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A Study of the Design of Heavy Industrial Concrete Pavements

Christopher Thomas Webster
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Christopher Thomas Webster entitled "A Study of the Design of Heavy Industrial Concrete Pavements." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

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To the Graduate Council:

I am submitting herewith a thesis written by Christopher Thomas Werle entitled "Insects Associated with Southern Magnolia (*Magnolia grandiflora* L.) in East Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Paris L. Lambdin
Paris L. Lambdin, Major Professor

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Insects Associated with Southern Magnolia (*Magnolia grandiflora* L.) in East Tennessee

A Thesis Presented for the Master of Science Degree
The University of Tennessee, Knoxville

Christopher T. Werle
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Abstract

No comprehensive studies have been conducted to assess the insect fauna associated with southern magnolia, *Magnolia grandiflora* L. Thus, a two-year study was initiated in 2000 to: 1) determine the richness and abundance of insect species associated with southern magnolia in East Tennessee, 2) compare the insect fauna collected from upper and lower tree canopy levels during 2001, 3) compare the insect fauna collected from pitfall traps and malaise traps at two sites, 4) compare the floral insect visitors of southern magnolia, and 5) develop a species database for future studies.

The insect fauna associated with southern magnolia was evaluated at two sites: 1) a forest site located at the University of Tennessee Forestry Experiment Station and Arboretum in Anderson Co., TN, and 2) an urban site located on the University of Tennessee Agriculture campus in Knox Co., TN. Insects were collected from six mature trees from November 2000 through June 2002 using four collecting methods (pitfall traps, malaise/pan traps in the upper and lower canopy, floral collection, and canopy fogging).

During this study, 5,757 insect specimens, representing 480 species in 119 families and 12 orders, were collected. Potential insect pests and beneficial predators, parasitoids, and pollinators also were identified. Significantly ($P < 0.05$) greater numbers of insects were collected from the upper canopies of trees than from the lower canopies, possibly due to the more rapid decay of specimens in traps from the upper level, which attracted dipterans in the families Calliphoridae, Muscidae, and Sarcophagidae. The number of species collected in the two canopy levels was similar ($n = 243$ and 230 species in upper and lower canopies, respectively). Significantly ($P < 0.05$) more specimens were collected at the urban site, probably due to more favorable environmental conditions including temperature and food resources. Significantly ($P < 0.05$) greater numbers of species were collected at the forest site, probably due to the greater diversity of plant life and habitat structure. Also, significantly ($P < 0.05$) more specimens and species were collected on the flowers of southern magnolia in 2002 than in the adjusted data (*0.6667) for 2001, in part due to the addition of floral sticky trap samples and collection times.

This newly developed database containing information on species associated with southern magnolia will be helpful to nursery producers, homeowners, and scientists to better understand the incidence and impact of exotic insects or diseases on plant health. This research may facilitate future studies on insect/plant interactions, alternate pest management strategies, biocontrol of pests, or pollination of flowers of southern magnolia.

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Chapter I
Literature Review

The generic name *Magnolia* was adopted by the Swedish botanist Carolus Linnaeus in 1753 when he cited *M. virginiana*, which had been introduced into Europe from America as early as 1688. The name was given to this handsome group of flowering trees as a tribute to the esteemed French botanist Pierre Magnol, who died in 1715. Linnaeus did not name the species *M. grandiflora* L. until 1759, but the tree was previously referenced by Miller (1731), with his description of a flowering (at least three years old) tree planted in gardens near London, indicating that the date of European introduction for this species was not later than 1728. Miller described this garden ornamental as *Magnolia foliis lanceolatis persistentibus caule erecto arboreo*, or *Magnolia* with evergreen spear-shaped leaves and an erect tree-like stalk. In addition, Miller described the newly introduced tree as being "...esteemed as one of the most beautiful trees in America", and the tree remains a favorite ornamental nearly 300 years after Miller's initial descriptions.

The southern magnolia is planted in lawns of southern homes, businesses, and civic buildings, and was adopted in 1900 as the state flower of Louisiana and Mississippi, and in 1935 as the state tree of Mississippi (Shearer 1987). Mississippi is now known as The Magnolia State, and the large blossoms can be seen on the car license plates and on the state quarter-dollar coin. This magnificent tree was not originally native to North America, having been introduced from Asia by southern plantation owners in the 1600's, but there can be no reservations as to its place in American history nor its persistence into the future as one of America's most beautiful tree species.

