A SURVEY OF ARTHROPOD BIODIVERSITY IN THE CANOPIES OF SOUTHERN RED OAK TREES IN THE MARYVILLE COLLEGE WOODS

A Report of a Senior Study

by

Jenna Ann Wade

Major: Biology

Maryville College

Fall, 2005

Date Approved ________________, by ________________

Faculty Supervisor

Date Approved ________________, by ________________

Editor

ABSTRACT

Over the past 75 years, biologists have become increasingly interested in how many and what kinds of organisms live in forest canopies. Numerous studies have shown that large quantities of insects reside in forest canopies, many of which were previously unknown to science. It has also been demonstrated that trees in tropical forests are often stratified in regard to the kinds of organisms found in them, with the canopies having more biological activity than the understories. In this study, the canopies and understories of four Southern Red Oaks located in the Maryville College Woods in Maryville, Tennessee were sampled over a period of eight weeks using a composite flight-interception trap. Two sample trees were located on top of a low ridge. The other two were located on the floodplain of a small creek. A total of 2,142 arthropods were collected from 11 Orders and 65 Families. Shannon’s and Simpson’s diversity indices indicated minimal difference between each sampling site. However, Sorenson’s quantitative index measuring community similarity revealed more distinct differences. The least similar communities were the ridgetop canopies versus the floodplain canopies, which shared 49% of the Families found in them. The most similar communities were all canopies compared to all understories, which shared 67% of the Families found in them. Some Families were collected only in the canopy. However, these Families cannot be assumed to be totally canopy-specific due to the small numbers collected and ground-dwelling species that they are known to contain.

TABLE OF CONTENTS

TABLE OF FIGURES

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank my advisor, Dr. Threadgill, for his guidance and assistance throughout the course of this study. I also greatly appreciate the help of Dr. Ernest Bernard and Renee Follum at the University of Tennessee in my insect identification efforts, and Dr. Cash for allowing me the use of lab supplies and field guides. Last, but certainly not least, I would like to thank my family for their support and Joshua Bryant, my “field assistant,” for his helpful efforts and never-ending encouragement and love.

CHAPTER I

INTRODUCTION

Since the birth of canopy science approximately 75 years ago, there has been an ever growing interest in discovering how many and what kinds of organisms live in the forest canopies. One of the first canopy studies can be attributed to O. W. Richards and his colleagues in 1929 when they used various traps and climbed into the rainforest canopy of Guiana (Hingston, 1930). They became the first scientists to quantitatively collect arthropods from the canopy of any tropical rainforest, gathering about 10,000 specimens over the course of 3 months (Hingston, 1930). Particularly in the past twenty years, there has been a rise in the number of canopy research projects in an attempt to obtain knowledge about canopy species diversity, species richness, their role in the environment, and conservation. In the early 1980's, there was a push to obtain a more accurate count of the number of species, leading to massive collecting efforts in the rainforests (Erwin, 2004). Better technology also led to the creation of innovative sampling and climbing techniques, giving scientists easy access to what Erwin termed "the last biotic frontier" due to the seemingly infinite, yet poorly studied richness of organisms that reside in the canopy (Basset, Novotny, Miller, & Kitching, 2003a). A recent eight year study conducted by Erwin and Pimienta revealed that one hectare in an equatorial rainforest contains about 6.03×10^{12} organisms, including over 60,000 species of arthropods (Erwin, 2004).

Although the number of species on the planet has always been an issue in the scientific community, some argue that the numbers are not as important as finding out what exists and conserving it (Erwin, 2004). Conservation efforts are becoming more important in the rainforests, where rapid loss of habitat makes canopy inhabitants particularly susceptible to becoming endangered or extinct (Basset et al., 2003a). Some of these areas that are being lost most rapidly to human disturbance contain more than half of the world’s species (Wilson as cited in Winchester, 1997). Between 1985 and 1990, approximately 210 million acres (85 million hectares) of tropical forests were cut or cleared for agriculture, fuel, or harvesting of wood products (Mastrantonio & Francis, 1997). Other estimates suggest that an area the size of the states of Ohio or Virginia is cut from tropical forests each year (Mastrantonio & Francis, 1997). Therefore, an accurate estimate of arthropod populations and diversity and an increased awareness of arthropod communities are essential for their survival (Basset et al., 2003a). If the organisms present and their importance and function in the ecosystem are known, private landowners or the government may choose to conserve areas of the rainforest that otherwise would have been destroyed.

Rainforests, however, are not the only forests that need to be conserved. Steps have also been taken towards conservation of the biodiversity of temperate forests in the United States. The amount of forestland in the U.S. has dramatically decreased since the country was first settled in the middle of the 17^{th} century, dropping from an estimated 423 to 302 million hectares (USDA, 2000). An emphasis has been placed on the management of private lands by the United States Department of Agriculture and others concerned with proper forest use and conservation. Although private landowners control nearly 71% of the nation’s timberland (USDA as cited in Mortimer, 2004), there are no specific national, regional, or in many cases even state, private forest policies (Mortimer, 2004). According to Mortimer (2004), owners of private forestlands usually do not implement any particular management goal and the land is used according to the desires of the landowner. Recent studies have shown that only five percent of private landowners in the United States have a written management plan (USDA, 2000). Since there is less control over their use, the biodiversity of private forests is especially important to know for conservation purposes. The National Research Council states that, “the potential of nonfederal forestlands to contribute to the maintenance of biodiversity is great, given their extent, variety, potential management flexibility, and that they are the primary forest category subject to conversion to non-forest uses” (as cited in Mortimer, 2004). In order for conservation of private forestland to occur, private landowners must be educated about the types of species living on their land and why they are important. A biodiversity study would be particularly useful to a private landowner to deduce whether or not any endangered species inhabit their land. One of the most effective ways to gain a measure of forest biodiversity is by sampling various habitats, being sure to include the forest canopy.

To date, most studies involving canopy sampling have been completed in equatorial rainforests. Studies conducted separately by Erwin, Kitching, Lowman, Southwood, and Stork consistently produced an abundance of data on canopy arthropod communities that has taken from years to decades to analyze (Erwin, 1995). Studies by Erwin in Panama and Peru produced 42,641 and 7,712 total arthropods, respectively, while Kitching’s study in the tropical rainforests of Australia produced upwards of 44,844 specimens (Erwin, 1995). While these numbers may seem indicative of extensive research, field studies resulting in huge collections have taken place at only twenty sites around the world, almost all of which are centered in northern South America (Erwin, 1995). From these twenty sites, a total of about 500 trees representing fewer than 100 species were sampled (Erwin, 1995).

It has been found that the upper canopy of a rainforest has more biological activity than the understory (Halle & Blanc as cited in Basset et al., 2003a). More light reaches the upper levels of the canopy, allowing a higher rate of photosynthesis and a greater number of plant species (Wright & Colley as cited in Basset et al. 2003a). In turn, a greater number of plant species can support a more diverse and abundant community of canopy-dwelling arthropods (Wright & Colley as cited in Basset et al., 2003a).

Although many studies have now been done on the biodiversity of rainforest canopies in tropical climates, only recently has attention been turned to the temperate forests found in North America (Winchester, 1997). Most of these studies are centered in Canada. Those taking place in the United States have been primarily completed in old-growth forests in the Pacific Northwest (Voegtlin as cited in Winchester, 1997). In British Columbia, arthropods in old-growth forests are thought to comprise 80-90% of the total species in the community (Asquith et al., as cited in Winchester, 1997).

Vance, Kirby, Malcolm, and Smith (2003) used flight-interception traps in pine and maple trees in South-central Ontario to sample communities of long-horned beetles. They collected 297 individuals from 28 species after 6 weeks of sampling (Vance et al., 2003). Species richness was higher in the canopy than in understory traps, while 11 beetle species were unique to each trap height (Vance et al., 2003). They also discovered that some beetle species were only found on one of the tree species (Vance et al., 2003). Vertical stratification in the occurrence of bark-beetle species has been documented in other temperate forests in Canada and Poland (Capecki, Safranyik et al. as cited in Simon, Gossner & Linsenmair 2003). It should be noted, however, that vertical stratification of temperate forests is often less pronounced than that typically found in tropical rainforests or can be nonexistent (Basset, Hammond, Barrios, Holloway & Miller, 2003b). The upper canopy of wet tropical forests is known for being structurally and environmentally distinct from the understory with varying degrees of microclimates and light exposure (Bell et al., as cited in Basset et al., 2003b), whereas temperate forests are often lacking in distinct differences among these strata (Basset et al., 2003b).

While a few studies of temperate forest canopies do exist, the lack of information concerning canopy arthropod assemblages in the southeastern U.S. is astonishing. In east Tennessee only a few studies have been performed to assess the biodiversity of arthropods in the dominant tree species. Knowledge of such biodiversity becomes increasingly important information due to the proximity of the Great Smoky Mountains National Park and several colleges and universities that could benefit from becoming aware of pest species or finding previously unrecognized rare or endangered species. Knowledge of canopy biodiversity could also be used to set up outdoor educational experiences for students or provide information and field sites for future professional research.

