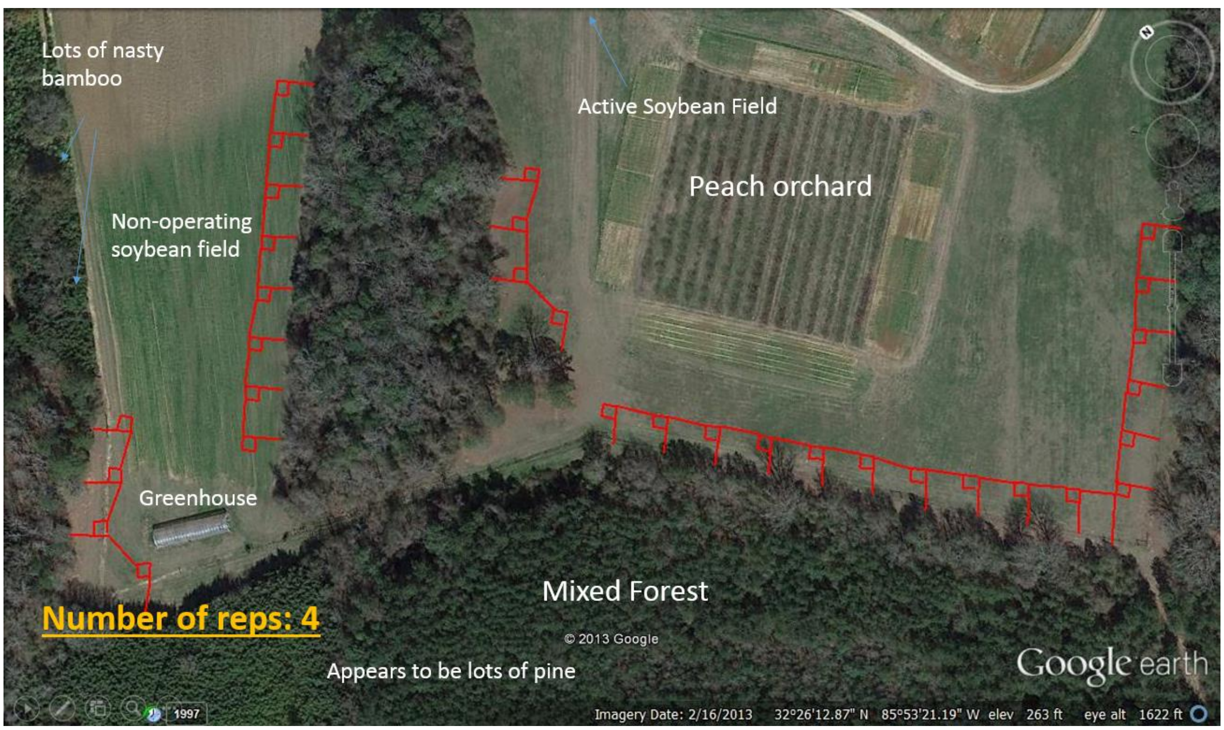

Image 2.2: Replicates 1-4

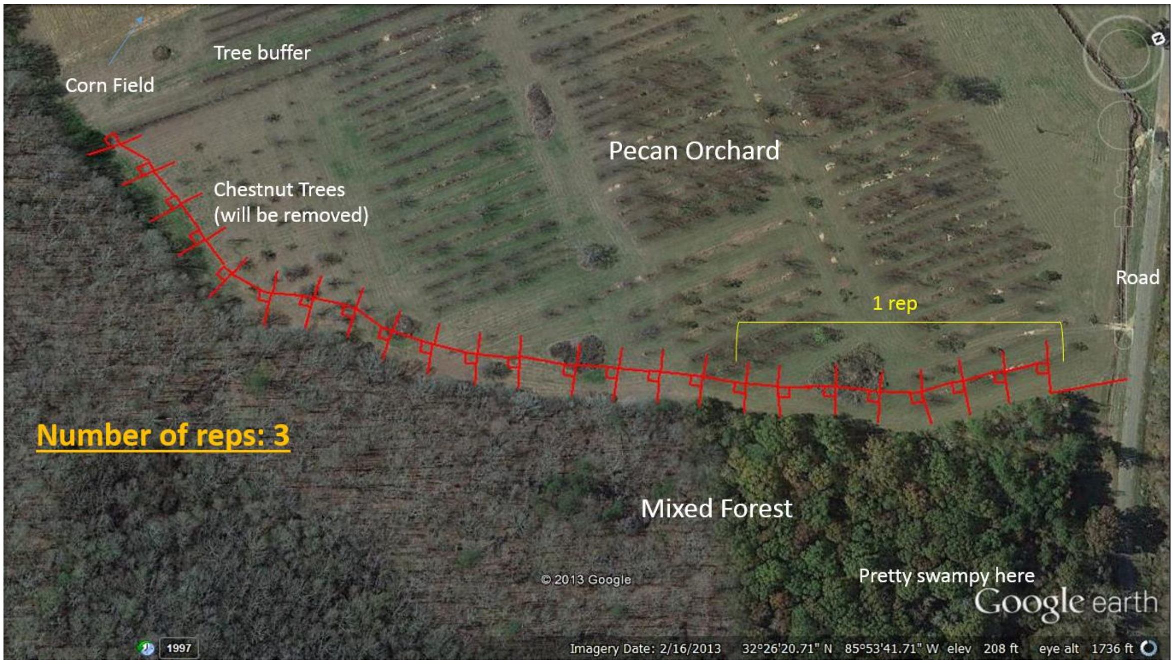

Image 2.3: Replicates 5-7

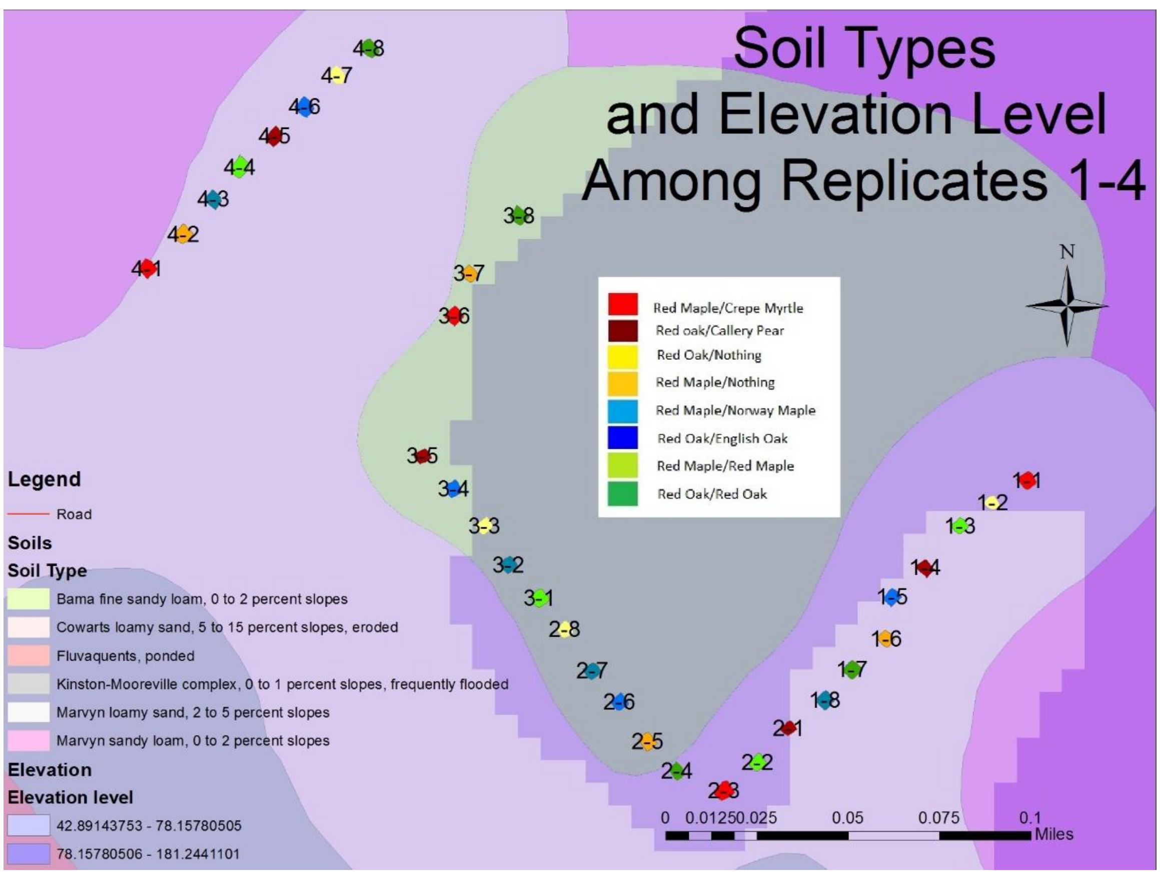

Image 2.4: Soil and elevation levels among replicates

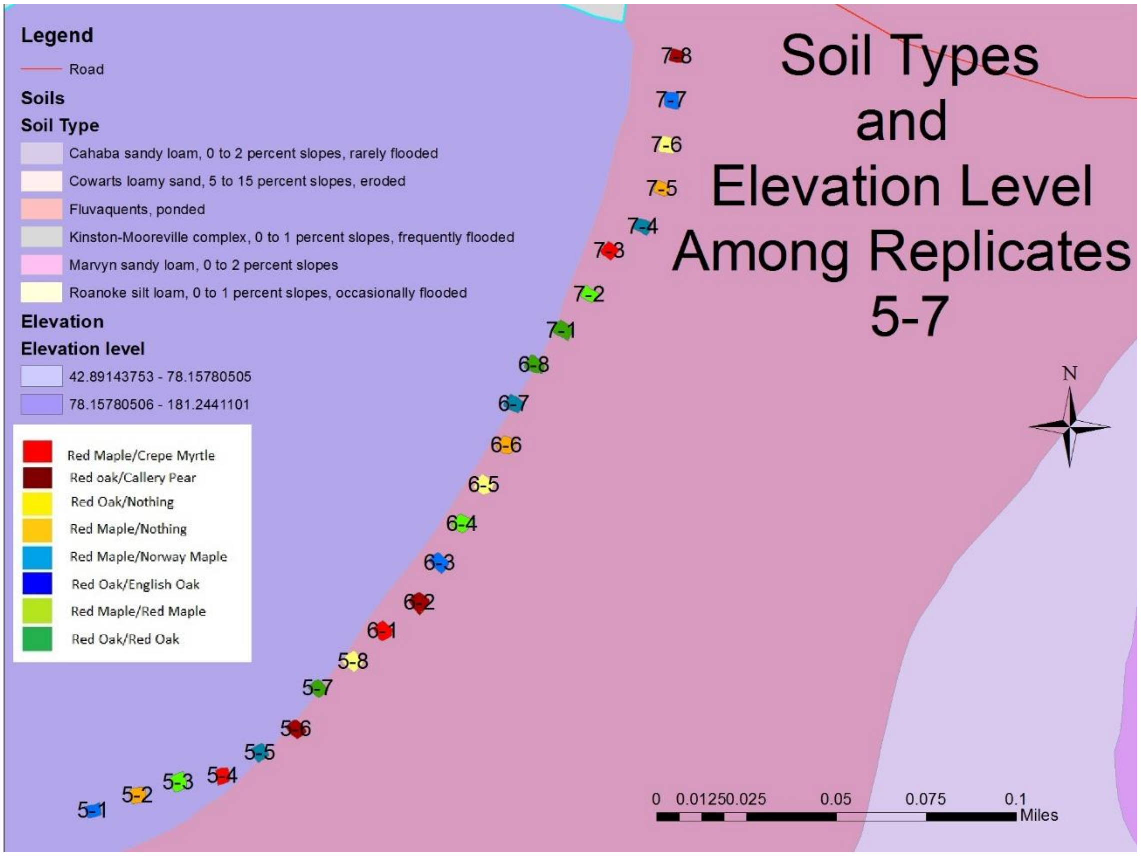

Image 2.5: Soil and elevation levels for replicates 5-7

Part 3: Caterpillars

Part 3.1 Family Geometridae

Image 3.11: *Ennomos magnaria* (Guenée, 1858) – Maple spanworm moth (Family Geometridae)

Image 3.12: *Iridopsis ephyraria* (Walker, 1860) – Pale-winged grey moth (Family Geometridae)

Part 3.2 Family Limacodidae

Image 3.21: *Acharia stimulea* (Clemens, 1860) – Saddleback caterpillar (Family Limacodidae)

Part 3.3 Family Lymantriidae

Image 3.31: *Orgyia leucostigma* (Smith, 1797) – white-marked tussock moth caterpillar (Family Lymantriidae)

Image 3.32: *Orgyia leucostigma* adult female (wingless) with eggmass

Part 3.4 Family Noctuidae

Image 3.41: *Acronicta americana* (Harris, 1841) – American dagger moth caterpillar (Family Noctuidae)

Image 3.42: *Hypena baltimoralis* (Guenée, 1854) – Baltimore bomolocha moth (Family Noctuidae) – freshly molted

Image 3.43: *Hypena baltimoralis* (Guenée, 1854) – Baltimore bomolocha moth (Family Noctuidae) – normal color

Image 3.44: *Morrisonia confusa* (Hübner, 1831) – Confused woodgrain moth (Family Noctuidae) – 3rd/4th instar

Image 3.45: *Morrisonia confusa* (Hübner, 1831) – Confused woodgrain moth (Family Noctuidae) – 5th instar

Image 3.46: *Palthis angulalis* (Hübner, 1796) – Dark-spotted palthis moth (Family Noctuidae)

Image 3.47: *Parallelia bistriaris* (Hübner, 1818) – Maple looper moth (Family Noctuidae) – 3rd/4th instar

Image 3.48: *Parallelia bistriaris* (Hübner, 1818) – Maple looper moth (Family Noctuidae) – typical pinkish 5th instar

Image 3.49: *Parallelia bistriaris* (Hübner, 1818) – Maple looper moth (Family Noctuidae) – 5th instar dark morph

Image 3.410: *Spodoptera ornithogallii* (Guenée, 1852) – Yellow-striped armyworm (Family Noctuidae)

Image 3.411: *Spodoptera ornithogallii* (Guenée, 1852) – Yellow-striped armyworm (Family Noctuidae) – Adult

Image 3.412: Mystery emergence, possibly *Spodoptera ornithogallii*

Part 3.5 Family Notodontidae

Image 3.51: *Schizura ipomoeae* (Doubleday, 1841) – Morning-glory prominent (Family Notodontidae)

Image 3.52: *Heterocampa guttivatta* (Walker, 1855) – Saddled prominent (Family Notodontidae)

Part 3.6 Family Psychidae

Image 3.61: *Thyridopteryx ephemeraeformis* (Haworth, 1803) – Evergreen bagworm (Family Psychidae) – larva

Image 3.62: *Thyridopteryx ephemeraeformis* (Haworth, 1803) – Evergreen bagworm (Family Psychidae) – pupa

Part 3.7 Family Saturniidae

Image 3.71: *Dryocampa rubicunda* egg clutch

Image 3.72: *Dryocampa rubicunda* hatching

Image 3.73: *Dryocampa rubicunda* (Fabricius, 1793) – Rosy maple moth/greenstriped mapleworm 2nd/3rd instar caterpillar (Family Saturniidae).