Biodiversity

Biodiversity, a combination of 'biological diversity', refers to the abundance and variety of organisms within a community. The most basic value of biodiversity, and of the pursuit of information pertaining to it, is intrinsic. Satisfaction may be derived from the knowledge that a diversity of organisms and habitats exists. Additional values of

biodiversity include aesthetic, ethical, and spiritual values (Simpson 1997). Biodiversity can also contribute financial benefits, as in the potential importance of newly described plant and animal species to the pharmaceutical industry.

Insects are the dominant group of animals on the earth today, both in abundance and in diversity of ecological niches occupied. Over one million species of insects have been described, and some authorities believe the total number of species of insects may exceed ten million (Wilson 1993). Insects are of great value as pollinators of flowers, as providers of products including honey and silk, as members of the food chain, as scavengers, as biological controls of pest organisms, and in medical and scientific research (Gaston et al. 1993). With a potential majority of insect species still undescribed, there exists a great value in preserving and studying the biodiversity of insects. Because so little is known regarding the number of species, or their biology, it is critical that these data be obtained prior to the loss of a given species. With the lack of knowledge regarding insects associated with *M. grandiflora*, it is imperitive that scientific research be conducted in an attempt to fill this gap, before it is too late.

General Biology of *M. grandiflora*

Commonly known as either southern magnolia or American bull bay, *M. grandiflora* fills the air with the sweet fragrance of its magnificent white blossoms from May through November (depending on cultivar). This bloom period is the longest such continuous period in the family Magnoliaceae (Pittcock 1986). Hillier (1981) commented that this genus includes the most magnificent flowering trees in the temperate region. This tree is also of interest due to the retention of its elementary structures for more than 100 million years, with fossil records starting in the upper Cretaceous Period (Leppik 1975).

The Magnoliaceae consists of 80 species worldwide, comprising both deciduous and evergreen trees and shrubs (Treseder 1978). Twenty-six species are native to North and South America, with the remainder in Asia. Several species have been imported and distributed throughout Europe. With the exception of *M. grandiflora*, the trees in the North American subgenus *Theorhodon* Spach are large tropical evergreens. Southern magnolia is a coastal plains species and is classified as a zone seven plant (Pittcock

1986), limiting the areas of growth to climates with minimum temperatures not dropping below -17.8 to -12.2 ^{o}C. Mature trees may reach 18 to 27 m with a normal diameter at breast height (dbh) of 0.6 to 0.9 m, but records indicate diameters as large as 1.5 m in Louisiana. The natural distribution in the U.S. extends from eastern Texas along the Gulf of Mexico to central Florida and north to the coastal areas of North Carolina (Fowells 1965). In general, these regions have rich, moist, acidic (pH of 4.0 to 6.0) soils that allow for good drainage. However, *M. grandiflora* are capable of surviving in swampy regions, drought-stricken areas, and in conditions of high heat or wind. This remarkable tolerance range is due in large part to the reddish-brown indumentum which protects the stomatic pores on the under-surfaces of the leaves (Pittcock 1986).

In central Florida, uplands with iron-stained sandy soils have become dominated by fire-climax, savanna vegetation (i.e., *Pinus palustris* Miller), and ground cover grasses (i.e., *Aristida stricta* Micheaux). This situation originated in part with the prescribed fires managed by the forest industry, according to Daubenmire (1990), who also reported that natural replacement of savanna by broadleaf forest occurs over widespread areas where burning and other human forest management has been discontinued. This natural climax community is characterized by the presence of *M. grandiflora* and several *Quercus* and *Carya* species, and defines a zone extending from central Florida northward into Georgia, but not westward into the Florida panhandle. At its northern and western limits, the *M. grandiflora*-*Q. virginiana* Miller zone abuts a different but closely related *M. grandiflora-Fagus grandifolia* Ehrhart zone. These two associations have previously been grouped with additional upland forests on the Atlantic Coastal Plain as the Southern Mixed Hardwood Forest. The range of *M. grandiflora* has also been noted by Howard (1948) as extending into the West Indies. In these forest zones, *M. grandiflora* is an ecologically important tree. The seeds are an important source of food for many types of birds, including bobwhite quail, wild turkeys and various songbirds. Small mammals like mice, squirrels, and opossums also utilize the early autumn crop of seeds (Halls 1977). Southern magnolia, with its densely-branched growth pattern and year-round leaf cover, provides valuable habitat for many bird and small mammal species

Because of its widespread use as an ornamental species, *M. grandiflora* is planted outside of its natural coastal distribution from New York to southern California, although north of Washington, it requires a protected environment (Treseder 1978). It is also extensively planted in India and Japan, and is one of the most widely cultivated evergreen ornamental trees in the world. In the British Isles and Europe, the date of introduction of this *Magnolia* was some time before 1732, the date published by J.C. Loudon in his *Arboretum et Fruticetum Britannicum* (1838).