Trieff (2002) assessed the insect fauna present in the canopies of Northern Red Oak trees (*Quercus rubra* L.) located in the Great Smoky Mountains National Park (GSMNP) and the University of Tennessee Arboretum. He fogged the canopy of one randomly selected tree from each of four sites along an elevational gradient ranging from 262 – 1,377m monthly starting in May and ending in September. Trieff recovered a total of 11,167 insect specimens, of which 203 species of beetles representing 45 families were identified from GSMNP. Sixty-four of these *Coleopteran* species had not been previously recorded in GSMNP, representing a 5.5% increase to the All Taxa Biodiversity Inventory (ATBI) database (Trieff, 2002). In GSMNP, the highest number of specimens and species were located at the lowest elevation site, however, diversity values were highest at the highest elevation site and lowest at the lowest elevation site. Fifty-five *Coleopteran* species were found only in the UT Arboretum collection (Trieff, 2002). The Asiatic oak weevil (*Cyrtepisomus castaneus*) made up 18.68% of the total number of beetles collected, which could have pest control implications (Trieff, 2002). This study contributed beneficial information to the GSMNP park staff and the University of Tennessee by adding to the ATBI database and providing information about the presence of pest species.

In a comparable study, Stanton (1994) fogged the crowns of 20 Northern Red Oak trees in a seed orchard in Johnson County, TN every two weeks from March to November in 1992 and 1993. After two years, he collected a total of 26,536 adult insect specimens representing 541 species in 143 Families and 15 Orders. Stanton (1994) also found the Asiatic Oak weevil to be the most abundant species, comprising 25% of all specimens collected.

Even though the two previously mentioned studies were carried out relatively close to Maryville, Tennessee, there is no research to date on the canopy arthropod biodiversity in Maryville or on the campus of Maryville College. Maryville College maintains about 120 acres (49 hectares) of private forest known as the Maryville College Woods.

The woods are managed according to a stewardship plan approved by the Tennessee Division of Forestry that ensures their proper use for education and advocates conservation. In order to accomplish the goals put forth in the stewardship plan, it is important for the college staff and students to be aware of the diversity as well as the benefit or threat produced by all species. If the species present are known, then attempts to conserve certain areas or turn others into outdoor educational experiences can be pursued. Given the lack of research completed on the forests of east Tennessee and also inspired by the global increase in interest concerning arthropod diversity and canopy assemblages, I propose to carry out a study to get a measure of arthropod biodiversity in the canopy of Southern Red Oaks (*Quercus falcata* Michaux) in the Maryville College Woods, compare data to the two existing studies that have been completed on Northern Red Oaks in eastern Tennessee, determine if any species are canopy specific, and see if there are elevational differences in species distribution.

Although the two prior studies that took place in east Tennessee used fogging to collect specimens, a variety of methods can be employed to obtain arthropods in the canopy of trees. Other methods frequently used in canopy sampling include branch clipping; hand collecting after climbing using single-rope techniques; non-attractive traps such as sticky, malaise and flight-interception traps; and attractive traps such as those that employ the use of light, bait, or water (Basset, Springate, Aberlenc & Delvare, 1997). Still other methods involve building or riding structures such as towers, cranes, walkways, or canopy rafts up into the canopy (Basset et al., 1997). Since these sampling methods are more time consuming and invasive, they are typically reserved for long-term studies in the rainforests.

While particular methods can be chosen to target a specific group of arthropods or a specific habitat, no single method exists to sample all habitats and arthropods that are present (Basset et al., 1997) A composite flight-interception trap was chosen for use in this study for several reasons. First, it was deemed safer than fogging with an insecticide and more practical than gaining the experience necessary to climb using single-rope techniques. It was also chosen because of its ability to catch a wide variety of insects. The composite flight-interception trap integrates features of both the malaise and regular flight-interception traps, resulting in a tent-like structure with collecting heads on both the top and bottom of the trap (Basset et al., 1997). By having collecting heads on the top and the bottom, the trap catches both insects that have the tendency to fly upward and those that tend to fall when encountering a vertical surface (Basset et al., 1997). The combination of these two features effectively reduces bias toward specific taxa (Basset et al., 1997). In a canopy survey in French Guiana, Delvare and Aberlenc concluded that both malaise and light traps were effective for entomological survey of the canopy, although light traps could attract organisms that were not canopy residents (as cited in Basset et al., 1997). In Cameroon, Basset et al. (1997) reported that composite flight-interception traps caught a wider variety of taxa than malaise traps alone when used for general surveys. Finally, in a review of sampling methods used to collect leaf-feeding beetles in Papua New Guinea, Basset reported that the composite flight-interception trap produced the greatest total number of morphospecies collected (Basset et al., 1997). In fact, 120 beetle species were collected exclusively with this trap. Therefore, the composite flight-interception trap was chosen for this research project because of its ease of use, successful utilization in similar studies, ability to catch a wide variety of insects, and minimal safety risk.

For this study, it is proposed that during the summer of 2005 a composite flight-interception trap will be placed in the canopy and understory of four Southern Red Oak trees in two different types of habitats that result from elevational changes in the Maryville College woods. The trap will be left at each sampling location for one week and specimens will be identified to appropriate taxon. Data analysis will make comparisons between communities within this study and between this study and published studies of canopy arthropods in Red Oaks in eastern Tennessee.

It is hypothesized that canopy sampling using a flight-interception trap will reveal an extremely diverse insect community, some canopy-specific arthropod species, and a difference in the taxa found in the two distinct habitats. Based on prior research published on Red Oaks in east Tennessee, it is also predicted that the Asiatic Oak Weevil will be one of the dominant beetle species collected.

CHAPTER II

MATERIALS AND METHODS

Permission to conduct the study was granted by the Human and Animal Participants Committee of Maryville College. Documentation of this request is included in Appendix A. Beginning June 2, 2005, a composite flight-interception trap was placed in the canopy and understory of four Southern Red Oak (*Quercus falcata* Michaux) trees in the Maryville College Woods over an eight week sampling period. Two of the trees were located on top of a low, dry ridge and the other two were located at the bottom of the ridge on the floodplain of a small creek. The habitat for each sample tree is shown in Table 1. The habitats differed substantially in their amount of moisture and surrounding vegetation. The floodplain was very moist during periods of rain and supported denser vegetation. The ridge top remained

Table 1. Habitat, Sampling Dates, and Sampling Heights of Southern Red Oak Trees in the Maryville College Woods.

Tree Number	Location/Habitat	Sampling Dates		Canopy Sampling Height(m)*
1	Ridge	Understory	6/2-6/9	11.9m
		Canopy	6/9-6/16	
2	Floodplain	Understory	6/22-6/29	9.1m
		Canopy	6/29-7/6	
3	Ridge	Understory	7/15-7/22	11.9m
		Canopy	7/22-7/29	
4	Floodplain	Understory	8/1-8/8	11.6m
		Canopy	8/8-8/15	

* All canopy sampling heights were estimated using a Suunto clinometer.

relatively dry and had sparser vegetation. The locations of the four sample trees are mapped in Appendix B. The Southern Red Oaks sampled were chosen based on habitat type, accessibility, and whether branches of suitable size were positioned adequately to enable trap placement.

The composite flight-interception trap used was purchased from Sante Traps in Lexington, Kentucky. The 1.2 x 2.7m trap consisted of a PVC pipe frame fitted with mesh netting that was black on the sides and bottom and white on the top to allow light through and draw the insects upward. The netting had removable 500mL collecting bottles attached to the top and bottom which were filled with 100% ethanol to serve as a killing agent.

The procedure used to hang the trap was duplicated in each sample tree. The trap was placed in a tree with the use of a slingshot, a metal weight, 20lb. test fishing line, and 30.5m lengths of nylon rope. The weight, attached to the fishing line, was shot over the desired branch with the slingshot. Once it was over the branch, a rope was tied to the fishing line in place of the weight and pulled back over the branch. The trap was then attached to the rope and raised or lowered as needed. An additional rope was attached to the side of the trap and secured to another tree to provide stability in strong winds. This procedure was repeated every two weeks when the trap was moved to a new tree.

Throughout the course of the study, all four trees were sampled according to an identical procedure. First, the trap was placed in the understory so that its top collecting bottle was at a height of approximately 3.5m and its bottom collecting bottle was at least 0.5m above the ground to prevent its being disturbed by small animals.

After one week the trap was lowered and the contents of both collecting bottles were emptied and taken back to the laboratory in Sutton Science Center where they were filtered, sorted according to Order, and stored at room temperature in dry, glass jars and petri dishes until they could be identified. The collecting bottles were then refilled with 100% ethanol, and the trap was raised to the canopy of the tree so that the top collecting bottle was at a height of approximately 12m. The heights of the canopy sampling for each tree are presented in Table 1. After one week in the canopy, the collecting bottles were emptied and their contents were taken back to the laboratory. The trap was then moved to the next tree and the sampling bottles were refilled with ethanol. This procedure was repeated every two weeks in each of the four sample trees to produce a total of eight samples from June to August, 2005. Sampling dates are presented in Table 1.