Image 3.74: *Dryocampa rubicunda* (Fabricius, 1793) 5th instar (Family Saturniidae)

Image 3.75: *Dryocampa rubicunda* (Fabricius, 1793) 5th instar (Family Saturniidae)

Image 3.76: *Dryocampa rubicunda* (Fabricius, 1793) adult moth (Family Saturniidae)

Image 3.77: *Dryocampa rubicunda* being eaten by *Polistes* wasp

Image 3.78: Defoliated maple tree after *Dryocampa rubicunda* attack

Image 3.79: *Antheraea polyphemus* (Cramer, 1776) – Giant polyphemus moth caterpillar (Family Saturniidae)

Part 3.7 Family Tortricidae

Image 3.71: *Choristoneura rosaceana* (Harris, 1841) – Oblique-banded leaf roller (Family Tortricidae)

Image 3.72: *Episimus tyrius* (Heinrich, 1923) – Maple tip-borer moth (Family Tortricidae) – leaf tie

Image 3.73: *Episimus tyrius* (Heinrich, 1923) – Maple tip-borer moth (Family Tortricidae)

Image 4.1: *Stagmomantis carolina* (Johansson, 1763) – Carolina mantis on maple

Image 4.2: *Stagmomantis carolina* (Johansson, 1763) – Carolina mantis on crepe myrtle

Image 4.3: predacious syrphid fly larva

Image 4.4: *Coccinella septempunctata* (Linnaeus, 1758) – Seven-spotted lady beetle

Image 4.4: *Harmonia axyridis* (Pallas, 1773) – Multicolored Asian lady beetle larva

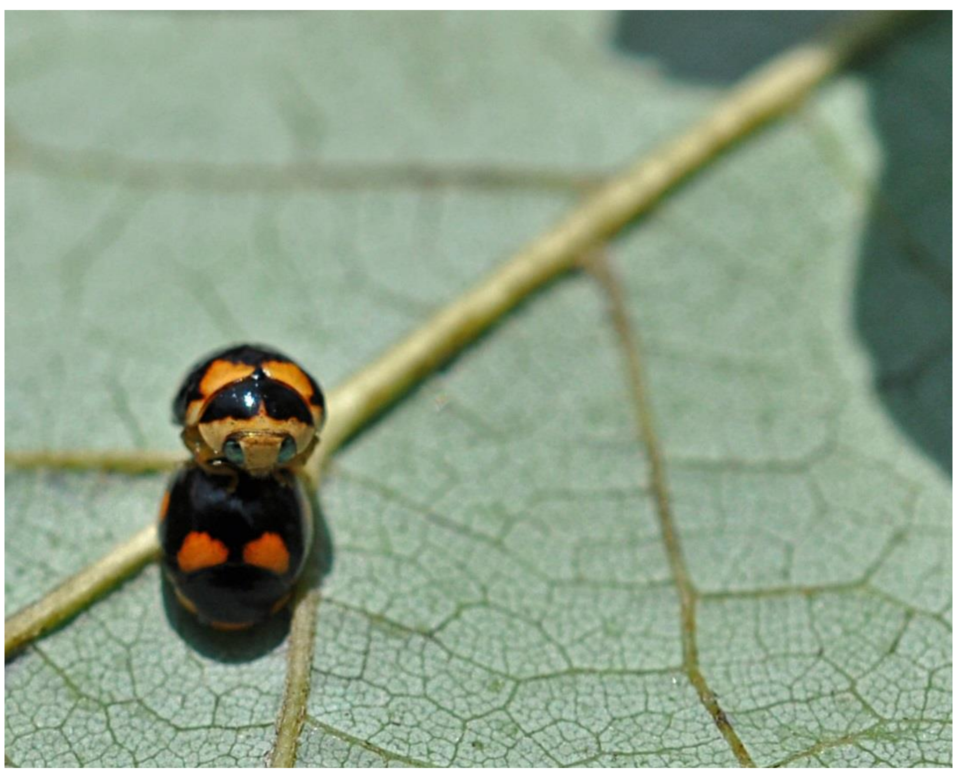

Image 4.5: *Brachiacantha ursina* (Fabricius, 1787) – Orange-spotted lady beetle

Image 4.6: *Anolis carolinensis* (Voigt, 1832) – Green anole

Image 4.7: Ichneumonid wasp on maple

Image 4.8: Ichneumonid wasp on crepe myrtle

Image 4.9: Potter wasp nest (Vespidae: Eumeninae)

Image 4.10: Spider leaf tier (Thomisidae)

Image 4.11: Spider leaf tier (Araneidae)

Image 4.11: *Tinocallis kahawaluokalani* (Kirkaldy) – Crepe myrtle aphid

Image 4.12: *Homalodisca vitripennis* (Germar, 1821) – glassy-winged sharpshooter

Part 5: Parasitoids Collected in Pan Traps

Image 5.1: Scelionidae

Image 5.2: Trichogrammatidae

Image 5.3: Aphelinidae

Image 5.4: Mymaridae

Image 5.5: Encyrtidae

Image 5.6: Ceraphronidae

Image 5.7: Braconidae

Image 5.8: Chalcididae

Image 5.9: Ichneumonidae

Image 5.10: Sarcophagidae (Diptera)

Image 5.11: Tachinidae (Diptera)

Supplementary Material for Chapter 2

Part 1: Eruciform Host Records for Selected Host Plants

Note: Diet breadth for each eruciform species is located at the bottom after the host records. Yellow highlighted species are non-native insects, and species that are listed in red font are sawflies (Hymenoptera: Symphyta). All other species are Lepidopterans. Data sources: Ferguson 1975, Johnson and Lyon 1991, Robinson et al. 2013

Acer – Order Sapindales, Family Aceraceae

Native Maple: *Acer saccharinum* (Silver Maple): Arctiidae: *Halysidota tessellaris* - Banded Tussock Moth, *Hyphantria cunea* – Fall Webworm Moth, *Lophocampa caryae*; **Geometridae:** *Alsophila pometaria, Ennomos magnaria, Ennomos subsignaria, Erannis tiliaria, Lambdina fervidaria* – Curve-lined Looper Moth, *Lambdina fiscellaria, Macaria aemulataria* – Common Angle Moth, *Paleacrita vernata, Speranza pustularia* - Lesser Maple Spanworm; **Gracillariidae:** *Caloptilia packardella, Cameraria aceriella, Cameraria saccharella, Phyllonorycter lucidicostella* – Lesser Maple Leaf Blotch Miner Moth, *Phyllonorycter trinotella*; **Lasiocampidae:** *Malacosoma americana*; **Lymantriidae:** *Dasychira vagans* – Variable Tussock Moth, *Leucoma salicis* – Satin Moth, *Lymantria dispar*, *Orgyia leucostigma*; **Noctuidae:** *Acronicta americana, Acronicta oblinita* – Smeared Dagger Moth, *Euxoa messoria* – Reaper Dart Moth, *Hypena baltimoralis, Lithophane antennata, Lithophane bethunei, Lithophane grotei, Lithophane laticinerea, Morrisonia confusa, Morrisonia latex, Orthosia hibisci, Papaipema nebris* – Stalk Borer Moth, *Parallelia bistriaris, Peridroma saucia* – Variegated Cutworm Moth, *Spaelotis clandestina* – Clandestine Dart Moth, *Sunira bicolorago;* **Notodontidae:** *Heterocampa biundata, Heterocampa guttivitta, Schizura ipomoeae*; **Oecophoridae:** *Machimia tentoriferella;* **Pantheidae:** *Colocasia flavicornis, Colocasia propinquilinea* – Closebanded Yellowhorn Moth; **Psychidae:** *Thyridopteryx ephemeraeformis;* **Saturniidae:** *Antheraea polyphemus, Automeris io, Dryocampa rubicunda, Eacles imperialis, Hyalophora cecropia*; **Sesiidae:** *Synanthedon acerni;* **Tortricidae:** *Cenopis pettitana, Episimus tyrius, Proteoteras aesculana, Proteoteras moffatiana*

Native Maple: *Acer saccharum* (Sugar Maple): Arctiidae: *Halysidota tessellaris, Haploa lecontei, Hyphantria cunea, Lophocampa caryae, Lophocampa maculata* – Spotted Tussock Moth, *Pyrrharctia isabella, Spilosoma virginica*; **Gelechiidae:** *Dichomeris ligulella*; **Geometridae:** *Alsophila pometaria, Besma endropiaria, Besma quercivoraria, Campaea perlata, Ennomos magnaria, Ennomos subsignaria, Erannis tiliaria, Eutrapela clemataria, Hypagyrtis unipunctata, Iridopsis ephyraria, Lambdina fiscellaria, Ligdia wagneri, Lomographa vestaliata, Lytrosis unitaria, Melanolophia canadaria, Nemoria mimosaria, Paleacrita vernata, Phigalia titea, Plagodis alcoolaria, Plagodis serinaria, Probole amicaria, Protoboarmia porcelaria, Speranza pustularia, Tetracis cachexiata*; **Gracillariidae:** *Caloptilia umbratella, Cameraria aceriella, Cameraria saccharella, Phyllonorycter lucidicostella*; **Incurvariidae:** *Paraclemensia acerifoliella*; **Lasiocampidae:** *Malacosoma americana, Malacosoma disstria*; **Limacodidae:** *Euclea delphinii, Phobetron pithecium, Prolimacodes badia, Tortricidia flexuosa, Tortricidia pallida* – Red-crossed Button Slug Moth; **Lymantriidae:** *Dasychira dorsipennata, Dasychira obliquata, Dasychira plagiata, Lymantria dispar, Orgyia antiqua, Orgyia leucostigma*; **Nepticulidae:** *Trifurcula* *saccharella*; **Noctuidae:** *Acronicta americana, Acronicta dactylina* – Fingered Dagger Moth, *Acronicta retardata, Amphipyra pyramidoides, Crocigrapha normani, Hypena baltimoralis, Lithophane antennata, Lithophane bethunei, Lithophane innominate, Lithophane laticinerea, Morrisonia confusa, Morrisonia latex, Orthosia garmani, Orthosia revicta, Palthis angulalis* – Dark-spotted Palthis Moth, *Parallelia bistriaris, Heterocampa biundata, Heterocampa guttivitta, Macrurocampa marthesia, Nadata gibbosa, Peridea basitriens, Peridea ferruginea* – Chocolate Prominent Moth, *Schizura concinna, Schizura ipomoeae, Schizura unicornis, Symmerista canicosta, Symmerista leucitys*; **Oecophoridae:** *Antaeotricha leucillana, Machimia tentoriferella*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Pococera asperatella*; **Saturniidae:** *Actias luna, Antheraea polyphemus, Dryocampa rubicunda, Eacles imperialis, Hyalophora cecropia*; **Sessiidae:** *Synanthedon acerni, Synanthedon acerrubri*; **Tortricidae:** *Acleris chalybeana, Archips cerasivorana, Catastega aceriella, Cenopis niveana* – Aproned Cenopis Moth, *Cenopis pettitana, Choristoneura fractivittana, Choristoneura rosaceana, Olethreutes appendiceum, Olethreutes glaciana, Olethreutes nigranum* – Variable Nigranum Moth, *Pandemis lamprosana, Pandemis limitata, Proteoteras aesculana, Proteoteras moffatiana*

Native Maple: *Acer rubrum* (Red Maple): Arctiidae: *Halysidota tessellaris* - Banded Tussock Moth, *Hyphantria cunea* – Fall Webworm Moth, *Lophocampa caryae* – Hickory Tussock Moth, *Lophocampa maculata* – Spotted Tussock Moth, *Spilosoma virginica* – Virginian Tiger Moth; **Geometridae:** *Alsophila pometaria* – Fall Cankerworm Moth, *Anavitrinella pampinaria* – Common Gray Moth, *Besma endropiaria* – Straw Besma Moth, *Biston betularia* – Peppered Moth, *Campaea perlata* – Pale Beauty Moth, *Ectropis crepuscularia* – Small Engrailed Moth, *Ennomos magnaria* – Maple Spanworm Moth, *Ennomos subsignaria* – Elm Spanworm Moth, *Erannis tiliaria* – Linden Looper Moth, *Eutrapela clemataria* – Curve-toothed Geometer Moth, *Hypagyrtis unipunctata* – One-spotted Variant Moth, *Iridopsis ephyraria* – Pale-winged Gray Moth, *Lambdina fiscellaria* – Hemlock Looper Moth, *Macaria aemulataria* – Common Angle Moth, *Macaria notata* – Birch Angle Moth, *Melanolophia canadaria* – Canadian Melanolophia Moth, *Melanolophia signataria* – Signate Melanolophia Moth, *Metanema determinata* – Dark Metanema Moth, *Nematocampa resistaria* – Horned Spanworm Moth, *Paleacrita vernata* – Spring Cankerworm Moth, *Phigalia titea* – Half-wing Moth, *Plagodis alcoolaria* – Hollow-spotted Plagodis Moth, *Plagodis serinaria* – Lemon Plagodis Moth, *Probole alienaria* – Alien Probole Moth, *Probole amicaria* – Friendly Probole Moth, *Prochoerodes lineola* – Large Maple Spanworm Moth, *Protoboarmia porcelaria* – Porcelain Gray Moth, *Selenia alciphearia* – Northern Selenia Moth, *Selenia kentaria* – Kent's Geometer Moth, *Speranza pustularia* – Lesser Maple Spanworm Moth, *Tetracis cachexiata* – White Slant-Line Moth, *Xanthotype sospeta* – Crocus Geometer Moth; **Gracillariidae:** *Caloptilia bimaculatella, Caloptilia umbratella, Cameraria aceriella* – Maple Leaf Blotch Miner Moth, *Cameraria saccharella, Phyllonorycter trinotella;* **Incurvariidae:** *Paraclemensia acerifoliella* – Maple Leafcutter Moth; **Lasiocampidae:** *Malacosoma americana* – Eastern Tent Caterpillar Moth; **Limacodidae:** *Lithacodes fasciola* – Yellow-shouldered Slug Moth; **Lymantriidae:** *Dasychira plagiata* – Northern Pine Tussock Moth, *Lymantria dispar* – Gypsy Moth, *Orgyia antiqua* – Rusty Tussock Moth, *Orgyia definita* – Definite Tussock Moth, *Orgyia leucostigma* – White-marked Tussock Moth; **Megalopygidae:** *Megalopyge crispata* - Black-waved Flannel Moth; **Noctuidae:** *Acronicta americana* – American Dagger Moth, *Acronicta retardata* – Retarded Dagger Moth, *Amphipyra pyramidoides* – Copper Underwing Moth, *Catocala cerogama* – Yellow-banded Underwing Moth, *Crocigrapha normani* – Norman's Quaker Moth, *Eupsilia sidus* – Sidus Sallow

Moth, *Eupsilia tristigmata* – Three-Spotted Sallow Moth, *Hypena baltimoralis* – Baltimore Bomolocha Moth, *Lithophane bethunei* – Bethune's Pinion Moth, *Lithophane grotei* – Grote's Pinion Moth, *Lithophane innominata* – Nameless Pinion Moth, *Lithophane laticinerea, Lithophane petulca* – Wanton Pinion Moth, *Morrisonia confusa* – Confused Woodgrain Moth, *Morrisonia latex* – Fluid Arches Moth, *Orthosia revicta* – Subdued Quaker Moth, *Parallelia bistriaris* – Maple Looper Moth, *Phlogophora periculosa* – Brown Angle Shades Moth, *Zale galbanata* – Maple Zale Moth, *Zale minerea* – Colorful Zale Moth; **Notodontidae:** *Datana ministra* – Yellow-necked Caterpillar Moth, *Heterocampa biundata* – Wavy-Lined Heterocampa Moth, *Heterocampa guttivitta* – Saddled Prominent Moth, *Nadata gibbosa* – White-dotted Prominent Moth, *Schizura ipomoeae* – Morning-glory Prominent Moth, *Symmerista leucitys* – Orange-humped Mapleworm Moth; **Oecophoridae:** *Antaeotricha leucillana* – Pale Gray Bird-dropping Moth, *Machimia tentoriferella* – Gold-striped Leaftier Moth; **Pantheidae:** *Colocasia flavicornis* – Yellowhorn Moth; **Psychidae:** *Thyridopteryx ephemeraeformis* – Evergreen Bagworm Moth; **Pyralidae:** *Herpetogramma pertextalis* – Bold-feathered Grass Moth, *Oreana unicolorella*, *Pococera asperatella* – Maple Webworm Moth; **Saturniidae:** *Actias luna* – Luna Moth, *Antheraea polyphemus* – Polyphemus Moth, *Automeris io* – Io Moth, *Dryocampa rubicunda* – Rosy Maple Moth, *Eacles imperialis* – Imperial Moth, *Hyalophora cecropia* – Cecropia Moth; **Sesiidae:** *Synanthedon acerni* – Maple Callus Borer Moth, *Synanthedon acerrubri* – Maple Clearwing Moth; **Tortricidae:** *Acleris chalybeana* – Lesser Maple Leafroller Moth, *Archips argyrospila* – Fruit-tree Leafroller Moth, *Catastega aceriella* – Maple Trumpet Skeletonizer Moth, *Cenopis pettitana* – Maple-basswood Leafroller Moth, *Choristoneura fractivittana* – Broken-banded Leafroller Moth, *Choristoneura parallela* – Parellel-banded Leafroller Moth, *Choristoneura rosaceana* – Oblique-banded Leafroller Moth, *Episimus tyrius* – Maple Tip Borer Moth, *Olethreutes appendiceum* – Serviceberry Leafroller Moth, *Orthotaenia undulana* – Dusky Leafroller Moth, *Pandemis lamprosana* – Woodgrain Leafroller Moth, *Proteoteras aesculana* – Maple Twig Borer Moth, *Proteoteras moffatiana* – Maple Bud Borer Moth, *Proteoteras willingana* – Eastern Boxelder Twig Borer Moth