In the landscaping industry, this tree is used as a lawn shading, accent or specimen tree, in lakeside or woodland plantings, as a street tree for residential areas and highway approaches, for tropical effects and for background accenting of large-growing deciduous shrubs and winter deciduous trees (Treseder 1978). It also makes an excellent tall evergreen to hide unsightly views. The increasing popularity of interiorscaping has researchers testing new plants as substitutes for the more common tropical tree species. One of the major limiting factors in developing interiorscape plants is the degree of irradiance the plants are exposed to during development. Martin and Ingram (1989) demonstrated that the southern magnolia possesses a structure and form suitable for use in interior environments, given sufficient sunlight prior to being placed in the interior environment. Southern magnolia trees were grown under full sunlight and under 80% shade to assess the ideal irradiance levels. Trees grown under full sunlight lasted an average of 2.5 months longer than those grown in partial shade, and also attained larger sizes.

Nursery propagation of *M. grandiflora* trees includes the use of seeds, hardwood cuttings, softwood cuttings, budding, and grafting. Covan (1987) notes that seed propagations require large time and effort commitments, and are considered too variable and unreliable. Hardwood cuttings are considered too limited, and budding and grafting are considered too expensive and time-consuming. Softwood cutting is a fast-expanding and reliable propagation method for *M. grandiflora*, and is preferred over other methods because of the tremendous success experienced at the Simpson Nurseries in Monticello, Florida (Covan 1987). In softwood cutting propagation, cuttings are taken from the current year's wood that has hardened, usually between June and August. Cuttings are

selected from trees with superior shape, growth, leaf size, and color, and are approximately 10 cm long with one or two whole leaves remaining. The base of the cuttings are cut at a slant, dipped in Potassium salt, and stuck into a pot of peat/sand medium. Callus appears in three to four weeks with roots appearing after six to eight weeks, ready to plant. One cultivar that has been reported propagated successfully using this method is the 'Little Gem', which is in high demand due to its ability to fit into smaller landscapes while retaining its evergreen character and fragrant blooms (Arena et al. 1998). In addition to its landscape uses, southern magnolia is sought after by furniture makers for its moderately heavy, creamy-colored lumber, and stands were heavily logged in the past (Treseder 1978).

Reproductive Biology of *M. grandiflora*

The southern magnolia branches only by means of proleptic shoots, where the floral shoot is formed the season prior to flowering within the resting apical meristem (Guedes 1979). As floral buds become active and cell division and elongation occurs, the outermost covering, or perule, opens and is shed. A second protective covering, the spatheceous bracts, is then exposed. As these bracts open, the tightly closed pale green perianth becomes visible. As the flowers open, they become fragrant, turn creamy-white and last for about two days.

In the perianth, the sepals and petals are undifferentiated and are referred to as tepals, occurring in three whorls of three. Above this area of the perianth is the androecium, which consists of the male portion of the flower, the anthers. Above the androecium lies the gynoecium, consisting of the female organs, or stigmas. The gynoecium protrudes in the form of a column composed of numerous stigmas which are spirally arranged.

Grains of pollen from *Magnolia* can be distinguished from the pollen of other genera in Magnoliaceae by their elongate and boat-shaped appearance, their approximate length of 41-63 μm, and the presence of a single furrow extending the length of the grain (Wodehouse 1935). The exine of these pollen grains can range from smooth to granular, but not reticulate. Flowers of *Magnolia* are protogynous, where the stigma is receptive before the anthers of the same flower are mature. The pollen, therefore, must come from

a different flower which has previously opened. As a result, the first flowers of the season usually do not set fruit (Thien 1974).