Once specimens had dried sufficiently, they were identified to Family using a dissecting microscope. Nomenclature followed <u>A Field Guide to Insects</u> (Borror & White, 1970), <u>A Field Guide to the Beetles of North America</u> (White, 1983), <u>A Field Guide to Eastern Butterflies</u> (Opler, 1992), and <u>An Introduction to the Study of Insects</u> (Borror, Triplehorn & Johnson, 1992). Those specimens that were difficult to identify to Family were taken to Dr. Ernest Bernard and Senior Research Assistant Renee Follum at the University of Tennessee, Knoxville, for assistance in identification.

Finally, diversity indices were calculated to make comparisons between samples. Simpson’s and Shannon’s diversity indices were calculated for the canopies combined, the understories combined, and each habitat. The Sorenson quantitative coefficient of similarity was calculated to compare all canopies versus all understories, ridgetop versus floodplain, ridgetop canopies versus floodplain canopies, and ridgetop understories versus floodplain understories.

CHAPTER III

RESULTS

A total of 2,142 insects were collected from 11 Orders and 65 Families. Three Orders contained 85% of the total number of specimens collected. The Coleoptera comprised 32% of the total, whereas the Lepidoptera and Homoptera made up 29% and 24%, respectively. A list of the number of specimens collected in all taxa encountered in the study is presented in Appendix C. Figure 1 presents the total number of specimens collected in each Order. Figure 2 compares the number of specimens found in all canopies and all understories according to Order. Coleoptera, Homoptera, and Hymenoptera each had about 25% more individuals collected in the understories than the canopies. A large number of Lepidoptera were also collected, but there was little difference between the numbers found in the canopies and understories. Three Orders, the Mecoptera, Neuroptera, and Orthoptera, were found only in the canopies, whereas the Odonata was found only in the understories.

The number of individuals in each Family from all of the canopies is presented along with those from all of the understories in Figure 3. The canopies had a Simpson's diversity index of 0.88 and Shannon's index of 1.21. The understories had a Simpson's diversity index of 0.90 and a Shannon's index of 1.21. Simpson's index indicates that there is only a 3% difference between the canopies and understories in the probability that two randomly selected individuals will belong to different Families. This means that these two communities are not very

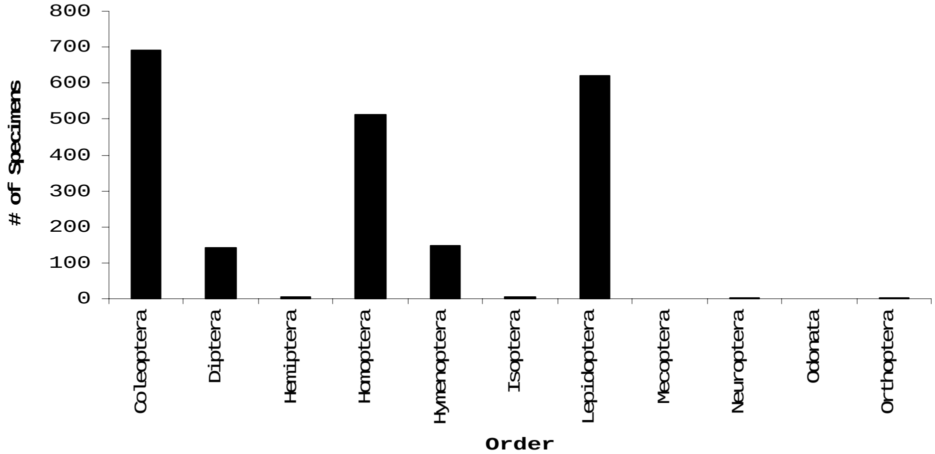


Figure 1. Total Number of Insects Collected from Four Southern Red Oaks in the Maryville College Woods, According to Order.

different in their levels of diversity. Sorenson's coefficient of similarity comparing the canopies with the understories was 67%, which means that they share 67% of the Families found in them. There were considerably more individuals belong to the Curculionidae, Ptilodactylidae, Cercopidae, Cicadellidae, Formicidae, and Pyralidae in

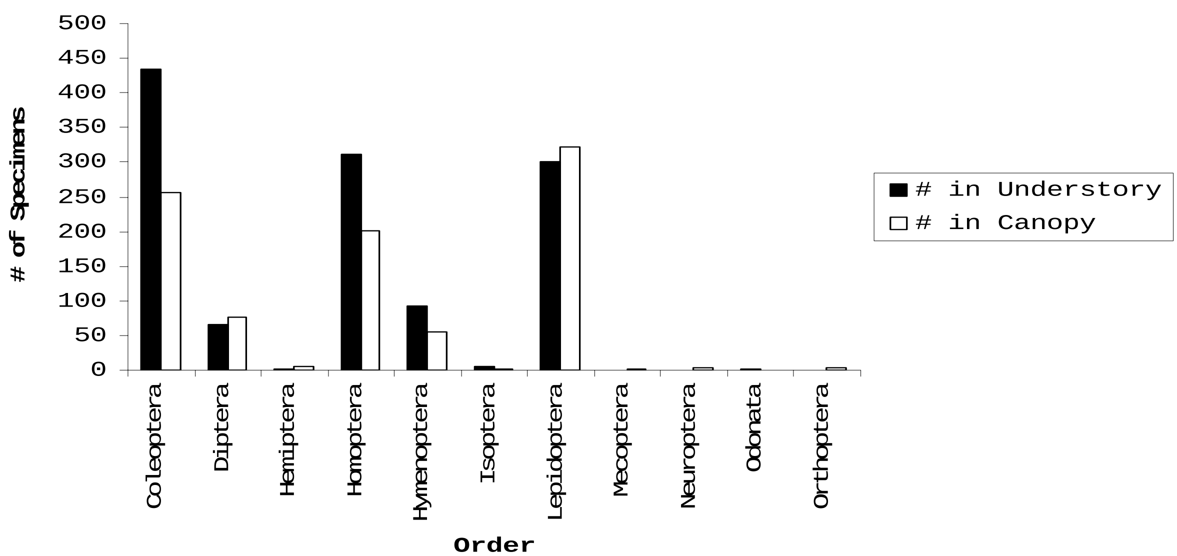


Figure 2. Total Number of Insects Collected in the Canopies of Four Southern Red Oaks in the Maryville College Woods Compared to Those Collected in Their Understories, According to Order.