Nonnative Maple: *Acer palmatum* (Japanese Maple):

Nonnative Maple: *Acer platanoides* (Norway Maple): Geometridae: *Speranza pustularia* – Lesser Maple Spanworm Moth; **Gracillariidae:** *Caloptilia packardella*, *Phyllonorycter trinotella*; **Limacodidae:** *Isa textula* – Crowned Slug Moth; **Lymantriidae:** *Lymantria dispar* – Gypsy Moth, *Orgyia leucostigma* – White-marked Tussock Moth; **Noctuidae:** *Acronicta americana* – American Dagger Moth; **Psychidae:** *Thyridopteryx ephemeraeformis* – Evergreen Bagworm Moth; **Saturniidae:** *Automeris io* – Io Moth, *Hyalophora cecropia* – Cecropia Moth; **Tortricidae:** *Proteoteras aesculana* – Maple Twig Borer Moth

Betula – Order Fagales, Family Betulaceae

Native Birch: *Betula nigra* (River Birch): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Bucculatricidae:** *Bucculatrix coronatella*; **Gelechiidae:** *Pseudotelphusa betulella*; **Geometridae:** *Ennomos magnaria, Nemoria bistriaria* – Red-fringed Emerald Moth*;* **Lasiocampidae:** *Malacosoma americana;* **Limacodidae:** *Phobetron pithecium* – Hag [Monkey Slug] Moth; **Lymantriidae:** *Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Morrisonia latex, Acronicta betulae* – Birch

Dagger Moth*;* **Notodontidae:** *Datana ministra*; **Pyralidae:** *Acrobasis betulivorella*; **Saturniidae:** *Antheraea polyphemus, Hyalophora cecropia*

Native Birch: *Betula lenta* (Sweet Birch): Drepanidae: *Habrosyne scripta* – Lettered Habrosyne Moth; **Geometridae:** *Biston betularia, Plagodis pulveraria* – American Barred Umber Moth; **Gracillariidae:** *Cameraria lentella*; **Lasiocampidae:** *Phyllodesma americana*; **Lymantriidae:** *Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Morrisonia confusa, Morrisonia latex, Polia imbrifera* – Cloudy Arches Moth, *Pyreferra pettiti*; **Notodontidae:** *Lochmaeus manteo* – Variable Oakleaf Caterpillar Moth; **Nymphalidae:** *Limenitis arthemis* - Red-spotted Purple, *Polygonia faunus*; **Papilionidae:** *Papilio glaucus*; **Saturniidae:** *Antheraea polyphemus, Hyalophora cecropia*; **Tenthredinidae:** *Croesus latitarsus* - Dusky Birch Sawfly

Nonnative Birch: *Betula pendula* (European White Birch): Saturniidae: *Actias luna* – Luna Moth, *Antheraea polyphemus* – Polyphemus Moth, *Hyalophora cecropia* – Cecropia Moth,

Nonnative Birch: *Betula platyphylla* (Japanese White Birch): NONE

Castanea – Order Fagales, Family Fagaceae

Native Chestnut: *Castanea dentata* (American Chestnut): Arctiidae: *Halysidota tessellaris, Hyphantria cunea, Lophocampa caryae, Spilosoma virginica*; **Coleophoridae:** *Coleophora leucochrysella*; **Eriocraniidae:** *Dyseriocrania griseocapitella* – Chinquapin Leaf-miner Moth; **Gelechiidae:** *Dichomeris ligulella, Dichomeris ventrella*; **Geometridae:** *Alsophila pometaria, Besma endropiaria, Biston betularia, Ennomos magnaria, Ennomos subsignaria, Euchlaena obtusaria, Eutrapela clemataria, Nematocampa resistaria* – Horned Spanworm Moth, *Paleacrita vernata, Plagodis alcoolaria, Pleuroprucha insulsaria* – Common Tan Wave Moth, *Probole amicaria, Tetracis crocallata* – Yellow Slant-line Moth; **Gracillariidae:** *Cameraria bethunella*; **Hesperiidae:** *Erynnis brizo* - Sleepy Duskywing; **Limacodidae:** *Natada nasoni* – Nason's Slug Moth, *Packardia elegans* – Elegant Tailed Slug Moth, *Prolimacodes badia*; **Lycaenidae:** *Satyrium calanus, Satyrium caryaevorum, Satyrium liparops*; **Lymantriidae:** *Dasychira dorsipennata, Dasychira meridionalis, Lymantria dispar, Orgyia leucostigma*; **Nepticulidae:** *Stigmella castaneaefoliella, Stigmella latifasciella*; **Noctuidae:** *Acronicta americana, Acronicta hamamelis* – Witch Hazel Dagger Moth, *Acronicta hastulifera* – Frosted Dagger Moth, *Acronicta lithospila, Acronicta ovata* – Ovate Dagger Moth, *Amphipyra pyramidoides, Catocala palaeogama* – Oldwife Underwing Moth, *Scolecocampa liburna* – Deadwood Borer Moth; **Notodontidae:** *Datana contracta* – Contracted Datana Moth, *Datana ministra, Heterocampa guttivitta, Macrurocampa marthesia* – Mottled Prominent Moth, *Schizura concinna, Schizura leptinoides, Symmerista albifrons*; **Oecophoridae:** *Machimia tentoriferella, Psilocorsis cryptolechiella, Psilocorsis quercicella*; **Pantheidae:** *Colocasia propinquilinea*; **Psychidae:** *Astala confederata, Thyridopteryx ephemeraeformis*; **Saturniidae:** *Actias luna, Anisota senatoria, Anisota stigma, Anisota virginiensis, Antheraea polyphemus, Eacles imperialis*; **Sesiidae:** *Paranthrene simulans, Synanthedon castaneae* – Chestnut Borer Moth; **Tortricidae:** *Amorbia humerosana* – White-line Leafroller Moth, *Cydia latiferreana* – Filbertworm Moth; **Yponomeutidae:** *Swammerdamia caesiella*

Native Chestnut: *Castanea pumila* (American Chinquapin): Arctiidae: *Grammia phyllira* – Phyllira Tiger Moth, *Hyphantria cunea*; **Gracillariidae:** *Neurobathra strigifinitella*; **Lymantriidae:** *Orgyia leucostigma*; **Noctuidae:** *Spragueia onagrus* – Black-dotted Spragueia Moth; **Notodontidae:**

Datana ministra; **Saturniidae:** *Anisota senatoria, Anisota stigma, Antheraea polyphemus, Eacles imperialis*; **Tortricidae:** *Ancylis burgessiana*

Nonnative Chestnut: *Castanea sativa* (European Chestnut): Coleophoridae: *Coleophora leucochrysella*; **Cossidae:** *Prionoxystus robiniae*; **Geometridae:** *Biston betularia*; **Gracillariidae:** *Neurobathra strigifinitella*; **Limacodidae:** *Isa textula, Parasa indetermina, Phobetron pithecium, Prolimacodes badia*; **Nepticulidae:** *Stigmella castaneaefoliella*; **Noctuidae:** *Acronicta americana*, *Acronicta lithospila*; **Notodontidae:** *Datana contracta, Datana ministra, Nadata gibbosa*; **Oecophoridae:** *Menesta tortriciformella, Psilocorsis cryptolechiella*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Cadra figulilella, Ectomyelois ceratoniae, Etiella zinckenella* – Gold-banded Etiella Moth, *Plodia interpunctella*; **Saturniidae:** *Actias luna, Anisota peigleri, Anisota senatoria, Anisota stigma, Anisota virginiensis, Antheraea polyphemus, Eacles imperialis*; **Sesiidae:** *Synanthedon scitula*; **Sphingidae:** *Amorpha juglandis*; **Tischeriidae:** *Coptotriche castaneaeella, Tischeria quercitella* – Oak Blotch Miner Moth; **Tortricidae:** *Ancylis burgessiana, Pseudexentera haracana, Pseudexentera spoliana* – Bare-patched Leafroller Moth

Nonnative Chestnut: *Castanea mollissima* (Chinese Chestnut): Noctuidae: *Morrisonia confusa*; **Saturniidae:** *Anisota stigma, Antheraea polyphemus, Hyalophora cecropia*

Cercis – Order Fabales, Family Fabaceae

Native Redbud: *Cercis Canadensis* (Eastern Redbud): Arctiidae: *Hyphantria cunea, Lophocampa maculata*; **Gelechiidae:** *Fascista cercerisella* – Redbud Leaffolder Moth; **Lasiocampidae:** *Malacosoma americana*; **Limacodidae:** *Parasa indetermina*; **Lycaenidae:** *Incisalia henrici*; **Lymantriidae:** *Orgyia leucostigma*; **Megalopygidae:** *Norape ovina* – White Flannel Moth; **Noctuidae:** *Acronicta americana, Amphipyra pyramidoides, Lithophane antennata*; **Notodontidae:** *Oligocentria semirufescens, Schizura concinna, Schizura ipomoeae*; **Papilionidae:** *Papilio troilus*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Desmia funeralis* – Grape Leaffolder Moth; **Saturniidae:** *Automeris io*; **Tortricidae:** *Archips argyrospila*

Cornus – Order Cornales, Family Cornaceae

Native Dogwood: *Cornus florida* (Flowering Dogwood): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Drepanidae:** *Eudeilinia herminiata* – Northern Eudeilinea Moth, *Euthyatira pudens* – Dogwood Thyatirid Moth; **Geometridae:** *Eutrapela clemataria, Probole amicaria, Xanthotype urticaria* – False Crocus Geometer Moth; **Heliozelidae:** *Antispila cornifoliella*; **Lasiocampidae:** *Malacosoma americana*; **Limacodidae:** *Parasa indetermina*; **Lycaenidae:** *Celastrina argiolus*; **Lymantriidae:** *Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Catocala ultronia, Morrisonia confusa*; **Notodontidae:** *Heterocampa biundata, Schizura concinna, Schizura unicornis* – Unicorn Caterpillar Moth; **Saturniidae:** *Automeris io, Hyalophora cecropia, Samia cynthia*; **Sesiidae:** *Synanthedon scitula, Synanthedon geliformis* – Pecan Bark Borer Moth; **Tortricidae:** *Choristoneura rosaceana, Epinotia lindana* – Diamondback Epinotia Moth

Nonnative Dogwood: *Cornus angustata* (Chinese Evergreen Dogwood): NONE

Nonnative Dogwood: *Cornus kousa* (Korean Dogwood): NONE

Fagus – Order Fagales, Family Fagaceae

Native Beech: *Fagus grandifolia* (American Beech): Arctiidae: *Halysidota tessellaris, Hyphantria cunea, Lophocampa caryae, Lophocampa maculata* – Spotted Tussock Moth; **Geometridae:** *Alsophila pometaria, Ennomos magnaria, Ennomos subsignaria, Lambdina fiscellaria, Melanolophia canadaria, Phigalia titea, Plagodis serinaria*; **Gracilariidae:** *Neurobathra strigifinitella*; **Incurvariidae:** *Paraclemensia acerifoliella*; **Lasiocampidae:** *Malacosoma americana*; **Limacodidae:** *Apoda y-inversum* – Yellow-collared Slug Moth, *Euclea delphinii, Lithacodes fasciola, Packardia elegans, Prolimacodes badia, Tortricidia pallida*; **Lycaenidae:** *Erora laeta*; **Lymantriidae:** *Dasychira dorsipennata, Dasychira obliquata*, *Lymantria dispar, Orgyia antiqua, Orgyia leucostigma*; **Noctuidae:** *Acronicta americana, Acronicta clarescens, Acronicta impressa, Acronicta ovata, Acronicta tristis, Crocigrapha normani, Lithophane bethunei, Morrisonia latex, Orthosia hibisci, Orthosia revicta, Panopoda rufimargo*; **Notodontidae:** *Dasylophia thyatiroides* – Gray-patched Prominent Moth, *Datana integerrima* – Walnut Caterpillar Moth, *Datana ministra, Heterocampa guttivitta, Lochmaeus manteo, Macrurocampa marthesia, Nadata gibbosa, Oligocentria semirufescens, Schizura ipomoeae, Schizura leptinoides, Schizura unicornis, Symmerista albifrons, Symmerista canicosta, Symmerista leucitys*; **Nymphalidae:** *Limenitis arthemis, nymphalis vaualbum*; **Oecophoridae:** *Machimia tentoriferella, Psilocorsis cryptolechiella, Psilocorsis quercicella*; **Pantheidae***: Charadra deridens, Colocasia flavicornis, Colocasia propinquilinea*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Pococera asperatella*; **Saturniidae:** *Actias luna, Anisota virginiensis, Antheraea polyphemus, Automeris io, Dryocampa rubicunda, Eacles imperialis, Hyalophora cecropia*; **Sphingidae:** *Amorpha juglandis*; **Tortricidae:** *Acleris chalybeana, Catastega aceriella, Cenopis pettitana, Choristoneura conflictana, Choristoneura fractivittana, Choristoneura fumiferana* – Spruce Budworm Moth, *Clepsis persicana* – White-triangle Tortrix Moth, *Olethreutes appendiceum, Olethreutes fagigemmeana, Pandemis lamprosana, Spilonota ocellana* – Eye-spotted Bud Moth

Ginkgo – Order Ginkgoales, Family Ginkgoaceae

Nonnative Ginkgo: *Ginkgo biloba* (Ginkgo Tree): Geometridae: *Biston betularia*; **Pyralidae:** *Euzophera semifuneralis*; **Saturniidae:** *Hyalophora cecropia*; **Tortricidae:** *Platynota stultana*

Ilex – Order Aquifoliales, Family Aquifoliaceae

Native Holly: *Ilex opaca* (American Holly): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Lycaenidae:** *Celastrina argiolus, Incisalia henrici, Satyrium liparops*; **Lymantriidae:** *Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Metaxaglaea violacea* – Holly Sallow Moth, **Notodontidae:** *Schizura unicornis*; **Saturniidae:** *Samia cynthia*

Nonnative Holly: *Ilex aquifolium* (English Holly): Tortricidae: *Choristoneura rosaceana* – Oblique-banded Leafroller Moth, *Rhopobota naevana* – Holly Tortrix Moth