The origin of insect pollination of this species is based on various extant archaic angiosperms, including members of the Magnoliaceae, sharing important characteristics in their pollination systems (Pellmyr and Thien 1986). Insect pollination was suggested to have evolved primarily through the coordination of the sexual life cycles of phytophagous insects with flowers in which floral odors served as chemical cues for mating sites and food. These floral fragrances may have originated from chemicals originally serving as herbivore feeding deterrents.

The primitive flowers of magnolia are borne singly, with a terminal position on the branch. Additionally, pollen, food hairs, unconcealed nectar, and soft petals are easily available as food for foraging insects on primitive floral types, as exemplified by the flowers of *M. grandiflora*. These floral types are adapted to be pollinated by insects with primitive sensory development, like Coleoptera. Leppik (1975) states that the selective pressure which beetles have exerted on floral evolution has been slow and unalterable, as their primitive sensory development has remained relatively unchanged in modern species. These insects select standard floral patterns for feeding and mating sites and avoid less promising variations from these familiar types. With only moderate floral specialization since the Cretaceous period, *M. grandiflora* exhibits a slow, almost stagnant evolutionary rate when compared to the swift progress of flower types in the Leguminoseae, Orchidaceae and other modern families.

Beetles, well known from the Mesozoic Period and occurring contemporaneously with the earliest angiosperms, typically resort to a style of pollination referred to as "mess and spoil" (Faegri and vander Pijl 1979). The large, unspecialized flowers of the *Magnolia* are believed to be associated with this pollination syndrome because of their roomy interior and the high lipid-content tissues that beetles may consume along with pollen (Beach 1982). The occurrence of more than 30 different free amino acids, most notably proline, have been detected in *Magnolia* pollen, clearly inferring that pollen-foraging on *Magnolia* flowers can provide a significant source of basic nitrogenous compounds (Yasukawa et al. 1992).

During the first stage of anthesis, beetles force their way into the buds to find shelter and food under the closed tepals, leaving only when the tepals are shed at the time of anther dehiscence (Pittcock 1986). They feed on the protein-rich pollen and a nectar-like sugary fluid excreted between the stigmas, and take advantage of the shelter made by tepals that close at night. The next morning the flower reopens, but the stigmas are no longer receptive to pollination and the pollen is shed, attracting a wide variety of non-pollinating beetles and bees. Upon leaving spent flowers to locate new, unopened flowers, pollinating beetles may carry pollen grains to the receptive stigmas of the new flower while searching for more pollen and nectar. Scarabs in the subfamily Cetoniinae are particularly adapted to this pollination method, and one member of this subfamily, *Trichiotinus piger* (F.), has been recorded as an important pollinator of *M. grandiflora* (Pittcock 1986, Leppik 1975, and Thien 1974). The dense hairs on the ventral portions of *T. piger* collect and hold large amounts of pollen. Leppik (1975) also notes that anthesis of *M. grandiflora* flowers coincides with the mass accumulation of the exotic Japanese beetle, *Popillia japonica* Newman, on the host, making this beetle a potentially important pollinator of the trees. The large numbers of these invasive beetles actually prevented other insects from visiting the flowers, with 25-30 individuals often being recorded on individual flowers. Other beetle pollinators of *M. grandiflora* include the two rose beetles, *Cetonia aurata* L. and *Cetonia stictica* L. (Leppik 1975 and Muller 1883), the nitidulid *Conotelus obscurus* Erichson (Leppik 1975 and Thien 1974), and the cerambycid *Strangalia luteicornis* (F.) (Thien 1974). These beetles visit the flowers for nectar and pollen until the petals drop. Becoming covered with pollen, they accomplish pollination by flying from flower to flower.

While present-day halictid and apid bees are attracted to magnolia flowers, fossil records show that the first occurrence of angiosperms predates that of bees. With the Diptera originating in the late Triassic Period, prior to the angiosperms, early flower pollinators may have consisted of flies and beetles. Flies have been shown to exhibit a similar floral foraging behavior to that of bees, and certain groups of flies are constant pollinators (Kearns 1992). According to Yasukawa et al. (1992), several families of Diptera, such as Syrphidae and Anthomyiidae, use *Magnolia* flowers for pollen foraging,