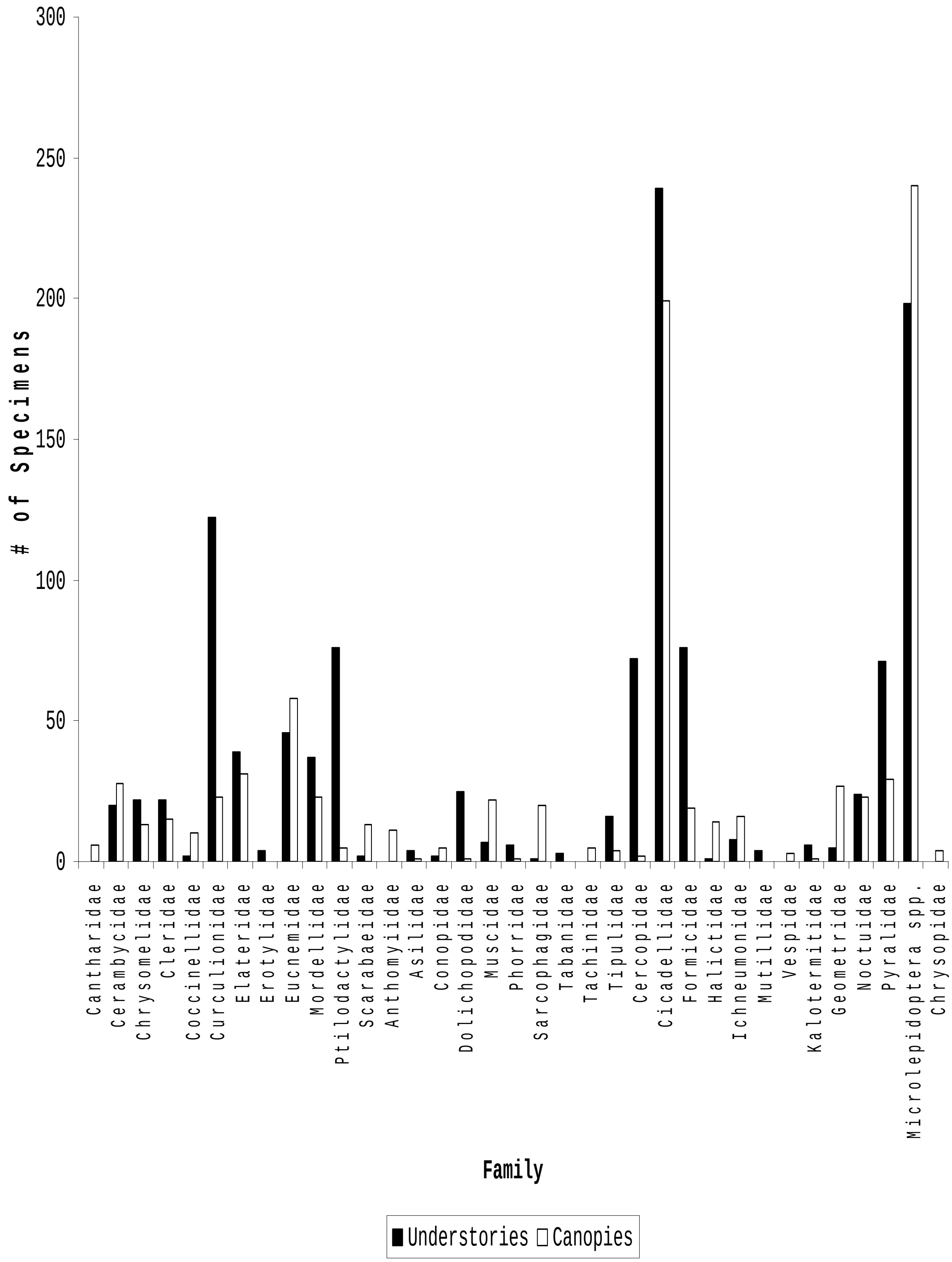


Figure 3. Number of Specimens Collected in Each Family in the Canopies of Four Southern Red Oaks in the Maryville College Woods Compared to Those Collected in Their Understories.

the understories than in the canopies. However, the canopies had a greater number of Sarcophagidae, Geometridae, and unidentified Microlepidoptera species.

The number of individuals in each Family from all ridgetop sample trees is presented along with those from all floodplain sample trees in Figure 4. The ridgetop sample trees had a Simpson's diversity index of 0.87 and a Shannon's index of 1.17. The floodplain sample trees had a Simpson's index of 0.91 and a Shannon's index of 1.22. Simpson's index indicates that there is a 4% difference in the diversity of the ridgetop and floodplain. Sorenson's coefficient of similarity comparing the ridgetop and floodplain was 59%, indicating that they have 59% of their Families in common. The ridgetop sample trees had a much greater number of Dolichopodidae, Cercopidae, Cicadellidae, Noctuidae, Pryalidae, and unidentified Microlepidoptera species. The floodplain sample trees had noticeably higher numbers of Ptilodactylidae and Formicidae.

The number of individuals in each Family from the canopies of all ridgetop sample trees is presented along with those of the canopies of the floodplain sample trees in Figure 5. The canopies of the ridgetop sample trees had a Simpson's diversity index of 0.84 and a Shannon's index of 1.10. The canopies of the floodplain trees had a Simpson's diversity index of 0.91 and a Shannon's index of 1.22. Simpson's index shows a 7.5% difference in diversity of the ridgetop and floodplain canopies. Sorenson's coefficient of similarity comparing ridgetop canopies to floodplain canopies was 49%, indicating that they share 49% of the Families found in them. The ridgetop canopies had much greater numbers of Cicadellidae, Noctuidae, Pyralidae, and unidentified Microlepidoptera species, while the floodplain canopies had higher numbers of Eucnemidae and Formicidae.

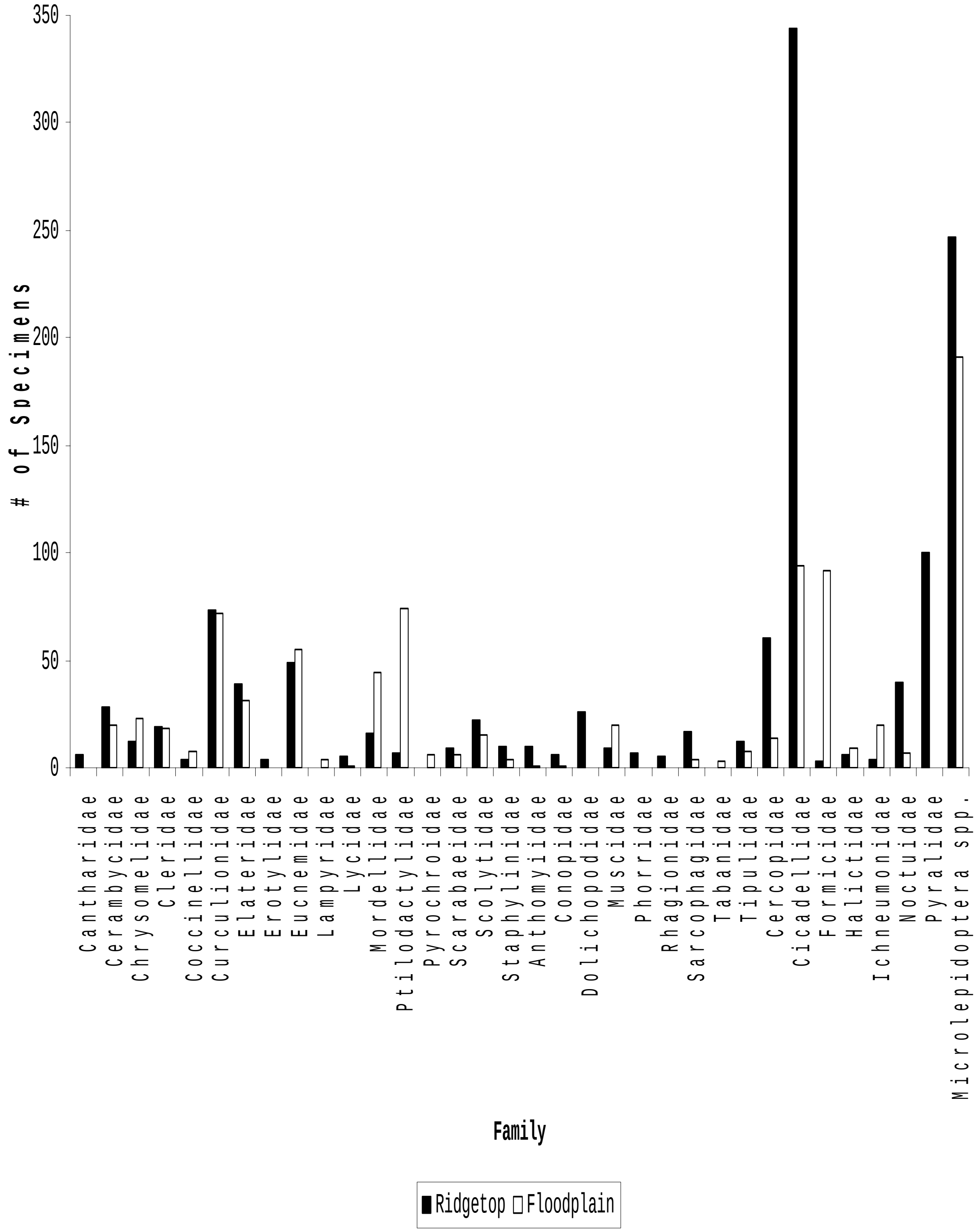


Figure 4. Number of Specimens Collected in Each Family in Ridgetop Southern Red Oaks in the Maryville College Woods Compared to Those Collected from Floodplain Southern Red Oaks.

The number of individuals in each Family from the understories of all ridgetop sample trees is presented along with those of the understories of the floodplain sample trees in Figure 6. The understories of the ridgetop sample trees had a Simpson's diversity index of 0.88 and a Shannon's index of 1.13. The understories of the floodplain sample trees had a Simpson's index of 0.89 and a Shannon's index of 1.12. Simpson's index shows only a 1% difference in diversity between the two areas. Sorenson's coefficient of similarity comparing ridgetop understories to floodplain understories was 52%, which means they have 52% of their Families in common. Ridgetop understories had much larger numbers of Dolichopodidae, Cercopidae, Cicadellidae, and Pyralidae compared to the floodplain. Floodplain understories, however, had larger numbers of Ptilodactylidae, Formicidae, and unidentified Microlepidoptera species.