Juniperus – Order Pinales, Family Cupressaceae

Native Juniper: *Juniperus virginiana* (Eastern Redcedar): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Cosmopterigidae:** *Periploca nigra*; **Gelechiidae:** *Coleotechnites albicostata* – White-edged Coleotechnites Moth, *Coleotechnites australis*, *Coleotechnites obliquistrigella*, *Dichomeris marginella* – Juniper Webworm Moth; **Geometridae:** *Digrammia continuata* – Curve-lined Angle Moth, *Eupithecia miserulata, Patalene olyzonaria* – Juniper Geometer Moth; **Lycaenidae:** *Callophrys gryneus* - Juniper Hairstreak, *Callophrys hesseli* - Hessel's Hairstreak, *Callophrys niphon* - Eastern Pine Elfin; **Lymantriidae:** *Lymantria dispar, Orgyia leucostigma*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Saturniidae:** *Eacles imperialis, Hyalophora cecropia*; **Tortricidae:** *Cudonigera houstonana* – Juniper Budworm Moth; **Yponomeutidae:** *Argyresthia freyella*

Nonnative Juniper: *Juniperus chinensis* – Chinese Juniper: Gelechiidae: *Dichomeris marginella* – Juniper Webworm Moth; **Geometridae:** *Digrammia continuata* – Curve-lined Angle Moth; **Saturniidae:** *Eacles imperialis*

Lagerstroemia – Order Myrtales, Family Lythraceae

Nonnative Crepe Myrtle: *Lagerstroemia indica*: Cosmopterigidae: *Pyroderces badia* – Florida Pink Scavenger Moth; **Psychidae:** *Oiketicus abbotii* – Abbot's Bagworm Moth; **Pyralidae:** *Uresiphita reversalis* – Genista Broom Moth; **Sphingidae:** *Manduca rustica* – Rustic Sphinx Moth

Ligustrum – Order Lamiales, Family Oleaceae

Nonnative Privet: *Ligustrum vulgare* (European Privet): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Crambidae:** *Palpita quadristigmalis* – Four-spotted Palpita Moth; **Geometridae:** *Paleacrita vernata*; **Lymantriidae:** *Orgyia leucostigma*; **Nymphalidae:** *Vanessa annabella* – West Coast Lady; **Saturniidae:** *Hyalophora cecropia*; **Sphingidae:** *Ceratomia undulosa* – Waved Sphinx Moth, *Manduca rustica, Sphinx chersis*

Nonnative Privet: *Ligustrum japonicum* (Japanese Privet): NONE

Nonnative Privet: *Ligustrum ovalifolium* (Oval-leaved Privet): Nymphalidae: *Vanessa annabella*; **Saturniidae:** *Automeris io, Samia cynthia*; **Sphingidae:** *Sphinx chersis*, *Sphinx franckii* – Franck's Sphinx Moth

Nonnative Privet: *Ligustrum lucidum* (Glossy Privet): NONE

Liquidambar – Order Saxifragales, Family Altingiaceae

Native Sweetgum: *Liquidambar styraciflua* (American Sweetgum): Arctiidae: *Halysidota tessellaris, Hyphantria cunea*; **Geometridae:** *Ceratonyx satanaria, Ennomos magnaria, Nemoria elfa* – Cypress Emerald Moth, *Nemoria saturiba*; **Gracillariidae:** *Phyllocnistis liquidambarisella*; **Lasiocampidae:** *Malacosoma americana, Malacosoma disstria*; **Lycaenidae:** *Satyrium kingi, Satyrium liparops*; **Lymantriidae:** *Dasychira atrivenosa, Dasychira leucophaea, Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Amphipyra pyramidoides, Paectes abrostoloides* – Large Paectes Moth, *Paectes pygmaea* – Pygmy Paectes Moth; **Notodontidae:** *Gluphisia septentrionis, Schizura concinna*; **Psychidae:** *Oiketicus abbotii, Thyridopteryx ephemeraeformis*; **Pyralidae:** *Euzophera semifuneralis, Sciota uvinella* – Sweetgum Leafroller Moth; **Saturniidae:** *Actias luna, Automeris io, Callosamia promethea, Callosamia securifera, Citheronia regalis, Eacles imperialis, Hyalophora cecropia, Samia cynthia*

Liriodendron – Order Magnoliales, Family Magnoliaceae

Native Liriodendron: *Liriodendron tulipifera* (Tulip Poplar): Arctiidae: *Halysidota tessellaris, Hyphantria cunea*; **Cosmopterigidae:** *Perimede erransella*; **Geometridae:** *Epimecis hortaria* – Tulip-tree Beauty Moth, *Erannis tiliaria*; **Gracillariidae:** *Phyllocnistis liriodendronella*; **Hyblaeidae:** *Hyblaea puera* – Teak Defoliator Moth; **Lymantriidae:** *Lymantria dispar*, *Orgyia leucostigma*; **Noctuidae:** *Spodoptera eridania* – Southern Armyworm Moth; **Papilionidae:** *Papilio glaucus, Papilio troilus*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Euzophera ostricolorella*; **Saturniidae:** *Actias luna, Antheraea polyphemus, Automeris io, Callosamia angulifera, Callosamia promethea, Callosamia securifera, Hyalophora cecropia, Samia cynthia*; **Tortricidae:** *Paralobesia liriodendrana* – Tulip-tree Leaftier Moth

Magnolia – Order Magnoliales, Family Magnoliaceae

Native Magnolia: *Magnolia grandiflora* (Southern Magnolia): Gracillariidae: *Phyllocnistis magnoliella* – Magnolia Serpentine Leafminer Moth; **Pyralidae:** *Euzophera magnolialis* – Magnolia Borer Moth, *Euzophera ostricolorella* – Root Collar Borer Moth; **Saturniidae:** *Callosamia securifera* – Sweetbay Silkmoth; **Tortricidae:** *Paralobesia liriodendrana* – Tulip-tree Leaftier Moth

Native Magnolia: *Magnolia virginiana* (Sweetbay Magnolia): Gracillariidae: *Phyllocnistis magnoliella*; **Papilionidae:** *Papilio glaucus, Papilio palamedes* - Palamedes Swallowtail, *Papilio polyxenes* - Black Swallowtail, *Papilio troilus* – Spicebush Swallowtail; **Saturniidae:** *Automeris io, Callosamia angulifera, Callosamia promethea, Callosamia securifera*; **Sphingidae:** *Eumorpha fasciatus* – Banded Sphinx Moth, *Eumorpha vitis* – Vine Sphinx Moth; **Tortricidae:** *Paralobesia cyclopiana, Paralobesia liriodendrana*

Nonnative Magnolia: *Magnolia stellata* (Star Magnolia): NONE

Nonnative Magnolia: *Magnolia liliiflora* (Japanese Magnolia): NONE

Malus – Order Rosales, Family Rosaceae

Native Crab Apple: *Malus angustifolia* (Southern Crab Apple): Arctiidae: *Haploa lecontei* – Leconte's Haploa Moth, *Hyphantria cunea* – Fall Webworm Moth; **Lasiocampidae:** *Malacosoma americana* – Eastern Tent Caterpillar Moth

Nonnative Crab Apple: *Malus floribunda* (Japanese Flowering Crab Apple): Noctuidae: *Acronicta impleta* – Yellow-haired Dagger Moth; **Saturniidae:** *Hyalophora cecropia* – Cecropia Moth

Myrica – Order Fagales, Family Myricaceae

Native Wax Myrtle: *Myrica cerifera*: Apatelodidae: *Apatelodes torrefacta*; **Geometridae:** *Nemoria bistriaria* – Red-fringed Emerald Moth, *Phrudocentra centrifugaria*, *Rheumaptera hastata* – Spear-Marked Black Moth; **Gracillariidae:** *Caloptilia flavella*; **Limacodidae:** *Alarodia slossoniae* – Packard's White Flannel Moth, *Isa textula*; **Lycaenidae:** *Calycopis cecrops* - redbanded hairstreak; **Nepticulidae:** *Stigmella myricafoliella*; **Noctuidae:** *Catocala muliercula* – Little Wife Underwing Moth; **Notodontidae:** *Clostera apicalis, Schizura apicalis* – Plaine Schizura Moth, *Schizura concinna*; **Pyralidae:** *Acrobasis cirroferella*; **Saturniidae:** *Antheraea polyphemus,* *Automeris io, Eacles imperialis, Hyalophora cecropia*; **Sesiidae:** *Synanthedon scitula*; **Sphingidae:** *Sphinx gordius* – Apple Sphinx Moth; **Tortricidae:** *Strepsicrates smithiana* – Bayberry Leaftier Moth

Nandina – Order Ranunculales, Family Berberidaceae

Nonnative Nandina: *Nandina domestica*:

Pinus – Order Pinales, Family Pinaceae

Native Pine: *Pinus taeda* (Loblolly Pine): Cosmopterigidae: *Melanocinclis lineigera*; **Gelechiidae:** *Battaristis vittella* – Stripe-backed Moth, *Exoteleia pinifoliella* – Pine Needleminer Moth; **Geometridae:** *Nepytia semiclusaria* – Pine Conelet Looper Moth; **Lycaenidae:** *Callophrys niphon* - Eastern Pine Elfin; **Noctuidae:** *Xestia elimata* – Southern Variable Dart Moth; **Psychidae:** *Thyridopteryx ephemeraeformis* – Evergreen Bagworm Moth; **Pyralidae:** *Dioryctria amatella* – Southern Pineconeworm Moth, *Dioryctria disclusa* – Webbing Coneworm Moth, *Dioryctria pygmaeella* – Bald Cypress Coneworm Moth, *Dioryctria taedae*, *Dioryctria taedivorella* – Lesser Loblolly Pineconeworm Moth, *Pococera melanogrammos* – Black-letter Pococera Moth, *Pococera robustella* – Pine Webworm Moth; **Saturniidae:** *Eacles imperialis*; **Sphingidae:** *Lapara coniferarum* – Southern Pine Sphinx Moth; **Tortricidae:** *Cydia erotella*, *Cydia ingens* – Longleaf Pine Seedworm Moth, *Eucosma cocana* – Shortleaf Pinecone Borer Moth, *Retinia comstockiana* – Pitch Twig Moth, *Rhyacionia aktita*, *Rhyacionia frustrana* – Nantucket Pine Tip Moth, *Rhyacionia rigidana* – Pitch Pine Tip Moth, *Rhyacionia subtropica* – Subtropical Pine Tip Moth, *Sparganothis sulfureana* – Sparganothis Fruitworm Moth; **Diprionidae**: *Neodiprion excitans* – Blackheaded Pine Sawfly, *Neodiprion hetricki* - Hetrick's Sawfly, *Neodiprion lecontei* - redheaded pine sawfly, *Neodiprion pratti pratti* - Virginia pine sawfly, *Neodiprion taedae linearis* - loblolly pine sawfly

Native Pine: *Pinus palustris* (Longleaf Pine): Blastobasidae: *Calosima lepidophaga*; **Gelechiidae:** *Exoteleia chillcotti*, *Exoteleia pinifoliella* – Pine Needleminer Moth; **Lasiocampidae:** *Tolype minta* – Southern Tolype Moth; **Pyralidae:** *Dioryctria abietella* – European species, *Dioryctria amatella*, *Dioryctria clarioralis* – Blister Coneworm Moth, *Pococera robustella* – Pine Webworm Moth; **Sphingidae:** *Lapara coniferarum*; **Tortricidae:** *Cydia ingens, Cydia anaranjada* – Slash Pine Seedworm Moth, *Rhyacionia frustrana* – Nantucket Pine Tip Moth, *Rhyacionia subtropica*, *Satronia tantilla* – Southern Pine Catkinworm Moth; **Diprionidae:** *Neodiprion excitans* – Blackheaded Pine Sawfly, *Neodiprion lecontei* - redheaded pine sawfly,

Nonnative Pine: *Pinus mugo* (Mugho Pine): Gelechiidae: *Exoteleia pinifoliella* – Pine Needleminer Moth; **Pyralidae:** *Dioryctria abietivorella* – Evergreen Coneworm Moth, *Dioryctria disclusa* – Webbing Coneworm Moth, *Pococera robustella* – Pine Webworm Moth; **Saturniidae:** *Citheronia sepulcralis* – Pine Devil Moth; **Diprionidae:** *Neodiprion sertifer* – European Pine Sawfly; **Pamphiliidae:** *Acantholyda erythrocephala* - Pine False Webworm (from Europe)

Platanus – Order Proteales, Family Platanaceae

Native Sycamore: *Platanus occidentalis* (American Sycamore): Arctiidae: *Halysidota harrisii* – Sycamore Tussock Moth, *Halysidota tessellaris, Hyphantria cunea, Lophocampa caryae*; **Gelechiidae:** *Gelechia albisparsella*; **Lymantriidae:** *Lymantria dispar, Orgyia leucostigma*;

Megalopygidae: *Megalopyge opercularis* – Southern Flannel Moth; **Nepticulidae:** *Ectoedemia clemensella, Ectoedemia platanella*; **Noctuidae:** *Acronicta americana, Lithophane signosa* – Signate Pinion Moth, *Scolecocampa liburna, Spodoptera frugiperda* – Fall Armyworm Moth; **Notodontidae:** *Datana contracta, Heterocampa guttivitta, Macrurocampa marthesia, Misogada unicolor* – Drab Prominent Moth; **Psychidae:** *Oiketicus abbotii, Thyridopteryx ephemeraeformis*; **Pyralidae:** *Diatraea saccharalis* – Sugarcane Borer Moth, *Euzophera semifuneralis, Pococera militella* – Sycamore Webworm Moth; **Saturniidae:** *Antheraea polyphemus, Automeris io, Citheronia regalis, Eacles imperialis, Hyalophora cecropia, Samia cynthia*; **Tortricidae:** *Adoxophyes furcatana, Ancylis divisana, Ancylis platanana, Pandemis lamprosana*

Populus – Order Malpighiales, Family Salicaceae

Native Poplar: *Populus deltoides* (Eastern Cottonwood): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Cossidae:** *Prionoxystus robiniae* – Carpenterworm Moth; **Geometridae:** *Lycia rachelae* – Twilight Moth, *Metanema inatomaria* – Pale Metanema Moth; **Lymantriidae:** *Leucoma salicis, Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Acronicta americana, Acronicta lepusculina* – Cottonwood Dagger Moth, *Amphipyra pyramidoides, Catocala amatrix, Catocala concumbens, Catocala unijuga, Ipimorpha pleonectusa, Lacinipolia renigera* – Bristly Cutworm Moth, *Lithophane baileyi* – Bailey's Pinion Moth, *Raphia frater, Spodoptera ornithogalli* – Yellow-striped Armyworm Moth; **Notodontidae:** *Datana ministra, Schizura concinna* – Red-humped Caterpillar Moth; **Nymphalidae:** *Limenitis archippus* – Viceroy, *Limenitis arthemis* - Red-spotted Purple, *Nymphalis antiopa*; **Saturniidae:** *Actias luna, Automeris io, Hyalophora cecropia*; **Sesiidae:** *Paranthrene dollii* – Poplar Clearwing Moth; **Sphingidae:** *Pachysphinx modesta, Paonias excaecata*; **Tortricidae:** *Choristoneura conflictana* – Large Aspen Tortrix Moth, *Gypsonoma haimbachiana* – Cottonwood Twig Borer Moth

Nonnative Poplar: *Populus nigra* (Lombardy Poplar): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth, *Lophocampa maculata*; **Gelechiidae:** *Anacampsis innocuella* – Dark-headed Aspen Leafroller Moth; **Geometridae:** *Erannis tiliaria, Glena cribrataria* – Dotted Gray Moth; **Hesperiidae:** *Erynnis icelus* - Aspen Dusky Wing; **Lymantriidae:** *Catocala amatrix* – Sweetheart Underwing Moth, *Catocala concumbens* – Pink Underwing Moth, *Catocala unijuga* – Once-married Underwing Moth, *Ipimorpha pleonectusa* – Even-lined Sallow Moth, *Leucoma salicis, Lymantria dispar, Orgyia leucostigma*; **Noctuidae:** *Acronicta americana, Acronicta oblinita, Amphipyra pyramidoides, Raphia frater* – Brother Moth, *Scoliopteryx libatrix* – Herald Moth; **Notodontidae:** *Clostera inclusa* – Angle-lined Prominent Moth, *Gluphisia septentrionis* – Common Gluphisia Moth, *Oligocentria semirufescens* – Red-washed Prominent Moth; **Nymphalidae:** *Limenitis archippus* – Viceroy, *Limenitis arthemis* - Red-spotted Purple, *Nymphalis antiopa, Papilio cresphontes* - Giant Swallowtail; **Oecophoridae:** *Antaeotricha leucillana*; **Pyralidae:** *Framinghamia helvalis*; **Sphingidae:** *Pachysphinx modesta* – Big Poplar Sphinx Moth, *Smerinthus cerisyi* – One-eyed Sphinx Moth; **Tortricidae:** *Apotomis removana* – Green Aspen Leafroller Moth