secretion sponging, and as mating sites. In Allain et al. (1999), Hymenoptera such as honeybees and sweat bees constituted nearly 75% of floral visitors on *M. grandiflora*, Coleoptera like Mordellidae accounted for about 11%, and Diptera were only 0.01%. Additionally, Hymenoptera carried 98.9% of the pollen (excluding pollen found in the corbiculae) removed from insect specimens. Despite these findings, Hymenoptera and Diptera are considered minor pollinators of *M. grandiflora*, because they cannot enter the flower during the receptive period unless it has been torn or pulled open. Eumes (1961) states that what was believed to be floral self incompatibility in Magnoliaceae has been more recently attributed to the absence of pollinating beetles at the brief and critical period of pollen shedding. This absence could explain the common problem of many aborted, twisted and deformed seed aggregates in nurseries. Problems with aborted and deformed aggregates, the timing of the flowers, the opening and closing of the tepals, and large quantities of food all suggest that the flowers of *Magnolia* are highly specialized for exclusive pollination by beetles (Eumes 1961 and Leppik 1975).

The widely recognized floral scent of *M. grandiflora* developed as a way to attract insect pollinators (Azuma et al. 1997a). Flowers in Magnoliaceae were found to emit various types of volatile compounds such as terpenoids, benzenoids, fatty acid esters and hydrocarbons in specific quantities (Azuma et al. 1997b). Flowers of *M. grandiflora* characteristically emit a series of monoterpenes, chiefly geraniol and its derivatives, which are also easily detected by the human sense of smell. Leppik (1975) states that the basal parts of the flower emit a stronger odor than other parts, thus encouraging fertilization. In addition to scent, the flowers of *M. grandiflora* fluoresce in ultraviolet light with the cone and stigmas deep red and the pollen bright yellow (Thien et al. 1995), making a conspicuous target for insect pollinators. The petals, unlike those of other *Magnolia* species that appear bright blue and purple, are not fluorescent in ultraviolet light. The colors and patterns displayed by the flowers in ultraviolet light, observance of pollinator behavior, and flower abundance in relation to light all suggest that the floral fluorescence is adaptive toward attracting insect pollinators (Azuma et al. 1997a).

In the Southern U.S., mature trees begin to bloom in early May and continue to bloom through October and November, depending on the cultivar and temperatures. The main

flush of flowers generally occurs in May and June, and sporadically thereafter. Fertilization of the flowers occurs throughout this period when the pollen grains have contacted the receptive surfaces of the stigmas, resulting in growth of the pollen tube. Male nucleus cells fuse with the female egg cells in the ovary of the carpels. Two female egg cells occur in each carpel resulting in a capacity for two seeds in each carpel. However, all ovaries are not fertilized. Aside from the influence of pollinating insects, this infertility may be related to temperature. Treseder (1978) reports that temperatures need to be as high as 21 to 26.7^{o} C for adequate fertilization.

Three distinct tissue types (pericarp, seed coat, and nucellus) within the seed were described by Evans (1933). The outermost layer, the pericarp, is bright red when mature and consists of three cellular layers: a three-layered epidermis, a layer of large fleshy cells containing oils, and a layer of small cells forming an inner epidermis. This pericarp contains 57% oil and a considerable quantity of reducing sugars, primarily glucose and sucrose to a lesser extent, which become more abundant as the seed prepares for germination. Beneath the pericarp is a hard, tan seed coat composed of several rows of cells with thick lignified cell walls. A single membranous layer of nucellus composed of large elongated cells occurs between the endosperm and the seed coat. The endosperm is massive, with a deep groove on one side into which fits a projection of the lignified coat. The endosperm oil content is 51%, and there are no starch grains. The embryo is extremely small (1 mm long and 0.4 mm diameter), but by the time the seed coat has split it can double in size. The embryo consists of a hypocotyl and two leaflike cotyledons between which lies a mass of undifferentiated cells, the plumule (Evans 1933).

When the ovaries have fully matured, and the seeds contained within have developed and begun to emerge, the structure is referred to as an aggregate. Each aggregate may contain up to 60 seeds (USDA Forest Service 1974), and as it dehydrates, it opens along dorsal sutures. The seeds are pushed out of the carpel due to the drying of the tissue of the carpel area and are suspended from the aggregate by a modified raphe, which is thread-like and fibrous. Seeds may germinate the following spring, given suitable environmental conditions of favorable temperature and the adequate presence of water and oxygen (Meyer et al. 1973). If seeds become dessicated, they will often lie dormant

for a year. When suitable environmental conditions exist, the process of seed germination is triggered with water imbibition and enzyme activation, initiation of embryo growth, rupture of the seed coat and emergence of the seedling (Copeland and McDonald 1985). Evans (1933) observed that viable seeds rarely germinated outside of the natural range limits of the trees.