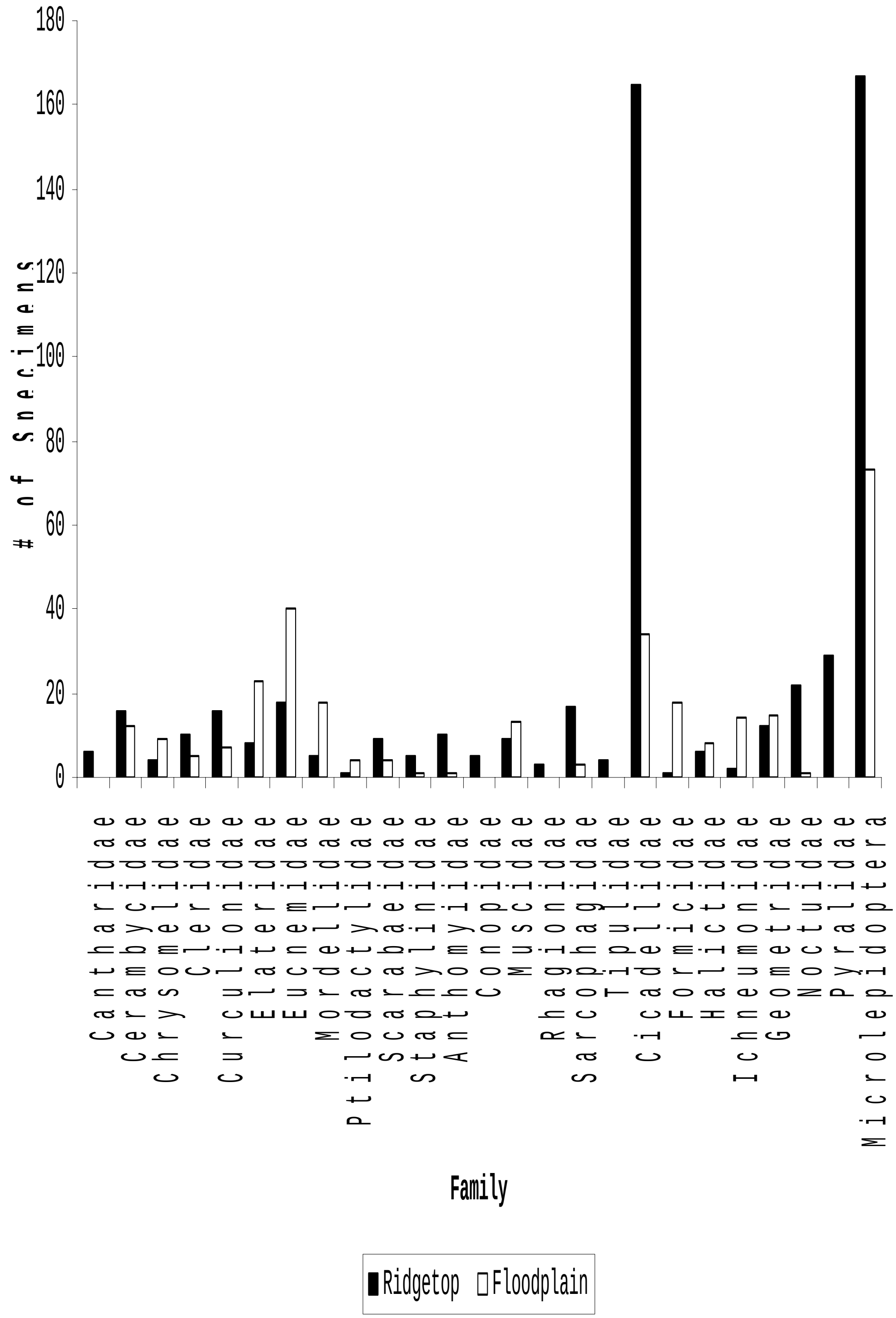


Figure 5. Number of Specimens Collected in Each Family in the Canopies of Ridgetop Southern Red Oaks in the Maryville College Woods Compared to Those Collected from the Canopies of Floodplain Southern Red Oaks.

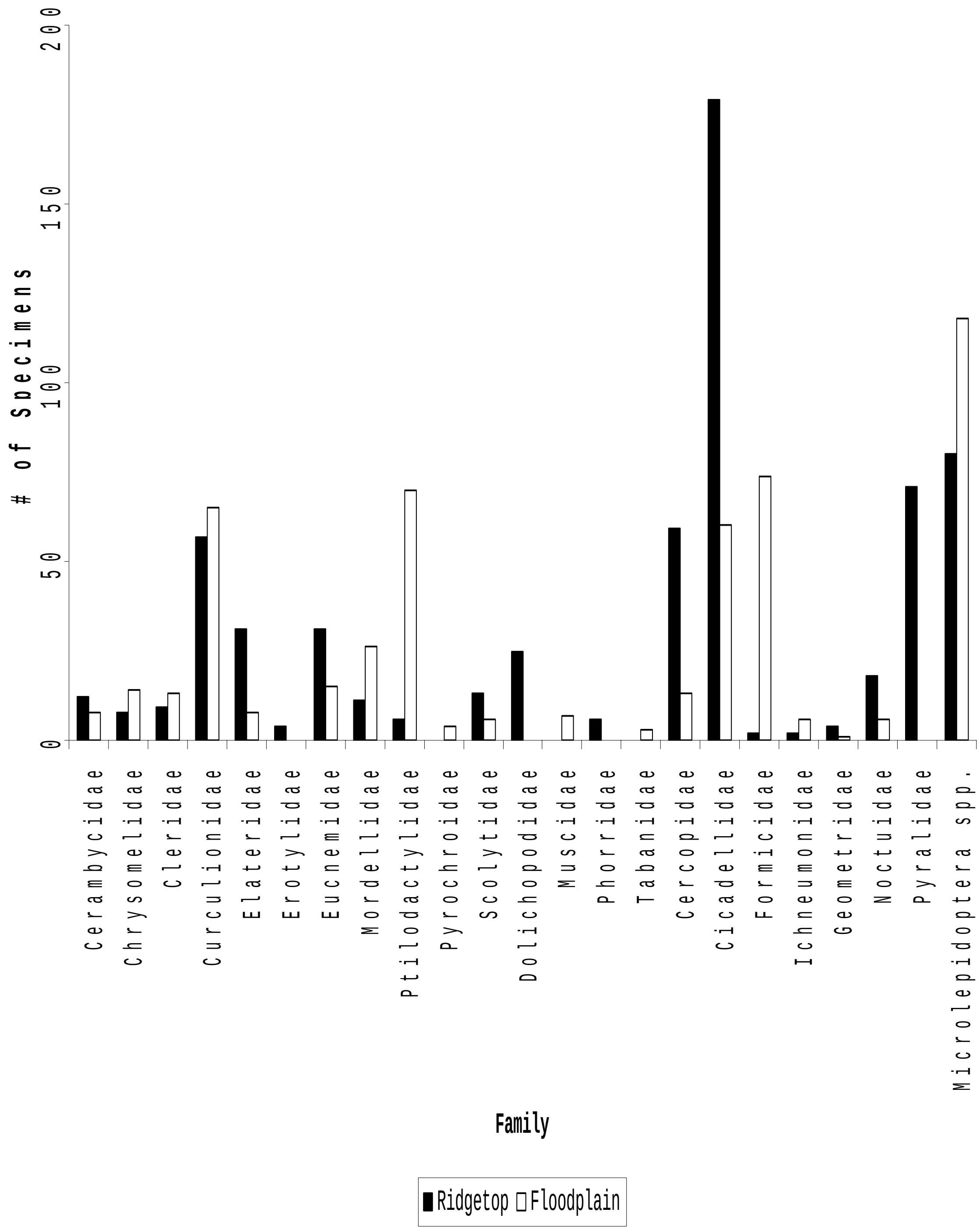


Figure 6. Number of Specimens Collected in Each Family in the Understories of Ridgetop Southern Red Oaks in the Maryville College Woods Compared to Those Collected in the Understories of Floodplain Southern Red Oaks.

CHAPTER IV

DISCUSSION

After all data were analyzed, 2,142 total insects were collected and identified from 11 Orders and 65 Families (see Appendix C). The Coleoptera was the largest Order, comprising 24 of the 65 Families caught and 32.3% of all insects identified (see Figure 1). Three of the Orders collected were found only in the canopy and one was found only in the understory (see Figure 2). The Mecoptera, Neuroptera, and Orthoptera were found only in the canopy in this study, however, it cannot be assumed that these Orders are always or even generally canopy-specific. In fact, the Orthoptera contains many Families that can be found in the understory (Borror & White, 1970). The very small numbers of insects collected in these Orders further emphasizes that they cannot be assumed to be canopy-specific. Families that were found only in the canopy include the Cantharidae, Platypodidae, Anthomyiidae, Calliphoridae, Lauzaniidae, Syrphidae, Tachinidae, Pentatomidae, Evaniidae, Vespidae, Agaristidae, Nymphalidae, Bittacidae, Chrysopidae, Blattidae, and Gryllidae (see Figure 3). Like the Orders found only in the canopy, these Families cannot be assumed to be canopy-specific due to the small numbers collected and their known ground-dwelling species (Borror & White, 1970). Some of these Families may contain canopy-specific species, however, identifications were not made to the species level. The hypothesis that there would be some canopy-specific taxa was supported within the study, however the findings cannot be generalized.