Prunus – Order Rosales, Family Rosaceae

Native Cherry: *Prunus americana* (American Plum): Arctiidae: *Hyphantria cunea*; **Coleophoridae:** *Coleophora laticornella* – Pecan Cigar Casebearer Moth; **Gelechiidae:** *Agnippe prunifoliella*; **Geometridae:** *Alsophila pometaria*, *Epirrita autumnata*, *Erannis tiliaria*, *Paleacrita vernata*;

Lasiocampidae: *Malacosoma americana***; Lycaenidae:** *Celastrina argiolus***,** *Incisalia henrici, Satyrium titus* - Coral Hairstreak, *Satyrium liparops*; **Lymantriidae:** *Orgyia antiqua, Orgyia leucostigma*; **Nepticulidae:** *Stigmella slingerlandella*; **Noctuidae:** *Acronicta americana, Acronicta clarescens, Acronicta hasta, Acronicta interrupta, Amphipyra pyramidoides, Argyrostrotis anilis* – Short-lined Chocolate Moth**,** *Catocala clintonii* – Clinton's Underwing Moth, *Catocala ultronia, Cerma cerintha, Euxoa auxiliaris* – Army Cutworm Moth, *Lithophane antennata, Lithophane innominata, Orthosia hibisci, Orthosia rubescens, Peridroma saucia, Phlogophora periculosa, Sunira bicolorago, Zale lunata*; **Notodontidae:** *Datana ministra, Schizura concinna, Schizura unicornis*; **Papilionidae:** *Papilio glaucus*; **Saturniidae:** *Hyalophora cecropia, Samia cynthia*; **Sesiidae:** *Synanthedon pictipes*; **Sphingidae:** *Smerinthus jamaicensis*

Native Cherry: ***Prunus serotina*** **(Black Cherry): Apatelodidae:** *Apatelodes torrefacta* – Spotted Apatelodes Moth; **Arctiidae:** *Hyphantria cunea* – Fall Webworm Moth*, Haploa lecontei* – Leconte's Haploa Moth, *Lophocampa caryae, Lophocampa maculata, Pyrrharctia isabella* – Isabella Tiger Moth, *Spilosoma dubia* – Dubious Tiger Moth, *Spilosoma latipennis* – Pink-legged Tiger Moth, *Spilosoma virginica*; **Coleophoridae:** *Coleophora malivorella* – Pistol Casebearer Moth, *Coleophora pruniella* – Cherry Casebearer Moth; **Gelechiidae:** *Filatima serotinella*; **Geometridae:** *Alsophila pometaria, Antepione thisoaria* – Variable Antepione Moth, *Biston betularia, Dyspteris abortivaria* – Badwing Moth, *Erannis tiliaria*, *Euchlaena effecta* – Effective Euchlaena Moth, *Euchlaena obtusaria* – Obtuse Euchlaena Moth, *Euchlaena pectinaria* – Forked Euchlaena Moth, *Eupithecia miserulata* – Common Eupithecia Moth, *Eutrapela clemataria, Hypagyrtis unipunctata, Iridopsis larvaria* – Bent-line Gray Moth, *Lambdina fiscellaria, Lomographa semiclarata* – Bluish Spring Moth, *Lomographa vestaliata* – White Spring Moth, *Melanolophia canadaria, Metarranthis amyrisaria*, *Metarranthis angularia* – Angled Metarranthis Moth, *Metarranthis duaria* – Ruddy Metarranthis Moth, *Metarranthis hypochraria* – Common Metarranthis Moth, *Metarranthis refractaria* – Refracted Metarranthis Moth, *Phaeoura quernaria, Nematocampa resistaria* – Horned Spanworm Moth, *Paleacrita vernata, Pero honestaria* – Honest Pero Moth, *Pero nerisaria*, *Phigalia titea, Plagodis phlogosaria* – Straight-lined Plagodis Moth, *Plagodis serinaria, Probole amicaria, Prochoerodes lineola* – Large Maple Spanworm Moth, *Rheumaptera prunivorata* – Ferguson's Scallop Shell Moth, *Rheumaptera undulata, Scopula limboundata* – Large Lace-border Moth, *Speranza pustularia* – Lesser Maple Spanworm Moth, *Tetracis cachexiata*; **Gracillariidae:** *Caloptilia serotinella*, *Phyllonorycter crataegella* – Apple Blotch Leafminer Moth, *Phyllonorycter propinquinella* – Cherry Blotch Miner Moth; **Lasiocampidae:** *Artace cribrarius* – Dot-lined White Moth, *Malacosoma americana, Malacosoma disstria* – Forest Tent Caterpillar Moth, *Phyllodesma americana* – Lappet Moth, *Tolype velleda* – Large Tolype Moth; **Limacodidae:** *Prolimacodes badia* – Skiff Moth; **Lycaenidae:** *Celastrina argiolus* –Holly Blue Butterfly, *Incisalia henrici* - Henry's Elfin, *Satyrium liparops, Satyrium titus* - Coral Hairstreak; **Lymantriidae:** *Dasychira dorsipennata* – Sharp-lined Tussock Moth, *Dasychira meridionalis* – Southern Tussock Moth, *Dasychira obliquata* – Streaked Tussock Moth, *Dasychira plagiata, Lymantria dispar, Orgyia antiqua*; **Noctuidae:** *Acronicta americana, Acronicta clarescens* – Clear Dagger Moth, *Acronicta funeralis* – Funerary Dagger Moth, *Acronicta hasta* – Speared Dagger Moth, *Acronicta impressa* – Impressed Dagger Moth, *Acronicta interrupta* – Interrupted Dagger Moth, *Acronicta lanceolaria, Acronicta lobeliae* – Greater Oak Dagger Moth, *Acronicta radcliffei* – Radcliffe's Dagger Moth, *Acronicta spinigera* – Nondescript Dagger Moth, *Amphipyra pyramidoides, Apamea amputatrix* – Yellow-headed Cutworm Moth, *Catocala ultronia*

– Ultronia Underwing Moth, *Cerma cerintha* – Tufted Bird-dropping Moth, *Chaetaglaea sericea* – Silky Sallow Moth, *Crocigrapha normani, Egira alternans* – Alternate Woodling Moth, *Epiglaea decliva* – Sloping Sallow Moth, *Eucirroedia pampina* – Scalloped Sallow Moth, *Eupsilia cirripalea* – Franclemont's Sallow Moth, *Eupsilia morrisoni* – Morrison's Sallow Moth, *Eupsilia sidus, Eupsilia tristigmata*, *Himella fidelis* – Intractable Quaker Moth, *Homorthodes furfurata* – Northern Scurfy Quaker Moth, *Hyppa xylinoides* – Common Hyppa Moth, *Lacinipolia lorea* – Bridled Arches Moth, *Lithophane antennata* – Ashen Pinion Moth, *Lithophane grotei* – Grote's Pinion Moth, *Lithophane laticinerea*, *Lithophane unimoda* – Dowdy Pinion Moth, *Lycophotia phyllophora* – Lycophotia Moth, *Morrisonia confusa* – Confused Woodgrain Moth, *Morrisonia latex* – Fluid Arches Moth, *Orthosia alurina* – Gray Quaker Moth, *Orthosia hibisci* – Speckled Green Fruitworm Moth, *Orthosia rubescens* – Ruby Quaker Moth, *Panopoda rufimargo* – Red-lined Panopoda Moth, *Sericaglaea signata* – Variable Sallow Moth, *Trichordestra legitima* – Striped Garden Caterpillar Moth, *Xestia normanianus* – Norman's Dart Moth, *Xystopeplus rufago* – Red-winged Sallow Moth, *Zale lunata* – Lunate Zale Moth, *Zale lunifera* – Bold-based Zale Moth; **Notodontidae:** *Cerura scitiscripta* – Black-etched Prominent Moth, *Furcula borealis* – White Furcula Moth, *Heterocampa biundata, Heterocampa guttivitta, Hyperaeschra georgica* – Georgian Prominent Moth, *Schizura concinna* – Red-humped Caterpillar Moth, *Schizura leptinoides* – Black-blotched Schizura Moth; **Nymphalidae:** *Limenitis archippus* – Viceroy, *Limenitis arthemis* - Red-Spotted Purple; **Papilionidae:** *Papilio glaucus* – Eastern Tiger Swallowtail, *Papilio troilus* – Spicebush Swallowtail; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Pyrausta subsequalis*; **Saturniidae:** *Antheraea polyphemus, Automeris io, Callosamia angulifera* – Tulip-tree Silkmoth, *Callosamia promethea* – Promethea Moth, *Citheronia regalis* – Regal Moth, *Eacles imperialis*, *Hemileuca maia, Hyalophora cecropia, Samia cynthia* – Ailanthus Silkmoth; **Sesiidae:** *Synanthedon pictipes* – Lesser Peachtree Borer Moth, *Synanthedon scitula* – Dogwood Borer Moth; **Sphingidae:** *Amorpha juglandis* – Walnut Sphinx Moth, *Paonias astylus* – Huckleberry Sphinx Moth, *Paonias excaecata* – Blind-eyed Sphinx Moth, *Paonias myops* – Small-eyed Sphinx Moth, *Smerinthus jamaicensis* – Twin-spotted Sphinx Moth, *Sphinx chersis* – Great Ash Sphinx Moth, *Sphinx drupiferarum* – Wild Cherry Sphinx Moth; **Tortricidae:** *Ancylis apicana*, *Ancylis burgessiana* – Oak Leaffolder Moth, *Archips cerasivorana* (Ugly-nest Caterpillar Moth), *Argyrotaenia quadrifasciana* – Four-lined Leafroller Moth, *Metendothenia separatana* – Pink-washed Leafroller Moth, *Olethreutes inornatana* – Inornate Olethreutes Moth, *Orthotaenia undulana* – Dusky Leafroller Moth, *Sparganothis umbrana*, *Xenotemna pallorana*

Nonnative Cherry: *Prunus avium* (Sweet Cherry): Arctiidae: *Hyphantria cunea* – Fall Webworm Moth; **Geometridae:** *Alsophila pometaria, Euchlaena pectinaria, Eumacaria madopata* – Brown-bordered Geometer Moth, *Scopula limboundata*; **Gracillariidae:** *Parornix geminatella* – Unspotted Tentiform Leafminer Moth, *Phyllonorycter crataegella*; **Limacodidae:** *Isa textula, Monoleuca semifascia* – Pin-striped Vermilion Slug Moth, *Parasa chloris* – Smaller Parasa Moth, *Parasa indetermina* – Stinging Rose Caterpillar Moth; **Lymantriidae:** *Lymantria dispar*; **Noctuidae:** *Acronicta lanceolaria, Catocala ultronia, Lithophane antennata*; **Notodontidae:** *Cerura scitiscripta, Furcula borealis*; **Pyralidae:** *Acrobasis indigenella* – Leaf Crumpler Moth, *Cadra cautella* – Almond Moth, *Cadra figulilella* – Raisin Moth, *Ectomyelois ceratoniae* – Locust Bean Moth, *Ephestiodes infimella*, *Euzophera semifuneralis* – American Plum Borer Moth, *Plodia interpunctella* – Indian Meal Moth; **Saturniidae:** *Automeris io, Hyalophora cecropia*; **Sesiidae:** *Synanthedon exitiosa* – Peachtree Borer Moth, *Synanthedon pictipes*; **Sphingidae:** *Sphinx drupiferarum*; **Tortricidae:**

Archips argyrospila – Fruit-tree Leafroller Moth, *Archips cerasivorana, Cenopis ferreana, Choristoneura rosaceana*, *Eulia ministrana* – Ferruginous Eulia Moth, *Pandemis pyrusana* – Pandemis Leafroller Moth

Nonnative Cherry: *Prunus serrulata* (Japanese Cherry): Noctuidae: *Acronicta clarescens* – Clear Dagger Moth, *Lithophane antennata* – Ashen Pinion Moth, *Sunira bicolorago* – Bicolored Sallow Moth

***Pyracantha* – Order Rosales, Family Rosaceae**

Nonnative Firethorn: *Pyracantha coccinea* (Scarlet Firethorn): Lymantriidae: *Orgyia leucostigma* – White-marked Tussock Moth; **Pyralidae:** *Acrobasis indigenella* – Leaf Crumpler Moth

***Pyrus* – Order Rosales, Family Rosaceae**

Nonnative Pear: *Pyrus calleryana* (Bradford Pear): NONE

***Quercus* – Order Fagales, Family Fagaceae**

Native Oak: *Quercus alba* (White Oak): Arctiidae: *Halysidota tessellaris***,** *Hyphantria cunea***,** *Hypoprepia fucosa* – Painted Lichen Moth**,** *Lophocampa caryae***,** *Lophocampa maculata***;** **Blastobasidae:** *Blastobasis glandulella* – Acorn Moth; **Bucculatricidae:** *Bucculatrix ainsliella* – Oak Skeletonizer Moth; **Coleophoridae:** *Coleophora querciella*; **Eriocraniidae:** *Eriocraniella mediabulla*; **Gelechiidae:** *Chionodes formosella*, *Dichomeris ligulella* – Palmerworm Moth, *Neotelphusa querciella*; **Geometridae:** *Alsophila pometaria***,** *Besma endropiaria*, *Besma quercivoraria* – Oak Besma Moth**,** *Ennomos magnaria***,** *Ennomos subsignaria***,** *Erannis tiliaria***,** *Eutrapela clemataria***,** *Hypagyrtis unipunctata***,** *Lambdina fervidaria***,** *Lambdina fiscellaria***,** *Nemoria bistriaria* – Red-fringed Emerald Moth**,** *Nemoria mimosaria* – White-Fringed Emerald Moth, *Paleacrita vernata***,** *Phaeoura quernaria*, *Phigalia titea***,** *Plagodis alcoolaria***,** *Plagodis serinaria*; **Gracillariidae:** *Acrocercops albinatella, Cameraria cincinnatiella* – Gregarious Oak Leafminer Moth, *Cameraria fletcherella, Cameraria hamadryadella, Cameraria tubiferella, Phyllonorycter aeriferella, Phyllonorycter argentifimbriella, Phyllonorycter basistrigella, Phyllonorycter fitchella, Phyllonorycter lucidicostella, Phyllonorycter quercialbella*; **Hesperiidae:** *Erynnis juvenalis*; **Lasiocampidae** *Malacosoma americana, Malacosoma disstria, Phyllodesma americana, Tolype velleda*; **Limacodidae:** *Isa textula*; **Lycaenidae:** *Erora laeta, Parrhasius m-album, Satyrium calanus, Satyrium edwardsii, Satyrium favonius* - Oak Hairstreak*;* **Lymantriidae:** *Dasychira basiflava* – Yellow-based Tussock Moth, *Dasychira dorsipennata, Dasychira vagans, Lymantria dispar, Orgyia antiqua, Orgyia leucostigma;* **Mimallonidae:** *Lacosoma chiridota;* **Noctuidae:** *Abagrotis alternata* – Greater Red Dart Moth, *Achatia distincta* – Distinct Quaker Moth, *Acronicta americana, Acronicta funeralis, Acronicta haesitata* – Hesitant Dagger Moth, *Amphipyra pyramidoides, Catocala amica, Catocala ilia* – Ilia Underwing Moth, *Catocala robinsonii* – Robinson's Underwing Moth, *Cosmia calami* – American Dun-bar Moth, *Crocigrapha normani, Himella fidelis, Hyperstrotia secta* – Black-patched Graylet Moth, *Lithophane bethunei, Morrisonia confusa, Morrisonia latex, Orthodes detracta* – Disparaged Arches Moth, *Orthosia hibisci, Orthosia revicta, Panopoda rufimargo, Peridroma saucia, Psaphida styracis* – Fawn Sallow Moth, *Psaphida thaxterianus, Pseudanthracia coracias* – Pseudanthracia Moth, *Sympistis badistriga* – Brown-lined Sallow Moth, *Zale aeruginosa* – Green-dusted Zale Moth, *Zale minerea;* **Nolidae:** *Meganola* *minuscula* – Confused Meganola Moth; **Notodontidae:** *Datana ministra, Heterocampa guttivitta, Heterocampa obliqua* – Oblique Heterocampa Moth, *Heterocampa umbrata* – White-blotched Heterocampa Moth, *Hyperaeschra georgica, Lochmaeus manteo, Nadata gibbosa, Oligocentria lignicolor* – White-streaked Prominent Moth, *Peridea angulosa* – Angulose Prominent Moth, *Schizura concinna, Schizura ipomoeae, Schizura leptinoides, Schizura unicornis, Symmerista albifrons* – White-headed Prominent Moth, *Symmerista canicosta;* **Oecophoridae:** *Antaeotricha osseella, Antaeotricha schlaegeri* – Schlaeger's Fruitworm Moth, *Machimia tentoriferella, Psilocorsis quercicella;* **Psychidae:** *Thyridopteryx ephemeraeformis;* **Pyralidae:** *Acrobasis minimella, Oreana unicolorella, Pococera asperatella, Pococera expandens;* **Saturniidae:** *Actias luna, Anisota senatoria, Anisota stigma, Anisota virginiensis, Antheraea polyphemus, Automeris io, Eacles imperialis, Hyalophora cecropia;* **Sesiidae:** *Paranthrene simulans;* **Sphingidae:** *Ceratomia undulosa;* **Tortricidae:** *Acleris semipurpurana, Archips argyrospila, Archips fervidana, Argyrotaenia alisellana* – White-spotted Leafroller Moth, *Argyrotaenia quercifoliana, Catastega aceriella* – Maple Trumpet Skeletonizer Moth*, Catastega timidella* – Oak Trumpet Skeletonizer Moth, *Cenopis pettitana*, *Choristoneura rosaceana, Cydia latiferreana* – Filbertworm Moth, *Olethreutes atrodentana, Olethreutes inornatana, Orthotaenia undulana, Pandemis limitata* – Three-lined Leafroller Moth; **Tenthredinidae:** *Periclista media*

Native Oak: *Quercus falcata* (Southern Red Oak): Cossidae: *Prionoxystus robiniae* – Carpenterworm Moth; **Eriocraniidae:** *Eriocraniella mediabulla*; **Gracillariidae:** *Cameraria hamadryadella;* **Lycaenidae:** *Satyrium favonius* – Oak Hairstreak, *Satyrium calanus* - Banded Hairstreak; **Notodontidae:** *Datana major* – Azalea Caterpillar; **Pyralidae:** *Acrobasis minimella;* **Saturniidae:** *Anisota consularis, Anisota peigleri, Anisota stigma, Anisota virginiensis, Antheraea polyphemus, Hemileuca maia*; **Sesiidae:** *Paranthrene simulans* – Red Oak Clearwing Moth; **Tortricidae:** *Archips fervidana, Acleris albicomana* – Red-edged Acleris Moth, *Acleris semipurpurana*, *Catastega aceriella*

Native Oak: *Quercus rubra* (Northern Red Oak): Arctiidae: *Halysidota tessellaris, Hyphantria cunea, Lophocampa caryae, Lophocampa maculata*; **Blastobasidae:** *Blastobasis glandulella*; **Bucculatricidae:** *Bucculatrix ainsliella*; **Cossidae:** *Prionoxystus macmurtrei* – Little Carpenterworm Moth; **Drepanidae:** *Pseudothyatira cymatophoroides* – Tufted Thyatirid Moth; **Gelechiidae:** *Chionodes formosella, Chionodes thoraceochrella, Dichomeris ligulella, Dichomeris picrocarpa* – Black-edged Carbatina Moth, *Neotelphusa querciella*; **Geometridae:** *Alsophila pometaria, Besma endropiaria, Besma quercivoraria, Ennomos magnaria, Ennomos subsignaria, Erannis tiliaria, Hethemia pistasciaria* – Pistachio Emerald Moth, *Hydriomena transfigurata* – Transfigured Hydriomena Moth, *Lambdina fervidaria, Lambdina fiscellaria, Lambdina pultaria* – Southern Oak Looper Moth, *Lomographa vestaliata, Metarranthis duaria, Phaeoura quernaria, Nemoria lixaria* – Red-bordered Emerald Moth, *Nemoria mimosaria, Paleacrita vernata, Phigalia titea, Plagodis alcoolaria, Plagodis phlogosaria*; **Gracillariidae:** *Acrocercops albinatella, Cameraria bethunella, Cameraria hamadryadella, Cameraria ulmella, Neurobathra strigifinitella, Phyllonorycter basistrigella, Phyllonorycter rileyella*; **Hesperiidae:** *Erynnis horatius, Erynnis juvenalis*; **Lasiocampidae:** *Malacosoma americana, Malacosoma disstria, Phyllodesma americana*; **Limacodidae:** *Euclea delphinii* – Spiny Oak-slug Moth, *Prolimacodes badia, Tortricidia flexuosa* – Abbreviated Button Slug Moth; **Lycaenidae:** *Satyrium calanus, Satyrium caryaevorum, Satyrium liparops*; **Lymantriidae:** *Dasychira dorsipennata, Dasychira plagiata, Lymantria dispar, Orgyia* *leucostigma,* **Nepticulidae:** *Ectoedemia platanella*, *Stigmella latifasciella*; **Noctuidae:** *Acronicta afflicta* – Afflicted Dagger Moth, *Acronicta americana, Acronicta grisea* – Gray Dagger Moth, *Acronicta haesitata, Acronicta hasta, Acronicta lithospila* – Streaked Dagger Moth, *Acronicta modica* – Medium Dagger Moth, *Acronicta noctivaga* – Night-Wandering Dagger Moth, *Acronicta tristis, Amphipyra pyramidoides* – Copper Underwing Moth, *Catocala amica, Catocala connubialis* – Connubial Underwing Moth, *Catocala ilia, Catocala lineella, Cosmia calami, Egira alternans, Eupsilia tristigmata, Hyperstrotia secta, Lithophane antennata, Lithophane bethunei, Lithophane innominata, Lithophane petulca, Morrisonia confusa, Morrisonia latex, Orthosia hibisci, Orthosia revicta, Orthosia rubescens, Panopoda rufimargo, Phoberia atomaris* – Common Oak Moth, *Ulolonche culea* – Sheathed Quaker Moth; **Notodontidae:** *Datana ministra, Heterocampa biundata, Heterocampa guttivitta, Heterocampa obliqua, Heterocampa umbrata, Hyparpax perophoroides, Lochmaeus manteo, Nadata gibbosa, Oligocentria lignicolor, Peridea angulosa, Symmerista canicosta, Symmerista leucitys*; **Nymphalidae:** *Limenitis archippus*; **Oecophoridae:** *Antaeotricha leucillana, Machimia tentoriferella, Psilocorsis cryptolechiella* – Black-fringed Leaftier Moth, *Psilocorsis quercicella, Psilocorsis reflexella* – Dotted Leaftier Moth; **Pantheidae:** *Charadra deridens* – Laugher Moth; **Pyralidae:** *Acrobasis minimella, Apomyelois bistriatella, Moodna ostrinella* – Darker Moodna Moth, *Oneida lunulalis* – Orange-tufted Oneida Moth, *Oreana unicolorella, Pococera expandens*; **Saturniidae:** *Actias luna, Anisota peigleri, Anisota senatoria, Anisota stigma, Anisota virginiensis, Antheraea polyphemus, Automeris io, Eacles imperialis, Hemileuca maia, Hyalophora cecropia*; **Sesiidae:** *Paranthrene simulans, Synanthedon pictipes*; **Sphingidae:** *Ceratomia undulosa*; **Tischeriidae:** *Coptotriche castaneaeella, Coptotriche citrinipennella*; **Tortricidae:** *Acleris albicomana, Acleris chalybeana, Acleris semipurpurana, Acleris subnivana, Ancylis burgessiana, Ancylis fuscociliana, Ancylis laciniana, Archips argyrospila, Archips fervidana, Archips semiferanus* – Oak Leafroller Moth*, Argyrotaenia quercifoliana, Catastega aceriella, Catastega timidella, Cenopis pettitana, Choristoneura fractivittana, Choristoneura rosaceana, Cydia latiferreana, Hedya chionosema* – White-spotted Hedya Moth, *Pandemis lamprosana, Pseudexentera cressoniana* – Shagbark Hickory Leafroller Moth, *Sparganothis umbrana*

Native Oak: ***Quercus stellata*** **(Post Oak): Gracillariidae:** *Cameraria hamadryadella, Phyllonorycter basistrigella, Phyllonorycter fitchella;* **Hesperiidae:** *Erynnis horatius* - Horace's Duskywing*, Erynnis juvenalis* - Juvenal's Duskywing; **Lasiocampidae:** *Malacosoma americana, Malacosoma disstria;* **Lycaenidae:** *Satyrium favonius* – Oak Hairstreak; **Lymantriidae:** *Lymantria dispar;* **Mimallonidae:** *Lacosoma chiridota;* **Noctuidae:** *Catocala amica* – Girlfriend Underwing Moth, *Catocala coccinata* – Scarlet Underwing Moth, *Catocala lineella* – Little Lined Underwing Moth, *Catocala micronympha* – Little Nymph Underwing Moth, *Catocala similis* – Similar Underwing Moth; **Nolidae:** *Meganola spodia* – Ashy Meganola Moth; **Notodontidae:** *Datana ministra, Lochmaeus manteo;* **Oecophoridae:** *Menesta melanella*, *Rectiostoma xanthobasis* – Yellow-vested Moth; **Saturniidae:** *Anisota stigma, Anisota virginiensis, Antheraea polyphemus, Automeris io, Hemileuca maia*

Native Oak: ***Quercus palustris*** **(Pin Oak)**: **Arctiidae:** *Halysidota tessellaris* - Banded Tussock Moth, *Lophocampa caryae;* **Geometridae:** *Lytrosis unitaria* - Common Lytrosis Moth; **Lymantriidae:** *Lymantria dispar* - Gypsy moth;**Mimallonidae:** *Lacosoma chiridota* - Scalloped Sack-bearer Moth; **Nepticulidae:** *Ectoedemia similella*; **Noctuidae:** *Acronicta americana* - American Dagger Moth, *Amphipyra pyramidoides* (Copper Underwing Moth); **Notodontidae:** *Datana ministra* (Yellow-necked Caterpillar Moth); **Nymphalidae:** *Limenitis arthemis* (Red-Spotted Purple); **Psychidae:** *Thyridopteryx ephemeraeformis* (Evergreen Bagworm Moth); **Pyralidae:** *Pococera expandens* (Striped Oak Webworm Moth); **Saturniidae:** *Anisota consularis* (Consular Oakworm Moth), *Anisota peigleri* (Peigler's Oakworm Moth), *Anisota senatoria* (Orange-tipped Oakworm Moth), *Anisota stigma* (Spiny Oakworm Moth), *Anisota virginiensis* (Pink-striped Oakworm Moth), *Antheraea polyphemus* (Polyphemus Moth), *Automeris io* (Io Moth), *Eacles imperialis* (Imperial Moth), *Hyalophora cecropia* (Cecropia Moth); **Sesiidae:** *Paranthrene simulans* (Red Oak Clearwing Moth); **Tortricidae:** *Acleris semipurpurana* (Oak Leaftier Moth), *Archips cerasivorana* (Ugly-nest Caterpillar Moth), *Archips fervidana* (Oak Webworm Moth), *Argyrotaenia quercifoliana* (Yellow-winged Oak Leafroller Moth); **Tenthredenidae:** *Caliroa quercuscoccineae* – Scarlet Oak Sawfly

Nonnative Oak: *Quercus acutissima* (Sawtooth Oak): Saturniidae: *Automeris io*

Nonnative Oak: *Quercus robur* (English Oak): Geometridae: *Biston betularia* (Peppered Moth), *Epirrita autumnata* (Autumnal Moth), *Phaeoura quernaria* (Oak Beauty); **Gracillariidae:** *Cameraria hamadryadella* (Solitary Oak Leafminer Moth); **Noctuidae:** *Acronicta impleta* (Yellow-haired Dagger Moth); **Notodontidae:** *Datana ministra* (Yellow-necked Caterpillar Moth), *Symmerista canicosta* (Red-humped Oakworm Moth); **Saturniidae:** *Anisota virginiensis* (Pink-striped Oakworm Moth), *Antheraea polyphemus* (Polyphemus Moth), *Hemileuca maia* (Buck Moth)

Rhododendron – Order Ericales, Family Ericaceae

Native Azalea: *Rhododendron calendulaceum (flame azalea): Lycaenidae:* *Satyrium kingi (King's hairstreak), Satyrium liparops (Striped Hairstreak), Strymon melinus (Gray Hairstreak);* ***Lymantriidae:*** *Lymantria dispar (Gypsy moth)*

Nonnative Azalea: *Rhododendron indicum* (Indica azalea): Gracillariidae: *Caloptilia azaleella* - Azalea leaf miner; **Notodontidae:** *Datana major* - Azalea caterpillar; **Saturniidae:** *Automeris io* - io moth

Salix – Order Malpighiales, Family Salicaceae

Native Willow: *Salix discolor* (American Willow): Geometridae: *Mesothea incertata* – Day Emerald Moth; **Lymantriidae:** *Lymantria dispar*; **Nymphalidae:** *Limenitis archippus, Nymphalis antiopa*; **Saturniidae:** *Hyalophora cecropia*; **Cephidae:** *Janus abbreviatus* – Willow Shoot Sawfly

Native Willow: *Salix nigra* (Black Willow): Noctuidae: *Catocala cara* – Darling Underwing Moth; **Nymphalidae:** *Limenitis archippus* – Viceroy, *Nymphalis antiopa* - Mourning Cloak; **Saturniidae:** *Automeris io* – Io Moth, *Hyalophora cecropia* – Cecropia Moth; **Cephidae:** *Janus abbreviatus* – Willow Shoot Sawfly

Nonnative Willow: *Salix babylonica* (Babylon willow/weeping willow): Gracillariidae: *Micrurapteryx salicifoliella* – Willow Leafblotch Miner Moth, *Phyllonorycter salicifoliella* – Willow Leaf Blotch Miner Moth; **Notodontidae:** *Clostera apicalis* – Apical Prominent Moth, *Schizura concinna* – Red-humped Caterpillar Moth; **Nymphalidae:** *Limenitis archippus* – Viceroy; **Saturniidae:** *Antheraea polyphemus* – Polyphemus Moth, *Automeris io* – Io Moth, *Hemileuca maia*

– Buck Moth, *Hyalophora cecropia* – Cecropia Moth; **Tortricidae:** *Acleris hastiana*; **Cephidae:** *Janus abbreviatus* – Willow Shoot Sawfly

Nonnative Willow: *Salix caprea* (Goat Willow): Saturniidae: *Actias luna, Automeris io, Eacles imperialis, Hemileuca maia*