It was also hypothesized that canopy sampling using a flight-interception trap would reveal both an extremely diverse insect community, and a difference in the taxa found in the two distinct habitats. The ridgetop habitat had much higher numbers of Dolichopodidae, Cercopidae, Cicadellidae, Noctuidae, Pyralidae, and unidentified Microlepidoptera (see Figure 4). The floodplain habitat had higher numbers of Mordellidae, Ptilodactylidae, and Formicidae (see Figure 4). The noticeable differences could be attributed to higher numbers of Lepidoptera in Tree 1, Cicadellidae in Tree 3, Ptilodactylidae in the Tree 2 understory, and Eucnemidae in the Tree 2 canopy (see Appendix C). There was also a much lower number of total insects collected from the Tree 4 canopy (see Appendix C).

The much higher number of Ptilodactylidae in the understory of Tree 2 in the floodplain habitat is readily explained by their biological characteristics. Ptilodactylidae live in riparian or semi-aquatic habitats, with most larvae having adaptations for survival under water or occurring in the leaf litter of wetter environments (Lawrence, Hastings, Paine & Zurcher, 2000). Lawrence et al.(2000) state that adults, which were caught in this study, are often collected on riparian vegetation or in flight-intercept traps. Therefore, their preference for wetter environments explains the greater numbers of Ptilodactylidae caught a habitat that often floods.

There was also a difference found in the total number of insects collected in the understory versus the canopy. The understory trapping periods captured 1,214 insects compared to 928 in the canopy trapping periods (see Figure 3). Ridgetop canopies had higher numbers of Cicadellidae, Noctuidae, Pyralidae, and unidentified Microlepidoptera, while floodplain canopies had greater numbers of Elateridae, Eucnemidae, Formicidae, and Ichneumonidae (see Figure 5). Ridgetop understories had greater numbers of Dolichopodidae, Cercopidae, Cicadellidae, and Pyralidae when compared to floodplain understories. Floodplain understories had higher numbers of Ptilodactylidae, Formicidae, and unidentified Microlepidoptera (see Figure 6). Vance et al.(2003) observed similar species richness in a Canadian temperate forest between trap heights. They also found that understory traps accumulated significantly higher abundances than canopy traps.

Although visual inspection of the figures indicated several distinct differences between canopy and understory and between the two habitat types, there was little difference in the Simpson’s and Shannon’s diversity indices calculated for the combined sampling sites. Simpson’s diversity index expresses the probability of two randomly selected individuals belonging to different families (Magurran, 1988). Although the diversity for each pair of sampling sites seems high, when Simpson’s index was applied there was little difference in diversity between sampling sites. According to Simpson’s index, the biggest difference was between the ridgetop and floodplain canopies. The ridgetop canopies had an 83.5% probability of randomly selecting two individuals from different Families, whereas that of the floodplain canopies was 91%. This equates to a 7.5% difference in diversity between the two areas.

When Shannon’s index was applied, results were obtained similar to those calculated by Simpson’s index. Unlike Simpson’s index, which expresses probability, Shannon’s index gives a measure of diversity that is relative to the other areas measured. Like Simpson’s index, the Shannon index revealed the largest difference as being between the ridgetop and floodplain canopies. There was a difference of 0.12 between these two areas, whereas all other differences between compared sampling sites were much smaller.

Sorenson’s Coefficient of Similarity for quantitative data revealed some differences between communities. Sorenson’s coefficient is calculated for a value between 0 and 1.0, which represents the percentage of Families found in both communities (Magurran, 1988). Therefore, the closer the index value is to one, the more similar the communities are. The comparison made between all canopies and all understories had a Sorenson’s index value of 0.67, meaning that these areas were 67% similar. This comparison revealed the most similarity, while all ridgetop samples compared to all floodplain samples had an index of 0.59. The areas become even less similar when the ridgetop and floodplain canopies and understories are compared. The ridgetop and floodplain canopies had a Sorenson’s index value of 0.49 and the understories had a value of 0.52. Therefore, the ridgetop and floodplain canopies were the two communities that differed most in the number of Families represented and the number of insects within those Families. The diversity indices supported the hypothesis that there would be differences between the sampling areas, although those differences were not as pronounced as anticipated.

In addition, it was hypothesized that the Asiatic Oak Weevil (*Cyrtepisomus castaneus*) would be one of the most abundant beetle species collected. The number of Asiatic Oak Weevils collected was unexpectedly low and the data did not support this hypothesis. There were only 21 Asiatic Oak Weevils found in all of the sampling areas combined, accounting for only 0.03% of all Coleoptera collected. This percentage was much lower than those found by Trieff (2002) and Stanton (1994). Trieff (2002) found that Asiatic Oak Weevils made up 18.68% of all beetles collected, while Stanton (1994) found that this species comprised 25% of his total sample. The difference between the percentages of Asiatic oak weevils found in this study and other similar studies performed in the area is probably the result of differences in sampling method. Trieff (2002) and Stanton (1994) both used fogging to sample. A fogging sampling method has an advantage over a flight-interception trap because the trap is only designed to catch insects that fly. Using a fogging method would effectively sample all insects present in the tree, whether they are engaged in flight or not. *Cyrtepistomus castaneus* are not known to be active flyers, which may explain the small number caught in the flight-interception trap (Ohio State, 2000). If more accurate counts of the abundance of this species are desired, it would be beneficial to use another sampling method that they are known to find more attractive, such as light traps or shallow pans of water (Ohio State, 2000). Bloem, Mizell, and O'Brien (2002) caught Asiatic Oak Weevils using traps that either sat on the ground and mimicked a tree or caught adults as they crawled up a tree trunk. They noted that pecan weevils, a species very similar to the Asiatic Oak weevil, have been shown to reach their position in pecan trees by walking up the tree trunk rather than flying after they emerge from their pupa stage in the ground (Raney & Eikenbary as cited in Bloem et al., 2002). Similar behavior has been observed in many weevils that attack fruit and nut trees (Bloem et al., 2002). This study further supports the idea that *C. castaneus* may fly only occasionally. The few Asiatic Oak Weevils that were caught in this study made up 15.7% of the Curculionidae collected. Even though there were not many Asiatic Oak Weevils, Curculionidae accounted for 19.4% of all beetles collected (see Appendix C). Interestingly, there was a much higher number of Curculionidae found in the understory (122) than the canopy (23) (see Figure 3). Many of the weevils collected seemed to be the same species, but no effort was made to identify any weevils other than *C. castaneus* to the species level. Although the number collected was much lower than expected, there were Asiatic Oak Weevils present in the sampling areas. The true population may be severely underestimated due to the sampling method.

Throughout the course of the study, there were several sources of error that could have affected the results obtained. The sampling method used presented many variables that could have impacted the amount and types of insects collected. Although it has been shown in previous studies that the composite flight interception trap is effective for catching a wide variety of insects, it is biased toward insects that fly. Therefore, numbers of insects collected from Families that do not routinely fly, such as ants, are not representative of the actual number present. The number of insects caught from these Families is solely dependent on the surrounding vegetation, because the trap must be close enough to a branch for non-flying insects to crawl onto it. The surrounding vegetation itself also posed the problem of ensuring that the insects collected came from Southern Red Oak trees. Other inherent errors of the trap include the susceptibility of the bottom collecting bottle to weather and precipitation. Often the bottom collecting bottle would fill up with rain water, possibly enabling some insects to climb out, and was also easily clogged by debris from high winds.

Sources of error in the design of the study may include the time of year and the behavior or lifecycle of certain insects. For example, some insects are seasonal and are more abundant at times when sampling did not occur. Also, certain insects may have been present but in juvenile stages when they are not mobile enough to get into the trap. Finally, there was one occasion in an understory sampling period where a small animal was able to reach the bottom collecting bottle, ripping a few small holes in the netting that may have enabled insects to climb out.

Overall, the hypotheses proposed at the onset of this study were generally supported. However, differences between the sampling areas were not as great as expected. Lower levels of diversity were probably due to a lack of the structural or environmental distinction between the canopy and understory that is so prevalent in tropical rainforests (Basset et al., 2003b). It has been documented that vertical stratification of temperate forests is often less pronounced than that typically found in tropical rainforests or can be nonexistent (Basset et al., 2003b). The level of stratification in temperate forests is just one of many areas that still need to be examined in order for scientists to gain a better understanding of canopy ecology. Although canopy studies are not a new idea, there is still much to learn about the organisms that live there, their relationship to the environment, and how they can be conserved.

REFERENCES

Basset, Y., Novotny, V., Miller, S. E., & Kitching, R. L. (2003a). Canopy entomology, an expanding field of natural science. In Y. Basset, V. Novotny, S. E. Miller, & R. L. Kitching (Eds.), Arthropods of tropical forests: Spatio-temporal dynamics and resource use in the canopy (pp. 4-6). Cambridge, UK: Cambridge University Press.

Basset, Y., Hammond, P. M., Barrios, H., Holloway, J. D., & Miller, S. E. (2003b). Vertical stratification of arthropod assemblages. In Y. Basset, V. Novotny, S. E. Miller, & R. L. Kitching (Eds.), Arthropods of tropical forests: Spatio-temporal dynamics and resource use in the canopy (pp. 17-27). Cambridge, UK: Cambridge University Press.

Basset, Y., Springate, N. D., Aberlenc, H. P., & Delvare, G. (1997). A review of methods for sampling arthropods in tree canopies. In N. E. Stork, J. Adis, & R. K. Didham (Eds.), Canopy arthropods (pp. 27-52). New York: Chapman & Hall.

Bloem, S., Mizell, R. F., & O'Brien, C. W. (2002). Old traps for new weevils: New records for Curculionids, Brentids, and Anthribids from Jefferson Co., Florida [Electronic Version]. Florida Entomologist, 85(4), 632-644. Retrieved November 3, 2005 from BioOne: https://bioone.org/.

Borror, D. J., Triplehorn, C. A., & Johnson, N. F. (1992). An introduction to the study of insects. New York: Saunders College Publishing.

Borror, D. J., & White, R. E. (1970). A field guide to insects: America north of Mexico. New York: Houghton Mifflin.

Erwin, T. L. (1995). Measuring arthropod biodiversity in the tropical forest canopy. In M. D. Lowman & N. M. Nadkarni (Eds.), Forest canopies (pp. 109-127). New York: Academic Press.

Erwin, T. L. (2004). The biodiversity question: How many species of terrestrial arthropods are there? In M. D. Lowman & H. B. Rinker (Eds.), Forest canopies (2nd ed., pp. 259-269). New York: Elsevier.

Hingston, R. G. (1930). The Oxford University expedition to British Guiana. [Electronic Version]. The Geographical Journal, 76(1), 1-20. Retrieved March 28, 2005 from JSTOR: http://www.jstor.org.

Lawrence, J. F., Hastings, A. M., Dallwitz, M. J., Paine, T. A., & Zurcher, E. J. (2000). Elateriformia (Coleoptera): descriptions, illustrations, identification, and information retrieval for families and subfamilies. Retrieved November 2, 2005, from http://delta-intkey.com.

Magurran, A. E. (1988). Ecological diversity and its measurement. Princeton: Princeton UP.

Mastrantonio, J. L. & Francis, J. K. (1997). A student guide to tropical forest conservation. Retrieved April 16, 2005, from http://www.fs.fed.us/global/lzone/student/tropical.htm.

Mortimer, M. (2004). Forest regulations in the USA: Evolving standards for conserving forest biodiversity in the last 300 years. In O. Honnay, K. Verheyen, B. Bossuyt, & M. Hermy (Eds.), Forest biodiversity: Lessons from history for conservation (pp. 269-280). Cambridge, MA: CABI Publishing.

Ohio State University Department of Entomology. (2000). Root weevils and their relatives. Retrieved October 31, 2005, from http://ohioline.osu.edu/hyg-fact/2000/2069.html.

Opler, P. A. (1992). A field guide to eastern butterflies. New York: Houghton Mifflin.

Simon, U., Gossner, M., & Linsenmair, K. E. (2003). Distribution of ants and bark-beetles in crowns of tropical oaks. In Y. Basset, V. Novotny, S. E. Miller, & R. L. Kitching (Eds.), Arthropods of tropical forests: Spatio-temporal dynamics and resource use in the canopy (pp. 59-68). Cambridge, UK: Cambridge University Press.

Stanton, R. C. (1994). Insect diversity and abundance within the canopy of a Northern Red Oak orchard in Eastern Tennessee. Unpublished master's thesis, University of Tennessee, Knoxville, Tennessee.

Trieff, D. (2002). Composition of the Coleopteran and associated insects collected by canopy fogging of Northern Red Oak trees in the Great Smoky Mountains National Park and the University of Tennessee Arboretum. Unpublished master's thesis, University of Tennesee, Knoxville, Tennessee.

USDA Forest Service. (2000). U. S. forest facts and historical trends. Retrieved April 16, 2005, from http://www.fs.fed.us/publications/.

Vance, C. C, Kirby, K. R., Malcom, J. R., & Smith, S. M. (2003). Community composition of Longhorned Beetles in the canopy and understory of Sugar Maple and White Pine stands in south-central Ontario [Electronic version]. Environmental Entomology, 32(5), 1066-1074. Retrieved February 20, 2005 from BioOne: https://bioone.org/.

White, R. E. (1983). A field guide to the beetles of North America. New York: Houghton Mifflin.

Winchester, N. N. (1997). Canopy arthropods of coastal Sitka Spruce trees on Vancouver Island, British Columbia, Canada. In N. E. Stork, J. Adis, & R. K. Didham (Eds.), Canopy arthropods (pp. 151-168). New York: Chapman & Hall.

MARYVILLE COLLEGE
HUMAN AND ANIMAL SUBJECTS REVIEW COMMITTEE
ANIMAL STUDY APPLICATION FORM

1. Student Name: Jenna Wade
2. Date: March 15, 2005

3. Senior Thesis Advisor: Threadgill

4. Pain or Distress Category: B (See listing of Pain or Distress Categories below)

For categories C,D, or E, USDA regulations require that the investigator consider alternative procedures. Please provide a narrative (for instance the end of Chapter 1) describing the methods and sources used to determine that alternatives are not available. If a computer assisted literature search was conducted, provide the names of the database(s) and date(s) of the search.

PAIN OR DISTRESS CATEGORIES

A. ACUTE STUDIES
Studies performed under anesthesia from which the animals are not permitted to regain consciousness, or performed on excised animal tissues collected under anesthesia or following euthanasia.

B. PAIN OR DISTRESS - NONE OR MINOR
Chronic studies that DO NOT involve survival surgery, induction of painful or stressful disease conditions, or pain or distress in excess of that associated with routine injections or blood collection. Included are induction or transplantation of tumors in animals (so long as the tumors do not cause pain and the animals are terminated prior to becoming seriously ill), administration of mildly toxic substances or drugs that cause no significant disease or distress, and antibody production as long as significant disease does not result and antigen booster doses do not include Complete Freund's Adjuvant (CFA).

C. PAINFUL PROCEDURES WITH ANESTHESIA/ANALGESIA
a. Survival surgical procedures.
b. Painful or potentially painful non-surgical procedures; e.g. bone marrow taps, injections into particularly sensitive areas such as foot pads, cardiac punctures, or traumatic procedures such as burns (burns may be category D, depending on severity).

D. MODERATE DISTRESS OR PAIN GENERALLY WITHOUT ANESTHESIA/ ANALGESIA/ TRANQUILIZERS
Induction of moderately distressful or painful disease conditions (examples: arthritis, administration of toxic chemicals, infectious challenges, immunosuppression resulting in infectious disease, peritonitis, severe inflammation, especially of weight bearing surfaces or resulting in external sores), whole body irradiation, stress models, septic shock, hypotensive shock, moderate painful stimuli (examples: low level electrical shock or heat), survival surgical procedures that have the potential to result in long term distressful illness (organ transplants, for example), induction of cardiac ischemia, booster immunizations with CFA, tumor induction or animal cultures that cause significant distress or pain, sight deprivation, restraint for periods longer than 12 hours.

E. INTENSE SUSTAINED OR REPEATED PAIN WITHOUT ANESTHESIA/ANALGESIA
Direct stimulation of CNS pain tracts, nociceptor stimulation by physical or chemical means that causes severe pain (e.g., corneal abrasions), or any category C (see above) procedure if performed without chemical relief of pain.

5. Species to be used variety of insects

6. Age of animals adults

7. Number of animals in study hundreds expected

8. Duration of study June – August 2005

9. Location of animals during the study (building and room) Maryville College Woods

10. List personnel to call if problems with animals develop:

Name	Daytime Phone	Nighttime Phone	Emergency No.
Jenna Wade	865-982-0399	865-300-0739	865-982-0399

Investigator Assurance

The information provided in this protocol form accurately reflects the intended use of animals for this research activity. Significant changes in procedures will not be undertaken without prior notification and approval of the Human and Animal Subjects Review Committee.

All persons involved in the use of animals on this protocol have been informed of the experimental objectives and methods. Each has received training in the execution of animal-related procedures he/she will perform prior to participation in the protocol, and will participate in any educational or training programs deemed appropriate or necessary by the Human and Animal Subjects Review Committee.

I agree to follow the provisions of the Animal Welfare Act and the guidelines of the National Institutes of Health on the care and use of laboratory animals.

I agree to use anesthesia, analgesia and tranquilization to relieve pain or distress whenever use of these agents will not jeopardize the scientific validity of the data. I have specifically consulted with the Human and Animal Subjects Review Committee regarding any experiments that are classified in pain/distress categories C, D, or E.

I will take appropriate steps to avoid exposure of persons working with these animals to any biohazardous agents used in the study.

State the reasons if you cannot attest to the accuracy of any of these statements:

11. HUSBANDRY REQUIREMENTS: Is anything other than routine care and equipment required?
YES___ No _x_ If "YES", please list below.