***Taxodium* – Order Pinales, Family Cupressaceae**

Native Cypress: *Taxodium distichum* (Bald Cypress): Cosmopterigidae: *Perimede erransella*; **Gelechiidae:** *Coleotechnites apicitripunctella* – Green Hemlock Needleminer Moth, *Coleotechnites variiella*; **Geometridae:** *Chloropteryx tepperaria* – Angle-winged Emerald Moth, *Iridopsis pergracilis* – Cypress Looper Moth; **Lymantriidae:** *Dasychira dominickaria, Dasychira plagiata, Lymantria dispar, Orgyia detrita* – Fir Tussock Moth; **Noctuidae:** *Cutina albopunctella*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Dioryctria amatella, Dioryctria ebeli* – South Coastal Coneworm Moth, *Dioryctria pygmaeella* – Bald Cypress Coneworm Moth; **Saturniidae:** *Eacles imperialis, Hyalophora cecropia*; **Sphingidae:** *Isoparce cupressi* – Bald Cypress Sphinx Moth

***Ulmus* – Order Rosales, Family Ulmaceae**

Native Elm: *Ulmus americana* (American Elm): Arctiidae: *Halysidota tessellaris, Haploa confusa* – Confused Haploa Moth, *Hyphantria cunea, Hypoprepia fucosa, Lophocampa caryae, Lophocampa maculata, Pyrrharctia isabella*; **Cossidae:** *Prionoxystus robiniae*; **Gelechiidae:** *Theisoa constrictella*; **Geometridae:** *Alsophila pometaria, Anavitrinella pampinaria, Biston betularia, Campaea perlata, Ectropis crepuscularia, Ennomos magnaria, Ennomos subsignaria, Erannis tiliaria, Euchlaena johnsonaria* – Johnson's Euchlaena Moth, *Euchlaena marginaria* – Ochre Euchlaena Moth, *Eutrapela clemataria, Hypagyrtis unipunctata, Iridopsis ephyraria, Lambdina fiscellaria, Lycia rachelae, Melanolophia canadaria, Melanolophia signataria, Nematocampa resistaria, Nemoria mimosaria, Paleacrita vernata, Phaeoura quernaria, Phigalia strigataria, Phigalia titea, Probole amicaria, Prochoerodes lineola, Protoboarmia porcelaria, Selenia kentaria, Tetracis cachexiata, Xanthotype sospeta*; **Gracillariidae:** *Cameraria ulmella, Phyllonorycter argentinotella*; **Incurvariidae:** *Paraclemensia acerifoliella*; **Lasiocampidae:** *Malacosoma disstria, Tolype velleda*; **Limacodidae:** *Lithacodes fasciola*; **Lymantriidae:** *Dasychira plagiata, Dasychira vagans, Lymantria dispar, Orgyia antiqua, Orgyia leucostigma*; **Noctuidae:** *Acronicta americana, Acronicta impleta, Acronicta interrupta, Acronicta morula* – Ochre Dagger Moth, *Acronicta spinigera, Acronicta vinnula* – Delightful Dagger Moth, *Amphipyra pyramidoides, Balsa malana* – Many-dotted Appleworm Moth, *Crocigrapha normani, Eupsilia morrisoni, Hypena abalienalis* – White-lined Bomolocha Moth, *Hyperstrotia pervertens* – Dotted Graylet Moth, *Hyperstrotia villificans* – White-lined Graylet Moth, *Lithophane bethunei, Lithophane disposita* – Dashed Gray Pinion Moth, *Lithophane laticinerea, Lithophane petulca, Melanchra adjuncta* – Hitched Arches Moth, *Morrisonia confusa, Morrisonia latex, Orthosia garmani* – Garman's Quaker Moth, *Orthosia hibisci, Orthosia revicta, Peridroma saucia, Zale minerea*; **Notodontidae:** *Datana ministra, Gluphisia septentrionis, Heterocampa guttivitta, Lochmaeus bilineata* – Double-lined Prominent Moth, *Lochmaeus manteo, Nerice bidentata* – Double-toothed Prominent Moth, *Peridea basitriens* – Oval-Based Prominent Moth, *Schizura concinna, Schizura ipomoeae, Schizura unicornis, Symmerista albifrons, Symmerista leucitys*; **Nymphalidae:** *Limenitis arthemis, Nymphalis antiopa, Nymphalis vaualbum* - Compton Tortoiseshell, *Polygonia comma* - Eastern Comma, *Polygonia faunus, Polygonia interrogationis* - Question Mark, *Polygonia progne* - Gray Comma, *Vanessa cardui* - Painted Lady; **Oecophoridae:** *Antaeotricha leucillana, Machimia tentoriferella*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Pyralidae:** *Canarsia ulmiarrosorella* – Elm Leaftier Moth, *Herpetogramma pertextalis, Oreana unicolorella, Pococera asperatella*; **Saturniidae:** *Antheraea polyphemus, Automeris io, Eacles imperialis, Hyalophora cecropia*; **Sphingidae:** *Ceratomia amyntor* – Elm Sphinx Moth, *Smerinthus jamaicensis*; **Tortricidae:** *Amorbia humerosana, Archips argyrospila, Archips negundana* – Larger Boxelder Leafroller Moth, *Argyrotaenia mariana* – Gray-banded Leafroller Moth, *Argyrotaenia velutinana* – Red-banded Leafroller Moth, *Cenopis pettitana*, *Choristoneura fractivittana, Choristoneura rosaceana, Olethreutes mysteriana* – Mysterious Olethreutes Moth, *Pandemis lamprosana, Pandemis limitata, Sparganothis sulfureana*; **Tenthredinidae:** *Fenusa ulmi* – Elm Leafminer

Native Elm: *Ulmus rubra* (Slippery Elm): Arctiidae: *Halysidota tessellaris, Hyphantria cunea, Lophocampa caryae, Lophocampa maculata*; **Geometridae:** *Alsophila pometaria, Ennomos magnaria, Ennomos subsignaria, Paleacrita vernata*; **Gracillariidae:** *Cameraria ulmella, Phyllonorycter argentinotella*; **Lymantriidae:** *Dasychira basiflava, Lymantria dispar, Orgyia leucostigma*; **Nepticulidae:** *Ectoedemia ulmella*; **Noctuidae:** *Acronicta americana, Hypena abalienalis*; **Nymphalidae:** *Nymphalis antiopa, Polygonia interrogationis*; **Oecophoridae:** *Machimia tentoriferella*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Saturniidae:** *Automeris io, Eacles imperialis, Hyalophora cecropia*; **Tortricidae:** *Cenopis pettitana*, *Pandemis lamprosana, Pandemis limitata*

Nonnative Elm: *Ulmus parvifolia* (Chinese Elm): Noctuidae: *Hypena scabra* – Green Cloverworm Moth; **Nymphalidae:** *Polygonia interrogationis*; **Psychidae:** *Thyridopteryx ephemeraeformis*; **Saturniidae:** *Automeris io, Hyalophora cecropia*

Nonnative Elm: *Ulmus procera* (English Elm): Arctiidae: *Lophocampa caryae*; **Cossidae:** *Prionoxystus robiniae*; **Lymantriidae:** *Lymantria dispar*; **Noctuidae:** *Acronicta americana*; **Saturniidae:** *Eacles imperialis*; **Tenthredinidae:** *Fenusa ulmi* – Elm Leafminer

Zelkova – Order Rosales, Family Ulmaceae

Nonnative Zelkova: *Zelkova serrata* (Japanese Zelkova): NONE

Part 2: Eruciform Species Diet Breadth

Note: Diet breadth reflects the number of plant families that each eruciform is known to be capable of feeding on. Sawfly species (Hymenoptera: Symphyta) are listed at the bottom. Yellow highlighted species are non-native. Data sources: Johnson and Lyon 1991, Robinson et al. 2013

Family	Eruciform Species	Diet Breadth
	Lepidoptera	
Apatelodidae	*Apatelodes torrefacta*	**16**
Arctiidae	*Grammia phyllira*	**5**
	Halysidota harrisii	**4**
	Halysidota tessellaris	**20**
	Haploa confusa	**8**
	Haploa lecontei	**13**
	Hyphantria cunea	**47**
	Hypoprepia fucosa	**5**
	Lophocampa caryae	**19**
	Lophocampa maculata	**15**
	Pyrrharctia isabella	**25**
	Spilosoma dubia	**2**
	Spilosoma latipennis	**6**
	Spilosoma virginica	**45**
Blastobasidae	*Blastobasis glandulella*	**1**
	Calosima lepidophaga	**1**
Bucculatricidae	*Bucculatrix ainsliella*	**1**
Coleophoridae	*Coleophora laticornella*	**2**
	Coleophora leucochrysella	**1**
	Coleophora malivorella	**3**
	Coleophora pruniella	**5**
	Coleophora querciella	**1**
Cossidae	*Prionoxystus macmurtrei*	**3**
	Prionoxystus robiniae	**9**
Cosmopterigidae	*Melanocinclis lineigera*	**1**
	Perimede erransella	**5**
	Periploca nigra	**1**
	Pyroderces badia	**15**
Crambidae	*Palpita quadristigmalis*	**1**
Drepanidae	*Eudeilinia herminiata*	**1**
	Euthyatira pudens	**2**
	Habrosyne scripta	**3**

	Pseudothyatira cymatophoroides	**6**
Eriocraniidae	*Dyseriocrania griseocapitella*	**1**
	Eriocraniella mediabulla	**1**
Gelechiidae	*Agnippe prunifoliella*	**1**
	Anacampsis innocuella	**3**
	Battaristis vittella	**1**
	Chionodes formosella	**1**
	Chionodes thoraceochrella	**1**
	Coleotechnites albicostata	**2**
	Coleotechnites apicitripunctella	**2**
	Coleotechnites australis	**1**
	Coleotechnites obliquistrigella	**2**
	Coleotechnites variiella	**2**
	Dichomeris ligulella	**13**
	Dichomeris marginella	**1**
	Dichomeris picrocarpa	**3**
	Dichomeris ventrella	**6**
	Exoteleia chillcotti	**1**
	Exoteleia pinifoliella	**1**
	Fascista cercerisella	**1**
	Filatima serotinella	**1**
	Gelechia albisparsella	**1**
	Neotelphusa querciella	**1**
	Pseudotelphusa betulella	**1**
	Theisoa constrictella	**1**
Geometridae	*Alsophila pometaria*	**13**
	Anavitrinella pampinaria	**24**
	Antepione thisoaria	**5**
	Besma endropiaria	**4**
	Besma quercivoraria	**7**
	Biston betularia	**25**
	Campaea perlata	**10**
	Ceratonyx satanaria	**2**
	Chloropteryx tepperaria	**4**
	Digrammia continuata	**4**

	Dyspteris abortivaria	**2**
	Ectropis crepuscularia	**25**
	Ennomos magnaria	**12**
	Ennomos subsignaria	**14**
	Epimecis hortaria	**3**
	Epirrita autumnata	**11**
	Erannis tiliaria	**17**
	Euchlaena effecta	**7**
	Euchlaena johnsonaria	**10**
	Euchlaena marginaria	**9**
	Euchlaena obtusaria	**3**
	Euchlaena pectinaria	**4**
	Eumacaria madopata	**1**
	Eupithecia miserulata	**15**
	Eutrapela clemataria	**16**
	Glena cribrataria	**2**
	Hethemia pistasciaria	**5**
	Hydria prunivorata	**3**
	Hydriomena transfigurata	**1**
	Hypagyrtis unipunctata	**13**
	Iridopsis ephyraria	**12**
	Iridopsis larvaria	**11**
	Iridopsis pergracilis	**1**
	Lambdina fervidaria	**9**
	Lambdina fiscellaria	**14**
	Lambdina pultaria	**1**
	Ligdia wagneri	**13**
	Lomographa semiclarata	**3**
	Lomographa vestaliata	**5**
	Lycia rachelae	**7**
	Lytrosis unitaria	**3**
	Macaria aemulataria	**7**
	Macaria notata	**4**
	Melanolophia canadaria	**17**
	Melanolophia signataria	**8**
	Mesothea incertata	**7**
	Metanema determinata	**4**
	Metanema inatomaria	**4**
	Metarranthis amyrisaria	**3**
	Metarranthis angularia	**1**

	Metarranthis duaria	**6**
	Metarranthis hypochraria	**4**
	Metarranthis refractaria	**2**
	Nematocampa resistaria	**9**
	Nemoria bistriaria	**5**
	Nemoria elfa	**1**
	Nemoria lixaria	**2**
	Nemoria mimosaria	**11**
	Nemoria saturiba	**1**
	Nepytia semiclusaria	**1**
	Paleacrita vernata	**13**
	Patalene olyzonaria	**2**
	Pero honestaria	**3**
	Pero nerisaria	**1**
	Phaeoura quernaria	**6**
	Phigalia strigataria	**2**
	Phigalia titea	**11**
	Phrudocentra centrifugaria	**1**
	Plagodis alcoolaria	**6**
	Plagodis phlogosaria	**7**
	Plagodis pulveraria	**8**
	Plagodis serinaria	**6**
	Pleuroprucha insulsaria	**8**
	Probole alienaria	**6**
	Probole amicaria	**8**
	Prochoerodes lineola	**16**
	Protoboarmia porcelaria	**8**
	Rheumaptera hastata	**7**
	Rheumaptera undulata	**8**
	Scopula limboundata	**5**
	Selenia alciphearia	**5**
	Selenia kentaria	**6**
	Speranza pustularia	**5**
	Tetracis cachexiata	**17**
	Tetracis crocallata	**6**
	Xanthotype sospeta	**16**
	Xanthotype urticaria	**9**
Gracillariidae	*Acrocercops albinatella*	**1**
	Caloptilia azaleella	**1**
	Caloptilia bimaculatella	**1**

	Caloptilia flavella	**1**
	Caloptilia packardella	**1**
	Caloptilia serotinella	**1**
	Caloptilia umbratella	**1**
	Cameraria aceriella	**2**
	Cameraria bethunella	**1**
	Cameraria cincinnatiella	**1**
	Cameraria fletcherella	**1**
	Cameraria hamadryadella	**3**
	Cameraria lentella	**2**
	Cameraria saccharella	**1**
	Cameraria tubiferella	**1**
	Cameraria ulmella	**2**
	Micrurapteryx salicifoliella	**1**
	Neurobathra strigifinitella	**2**
	Parornix geminatella	**1**
	Phyllocnistis liquidambarisella	**1**
	Phyllocnistis liriodendronella	**1**
	Phyllocnistis magnoliella	**1**
	Phyllonorycter aeriferella	**1**
	Phyllonorycter argentifimbriella	**1**
	Phyllonorycter argentinotella	**1**
	Phyllonorycter basistrigella	**1**
	Phyllonorycter crataegella	**1**
	Phyllonorycter fitchella	**2**
	Phyllonorycter lucidicostella	**2**
	Phyllonorycter propinquinella	**2**
	Phyllonorycter quercialbella	**1**
	Phyllonorycter rileyella	**1**
	Phyllonorycter salicifoliella	**1**
	Phyllonorycter trinotella	**1**

Heliozelidae	*Antispila cornifoliella*	**1**
Hesperiidae	*Erynnis brizo*	**1**
	Erynnis horatius	**2**
	Erynnis juvenalis	**3**
Hyblaeidae	*Hyblaea puera*	**14**
Incurvariidae	*Paraclemensia acerifoliella*	**5**
Lasiocampidae	*Artace cribrarius*	**5**
	Malacosoma americana	**17**
	Malacosoma disstria	**16**
	Phyllodesma americana	**12**
	Tolype minta	**1**
	Tolype velleda	**9**
Limacodidae	*Apoda y-inversum*	**3**
	Alarodia slossoniae	**4**
	Euclea delphinii	**8**
	Isa textula	**6**
	Lithacodes fasciola	**10**
	Monoleuca semifascia	**3**
	Natada nasoni	**2**
	Packardia elegans	**1**
	Parasa chloris	**5**
	Parasa indetermina	**6**
	Phobetron pithecium	**8**
	Prolimacodes badia	**12**
	Tortricidia flexuosa	**4**
	Tortricidia pallida	**2**
Lycaenidae	*Callophrys gryneus*	**1**
	Callophrys hesseli	**2**
	Callophrys niphon	**2**
	Calycopis cecrops	**5**
	Celastrina argiolus	**27**
	Erora laeta	**3**
	Incisalia henrici	**7**
	Parrhasius m-album	**2**
	Satyrium calanus	**5**
	Satyrium caryaevorum	**4**
	Satyrium edwardsii	**3**
	Satyrium favonius	**1**
	Satyrium kingi	**4**
	Satyrium liparops	**10**
	Satyrium titus	**1**