12. Is it likely that pain/discomfort will be experienced by animals in this protocol?
YES___ NO_x_____If "YES", describe:

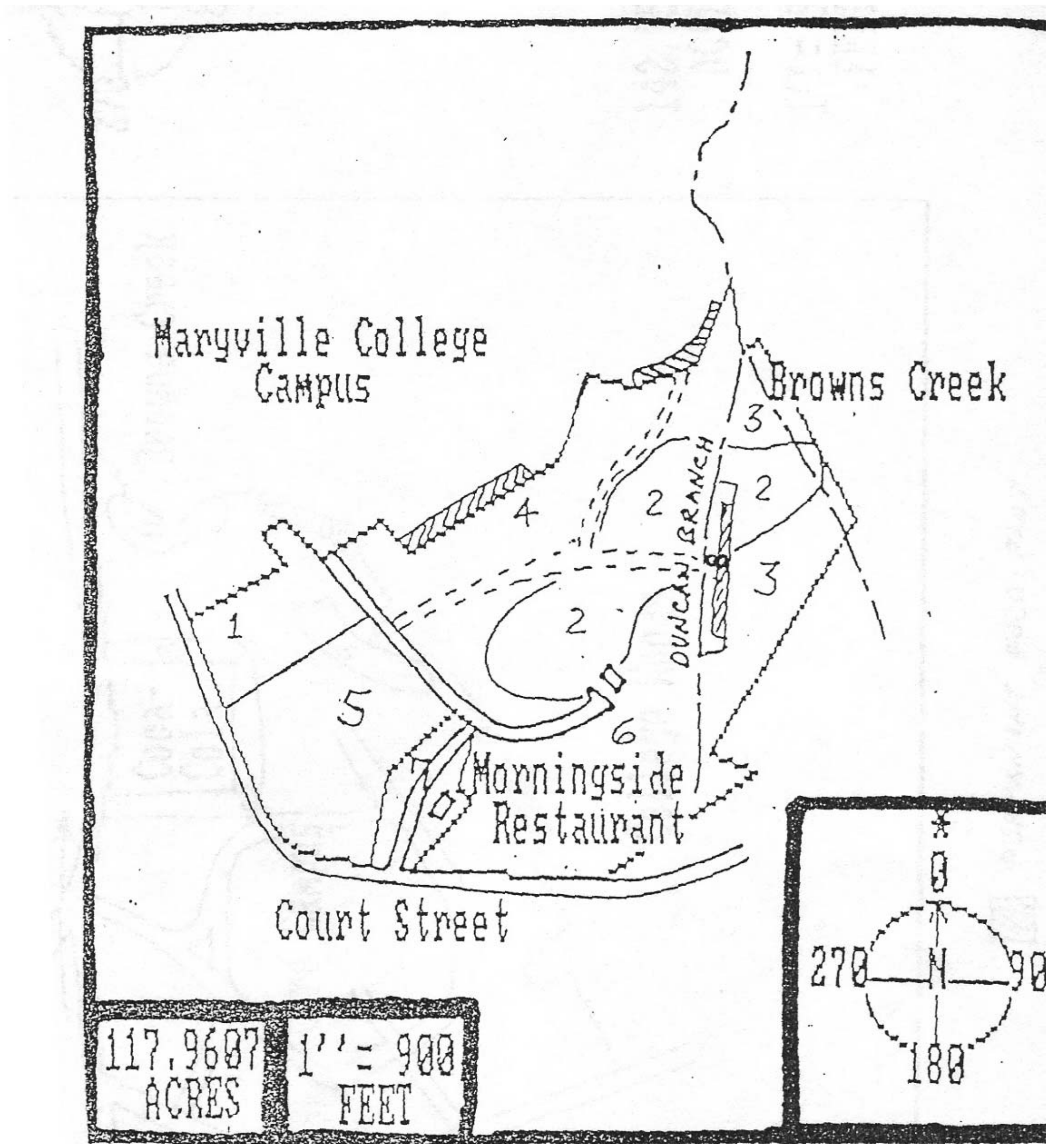
13. What will happen to the animals at the end of the study? If euthanasia is required, state the methods.
Animals will be euthanized in 100% alcohol

14. Briefly describe your proposed research project (or attach a research proposal). Be sure to include a justification for the species and number.

I am going to use an aerial malaise trap to sample insects in the canopy and understory of red oak trees in the Maryville College woods. Insects fly into the trap and into a bottle containing alcohol. There are no known endangered insects in the sample area.

This project has been reviewed and approved by the Maryville College Human and Animal Use Committee.

March 20, 2005



Appendix B. Maryville College Stewardship Plan – Woodland Area.

Order	Family	Tree 1 Understory	Tree 1 Canopy	Tree 2 Understory	Tree 2 Canopy	Tree 3 Understory	Tree 3 Canopy	Tree 4 Understory	Tree 4 Canopy
Coleoptera	Anthribidae	1	0	0	0	0	0	0	0
	Cantharidae	0	6	0	0	0	0	0	0
	Carabidae	0	0	0	0	0	0	1	0
	Cerambycidae	4	13	4	12	8	3	4	0
	Chrysomelidae	1	1	11	2	7	3	3	7
	Cicindelidae	1	0	0	0	0	0	0	0
	Cleridae	6	7	7	4	3	3	6	1
	Coccinellidae	0	3	1	6	0	1	1	0
	Cucujidae	1	0	0	0	0	0	0	0
	Curculionidae	39	3	6	1	18	13	59	6
	Elateridae	19	4	3	22	12	4	5	1
	Erotylidae	3	0	0	0	1	0	0	0
	Eucnemidae	19	14	12	40	12	4	3	0
	Lagriidae	1	1	0	0	0	0	0	0
	Lampyridae	0	0	2	2	0	0	0	0
	Lycidae	2	2	1	0	1	0	0	0
	Mordellidae	6	5	26	18	5	0	0	0
	Mycetophagidae	1	0	0	0	0	0	0	0
	Platypodidae	0	0	0	0	0	1	0	0
	Ptilodactylidae	0	1	68	3	6	0	2	1
	Pyrochroidae	0	0	3	0	0	0	1	2
	Scarabaeidae	0	1	1	4	0	8	1	0
	Scolytidae	10	4	3	3	3	5	3	6

	Staphylinidae	3	4	0	1	2	1	3	0
Diptera	Anthomyiidae	0	10	0	1	0	0	0	0
	Asilidae	2	0	2	0	0	0	0	1
	Calliphoridae	0	0	0	1	0	0	0	0
	Conopidae	0	4	1	0	1	1	0	0
	Dolichopodidae	25	1	0	0	0	0	0	0
	Lauzaniidae	0	1	0	0	0	0	0	0
	Muscidae	0	7	6	11	0	2	1	2
	Phorridae	6	1	0	0	0	0	0	0
	Rhagionidae	2	3	0	0	0	0	0	0
	Sarcophagidae	0	11	0	3	0	6	1	0
	Syrphidae	0	1	0	0	0	1	0	0
	Tabanidae	0	0	2	0	0	0	1	0
	Tachinidae	0	3	0	2	0	0	0	0
	Tipulidae	8	1	6	0	0	3	2	0
Hemiptera	Pentatomidae	0	2	0	0	0	0	0	0
	Reduviidae	0	1	0	1	1	1	0	0
Homoptera	Cercopidae	0	0	0	1	59	1	13	0
	Cicadellidae	54	58	19	29	125	107	41	5
	Membracidae	0	0	0	0	1	0	0	0
Hymenoptera	Chrysididae	1	2	1	0	0	0	1	0
	Evaniidae	0	2	0	0	0	0	0	0
	Formicidae	1	0	16	15	1	1	58	3
	Halictidae	0	6	0	8	0	0	1	0

	Ichneumonidae	1	0	3	3	1	2	3	11
	Mutillidae	2	0	2	0	0	0	0	0
	Tenthredinidae	1	0	0	0	0	0	0	0
	Vespidae	0	1	0	1	0	1	0	0
Isoptera	Kalotermitidae	3	1	0	0	0	0	3	0
Lepidoptera	Agaristidae	0	1	0	0	0	0	0	0
	Apatelodidae	0	0	0	0	1	0	0	0
	Geometridae	3	10	1	14	1	2	0	1
	Noctuidae	13	18	0	0	5	4	6	1
	Nymphalidae	0	0	0	0	0	1	0	1
	Pyralidae	69	25	0	0	2	4	0	0
	Zygaenidae	1	0	0	0	0	0	0	0
	Microlepidoptera	39	131	39	35	41	36	79	38
Mecoptera	Bittacidae	0	0	0	1	0	0	0	0
Neuroptera	Chrysopidae	0	1	0	1	0	1	0	1
Odonata	Calopterygidae	0	0	1	0	0	0	0	0
Orthoptera	Blattidae	0	0	0	2	0	0	0	0
	Gryllidae	0	0	0	0	0	2	0	0
	Total	348	371	247	247	317	222	302	88