	Strymon melinus	**31**
Lymantriidae	*Dasychira atrivenosa*	**1**
	Dasychira basiflava	**7**
	Dasychira dominickaria	**1**
	Dasychira dorsipennata	**9**
	Dasychira leucophaea	**7**
	Dasychira meridionalis	**5**
	Dasychira obliquata	**7**
	Dasychira plagiata	**13**
	Dasychira vagans	**7**
	Leucoma salicis	**4**
	Lymantria dispar	**43**
	Orgyia antiqua	**24**
	Orgyia definita	**7**
	Orgyia detrita	**5**
	Orgyia leucostigma	**52**
Megalopygidae	*Megalopyge crispata*	**8**
	Megalopyge opercularis	**12**
	Norape ovina	**3**
Mimallonidae	*Lacosoma chiridota*	**1**
Nepticulidae	*Ectoedemia clemensella*	**1**
	Ectoedemia platanella	**1**
	Ectoedemia similella	**1**
	Ectoedemia ulmella	**1**
	Stigmella castaneaefoliella	**1**
	Stigmella latifasciella	**1**
	Stigmella myricafoliella	**1**
	Stigmella slingerlandella	**1**
	Trifurcula saccharella	**1**
Noctuidae	*Abagrotis alternata*	**8**
	Achatia distincta	**8**
	Acronicta afflicta	**2**
	Acronicta americana	**15**
	Acronicta betulae	**1**
	Acronicta clarescens	**3**
	Acronicta dactylina	**8**
	Acronicta funeralis	**10**
	Acronicta grisea	**8**
	Acronicta haesitata	**1**
	Acronicta hamamelis	**4**
	Acronicta hasta	**2**

	Acronicta hastulifera	**7**
	Acronicta impleta	**12**
	Acronicta impressa	**9**
	Acronicta interrupta	**7**
	Acronicta lanceolaria	**8**
	Acronicta lepusculina	**4**
	Acronicta lithospila	**2**
	Acronicta lobeliae	**2**
	Acronicta modica	**1**
	Acronicta morula	**3**
	Acronicta noctivaga	**5**
	Acronicta oblinita	**23**
	Acronicta ovata	**2**
	Acronicta radcliffei	**6**
	Acronicta retardata	**1**
	Acronicta spinigera	**4**
	Acronicta tristis	**4**
	Acronicta vinnula	**1**
	Amphipyra pyramidoides	**17**
	Apamea amputatrix	**7**
	Argyrostrotis anilis	**2**
	Balsa malana	**3**
	Catocala amatrix	**1**
	Catocala amica	**1**
	Catocala cerogama	**2**
	Catocala clintonii	**3**
	Catocala cara	**1**
	Catocala coccinata	**1**
	Catocala concumbens	**1**
	Catocala connubialis	**3**
	Catocala ilia	**1**
	Catocala lineella	**1**
	Catocala micronympha	**1**
	Catocala muliercula	**1**
	Catocala palaeogama	**3**
	Catocala robinsonii	**2**
	Catocala similis	**2**
	Catocala ultronia	**6**
	Catocala unijuga	**1**
	Cerma cerintha	**2**
	Chaetaglaea sericea	**3**

	Cosmia calami	**2**
	Crocigrapha normani	**11**
	Cutina albopunctella	**1**
	Egira alternans	**5**
	Epiglaea decliva	**2**
	Eucirroedia pampina	**3**
	Eupsilia cirripalea	**1**
	Eupsilia morrisoni	**4**
	Eupsilia sidus	**10**
	Eupsilia tristigmata	**10**
	Euxoa auxiliaris	**16**
	Euxoa messoria	**16**
	Himella fidelis	**5**
	Homorthodes furfurata	**3**
	Hypena abalienalis	**2**
	Hypena baltimoralis	**1**
	Hypena scabra	**12**
	Hyperstrotia pervertens	**2**
	Hyperstrotia secta	**1**
	Hyperstrotia villificans	**1**
	Hyppa xylinoides	**13**
	Ipimorpha pleonectusa	**2**
	Lacinipolia lorea	**8**
	Lacinipolia renigera	**12**
	Lithophane antennata	**8**
	Lithophane baileyi	**4**
	Lithophane bethunei	**9**
	Lithophane disposita	**3**
	Lithophane grotei	**3**
	Lithophane innominata	**9**
	Lithophane laticinerea	**9**
	Lithophane petulca	**8**
	Lithophane signosa	**1**
	Lithophane unimoda	**6**
	Lycophotia phyllophora	**5**
	Melanchra adjuncta	**15**
	Metaxaglaea violacea	**1**
	Morrisonia confusa	**14**
	Morrisonia latex	**10**
	Orthodes detracta	**6**
	Orthosia alurina	**3**

	Orthosia garmani	**8**
	Orthosia hibisci	**18**
	Orthosia revicta	**9**
	Orthosia rubescens	**8**
	Paectes abrostoloides	**1**
	Paectes pygmaea	**1**
	Palthis angulalis	**11**
	Panopoda rufimargo	**4**
	Papaipema nebris	**31**
	Parallelia bistriaris	**3**
	Peridea ferruginea	**2**
	Peridroma saucia	**40**
	Phlogophora periculosa	**11**
	Phoberia atomaris	**1**
	Polia imbrifera	**3**
	Psaphida styracis	**2**
	Psaphida thaxterianus	**1**
	Pseudanthracia coracias	**2**
	Pyreferra pettiti	**2**
	Raphia frater	**2**
	Scolecocampa liburna	**5**
	Sericaglaea signata	**3**
	Spaelotis clandestina	**18**
	Spodoptera eridania	**31**
	Spodoptera frugiperda	**32**
	Spodoptera ornithogalli	**24**
	Spragueia onagrus	**3**
	Sunira bicolorago	**8**
	Sympistis badistriga	**5**
	Trichordestra legitima	**11**
	Ulolonche culea	**1**
	Xestia elimata	**3**
	Xestia normanianus	**4**
	Xystopeplus rufago	**4**
	Zale aeruginosa	**2**
	Zale galbanata	**1**
	Zale lunata	**7**
	Zale lunifera	**2**
	Zale minerea	**10**
Nolidae	*Meganola minuscula*	**2**
	Meganola spodia	**1**

Notodontidae	*Cerura scitiscripta*	**4**
	Clostera apicalis	**3**
	Dasylophia thyatiroides	**3**
	Datana contracta	**7**
	Datana integerrima	**7**
	Datana major	**4**
	Datana ministra	**14**
	Furcula borealis	**2**
	Gluphisia septentrionis	**6**
	Heterocampa biundata	**10**
	Heterocampa guttivitta	**15**
	Heterocampa obliqua	**1**
	Heterocampa umbrata	**5**
	Hyperaeschra georgica	**3**
	Hyparpax perophoroides	**1**
	Lochmaeus bilineata	**4**
	Lochmaeus manteo	**9**
	Macrurocampa marthesia	**5**
	Misogada unicolor	**2**
	Nadata gibbosa	**7**
	Nerice bidentata	**1**
	Oligocentria lignicolor	**4**
	Oligocentria semirufescens	**7**
	Peridea angulosa	**3**
	Peridea basitriens	**2**
	Schizura apicalis	**3**
	Schizura concinna	**20**
	Schizura ipomoeae	**14**
	Schizura leptinoides	**8**
	Schizura unicornis	**15**
	Symmerista albifrons	**6**
	Symmerista canicosta	**3**
	Symmerista leucitys	**5**
Nymphalidae	*Limenitis archippus*	**7**
	Limenitis arthemis	**9**
	Nymphalis antiopa	**14**
	Nymphalis vaualbum	**3**
	Polygonia comma	**6**
	Polygonia faunus	**6**

	Polygonia interrogationis	**6**
	Polygonia progne	**4**
	Vanessa annabella	**6**
	Vanessa cardui	**25**
Oecophoridae	*Antaeotricha leucillana*	**10**
	Antaeotricha osseella	**1**
	Antaeotricha schlaegeri	**2**
	Machimia tentoriferella	**12**
	Menesta melanella	**1**
	Menesta tortriciformella	**3**
	Psilocorsis cryptolechiella	**7**
	Psilocorsis quercicella	**1**
	Rectiostoma xanthobasis	**1**
Pantheidae	*Charadra deridens*	**5**
	Colocasia flavicornis	**6**
	Colocasia propinquilinea	**6**
Papilionidae	*Papilio glaucus*	**17**
	Papilio palamedes	**2**
	Papilio polyxenes	**5**
	Papilio troilus	**5**
Psychidae	*Astala confederata*	**3**
	Oiketicus abbotii	**22**
	Thyridopteryx ephemeraeformis	**50**
Pyralidae	*Acrobasis betulivorella*	**1**
	Acrobasis cirroferella	**1**
	Acrobasis indigenella	**2**
	Acrobasis minimella	**1**
	Apomyelois bistriatella	**5**
	Cadra cautella	**35**
	Cadra figulilella	**12**
	Canarsia ulmiarrosorella	**2**
	Desmia funeralis	**3**
	Diatraea saccharalis	**2**
	Dioryctria abietella	**1**
	Dioryctria abietivorella	**1**
	Dioryctria amatella	**2**
	Dioryctria clarioralis	**1**
	Dioryctria disclusa	**1**

	Dioryctria ebeli	**2**
	Dioryctria pygmaeella	**2**
	Dioryctria taedae	**1**
	Dioryctria taedivorella	**1**
	Ectomyelois ceratoniae	**23**
	Ephestiodes infimella	**3**
	Etiella zinckenella	**9**
	Euzophera ostricolorella	**2**
	Euzophera magnolialis	**1**
	Euzophera ostricolorella	**2**
	Euzophera semifuneralis	**14**
	Herpetogramma pertextalis	**11**
	Moodna ostrinella	**9**
	Oneida lunulalis	**1**
	Oreana unicolorella	**7**
	Plodia interpunctella	**25**
	Pococera asperatella	**4**
	Pococera expandens	**1**
	Pococera melanogrammos	**2**
	Pococera militella	**1**
	Pococera robustella	**1**
	Pyrausta subsequalis	**2**
	Sciota uvinella	**1**
	Uresiphita reversalis	**3**
Saturniidae	*Actias luna*	**19**
	Anisota consularis	**1**
	Anisota peigleri	**1**
	Anisota senatoria	**7**
	Anisota stigma	**5**
	Anisota virginiensis	**8**
	Antheraea polyphemus	**25**
	Automeris io	**37**
	Callosamia angulifera	**5**
	Callosamia promethea	**23**
	Callosamia securifera	**4**
	Citheronia sepulcralis	**1**
	Citheronia regalis	**18**
	Dryocampa rubicunda	**5**
	Eacles imperialis	**37**
	Hemileuca maia	**8**

	Hyalophora cecropia	**42**
	Samia cynthia	**39**
Sesiidae	*Paranthrene dollii*	**1**
	Paranthrene simulans	**1**
	Synanthedon acerni	**1**
	Synanthedon acerrubri	**1**
	Synanthedon castaneae	**1**
	Synanthedon exitiosa	**1**
	Synanthedon geliformis	**4**
	Synanthedon pictipes	**2**
	Synanthedon scitula	**11**
Sphingidae	*Amorpha juglandis*	**5**
	Ceratomia amyntor	**7**
	Ceratomia undulosa	**4**
	Eumorpha fasciatus	**3**
	Eumorpha vitis	**3**
	Isoparce cupressi	**3**
	Lapara coniferarum	**1**
	Manduca rustica	**11**
	Pachysphinx modesta	**4**
	Paonias astylus	**3**
	Paonias excaecata	**11**
	Paonias myops	**7**
	Smerinthus jamaicensis	**8**
	Sphinx chersis	**6**
	Sphinx drupiferarum	**5**
	Sphinx franckii	**2**
	Sphinx gordius	**6**
Tischeriidae	*Coptotriche castaneaeella*	**1**
	Coptotriche citrinipennella	**1**
	Tischeria quercitella	**1**
Tortricidae	*Acleris albicomana*	**4**
	Acleris chalybeana	**5**
	Acleris hastiana	**7**
	Acleris semipurpurana	**3**
	Acleris subnivana	**2**
	Adoxophyes furcatana	**1**
	Amorbia humerosana	**14**
	Ancylis apicana	**4**
	Ancylis burgessiana	**3**

	Ancylis divisana	**2**
	Ancylis fuscociliana	**3**
	Ancylis laciniana	**1**
	Ancylis platanana	**3**
	Archips argyrospila	**27**
	Archips cerasivorana	**9**
	Archips fervidana	**4**
	Archips negundana	**5**
	Archips semiferanus	**5**
	Argyrotaenia alisellana	**1**
	Argyrotaenia mariana	**9**
	Argyrotaenia quadrifasciana	**1**
	Argyrotaenia quercifoliana	**6**
	Argyrotaenia velutinana	**24**
	Catastega aceriella	**3**
	Catastega timidella	**3**
	Cenopis ferreana	**15**
	Choristoneura conflictana	**9**
	Choristoneura fractivittana	**5**
	Choristoneura fumiferana	**6**
	Choristoneura parallela	**10**
	Choristoneura rosaceana	**27**
	Clepsis persicana	**24**
	Cudonigera houstonana	**2**
	Cydia anaranjada	**1**
	Cydia erotella	**1**
	Cydia ingens	**1**
	Cydia latiferreana	**5**
	Epinotia lindana	**2**
	Episimus tyrius	**2**
	Eucosma cocana	**1**
	Eulia ministrana	**12**
	Gypsonoma haimbachiana	**1**
	Hedya chionosema	**2**
	Metendothenia separatana	**3**

	Olethreutes appendiceum	**12**
	Olethreutes atrodentana	**1**
	Olethreutes fagigemmeana	**2**
	Olethreutes glaciana	**6**
	Olethreutes inornatana	**5**
	Olethreutes mysteriana	**1**
	Olethreutes nigranum	**3**
	Orthotaenia undulana	**14**
	Pandemis lamprosana	**15**
	Pandemis limitata	**14**
	Pandemis pyrusana	**5**
	Paralobesia cyclopiana	**1**
	Paralobesia liriodendrana	**1**
	Platynota stultana	**25**
	Proteoteras aesculana	**3**
	Proteoteras moffatiana	**3**
	Proteoteras willingana	**1**
	Pseudexentera cressoniana	**3**
	Pseudexentera haracana	**1**
	Pseudexentera spoliana	**3**
	Retinia comstockiana	**1**
	Rhopobota naevana	**5**
	Rhyacionia aktita	**1**
	Rhyacionia frustrana	**1**
	Rhyacionia rigidana	**1**
	Rhyacionia subtropica	**1**
	Satronia tantilla	**1**
	Sparganothis acerivorana	**3**
	Sparganothis niveana	**3**
	Sparganothis pettitana	**8**
	Sparganothis sulfureana	**21**
	Sparganothis umbrana	**5**
	Spilonota ocellana	**10**
	Strepsicrates smithiana	**3**
	Xenotemna pallorana	**8**
Yponomeutidae	*Argyresthia freyella*	**2**

	Swammerdamia caesiella	**3**
	Symphyta	
Cephidae	*Janus abbreviates*	**1**
Diprionidae	*Neodiprion excitans*	**1**
	Neodiprion hetricki	**1**
	Neodiprion lecontei	**1**
	Neodiprion pratti pratti	**1**
	Neodiprion sertifer	**1**
	Neodiprion taedae linearis	**1**
Pamphiliidae	*Acantholyda erythrocephala*	**1**
Tenthredinidae	*Caliroa quercuscoccineae*	**1**
	Croesus latitarsus	**1**
	Fenusa ulmi	**1**
	Periclista media	**1**

Sources of data

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