Pests of *M. grandiflora*

In addition to the secondary compounds released by flowers, foliage damaged by herbivores releases volatiles which attract predators and parasitoids searching for prey/hosts. One specific compound [(E)-4,8-dimethyl-1,3,7-nonatriene)] is emitted by both flowers and damaged foliage, suggesting that the interaction between flower and pollinator and the chemical communication between the first and third trophic levels may be interrelated (Azuma et al. 1997a). Although *M. grandiflora* is believed to be a generally pest-free plant, knowledge of these compounds and the insects that use them could prove important to growers should problems with pest insects arise.

Relatively few (24) insect species have been recorded in literature from southern magnolia. However, Baker (1972) lists 18 pest species associated with this tree, the majority (nine species) of which are scale insects (Table 1). Leibee and Savage (1994) discuss the magnolia white scale [*Pseudaulacaspis cockerelli* (Cooley)], considered the most serious economic pest of ornamentals in Florida. This polyphagous species is cosmopolitan in distribution, feeding on the leaves, stems, and branches of its hosts, with heavy infestations causing chlorotic spots and premature leaf drop (Kosztarab 1996). Also known as the false oleander scale, *P. cockerelli* was first recorded in 1942 and exists on about 200 recorded hosts (Leibee and Savage 1994). This introduced pest is now found throughout the southeastern U.S., with its rapid distribution being attributed to movement of infested nursery stock. Insecticidal control of scale insects, using compounds such as diazinon, malathion and dimethoate, is most effective against the crawler stage. Dimethoate foliar sprays and soil drenches were evaluated by Leibee and Savage (1994) against foliar sprays of bifenthrin and fenoxycarb for efficacy against *P. cockerelli*. While the soil drench of dimethoate resulted in the highest mortality (62%) of

Table 1. Insect species previously listed as associated with *Magnolia grandiflora* L.

Order	Family	Species
Homoptera	Asterolecaniidae	*Asterolecanium arabidis* (Signoret)
		Asterolecanium pustulans (Cockerell)
	Coccidae	*Ceroplastes ceriferus* (F.)
		Neolecanium cornuparvum (Thro)
		Toumeyella liriodendri (Gmelin)
		Lecanium corni Bouche
	Diaspididae	*Aspidiotus perniciosus* Comstock
		Diaspidiotus liquidambaris (Kotinsky)
		Pseudaulacaspis cockerelli (Cooley)
	Pseudococcidae	*Ferrisia virgata* (Cockerell)
Hemiptera	Coreidae	*Leptoglossus fulvicornis* (Westwood)
Coleoptera	Cerambycidae	*Strangalia luteicornis* (F.)
	Curculionidae	*Odontopus calceatus* (Say)
	Platypodidae	*Platypus quadridentatus* (Olivier)
		Platypus compositus (Say)
	Scarabaeidae	*Phyllophaga forsteri* (Burmeister)
	Scolytidae	*Xyloterinus politus* (Say)
Lepidoptera	Gracillariidae	*Phyllocnistis magnoliella* (Chamberlin)
	Pyralidae	*Euzophora ostricolorella* (Hulst)
		Euzophora magnolialis (Capps)
	Tortricidae	*Paralobesia liriodendrana* (Kraft)
Hymenoptera	Eupelmidae	*Anastatus reduvii* (Howard)
	Scelionidae	*Gryon carinatifrons* (Ashmead)
		Gryon pennsylvanicum (Ashmead)

mature scales, all treatments were effective at preventing scale establishment on new magnolia growth. However, none of the treatments effectively controlled adult *P. cockerelli*, attesting to the importance of treating during the crawler stage. The insect growth regulator fenoxycarb might be preferred, since it is the least toxic to mammals and is reported to be safe to parasitoids and predators. However, the systemic nature of the convenient and relatively safe soil drench of dimethoate may be preferred by some growers (Leibee and Savage 1994). Other scales previously listed as associated with magnolia include the Magnolia scale [*Neolecanium cornuparvum* (Thro)] and the coccid *Toumyella liriodendri* (Gmelin) (Williams and Kosztarab 1972).

Moths and beetles are also included as foliage or seed feeders on *M. grandiflora*. Bark tunnelers, such as *Euzophora ostricolorella* (Hulst) and *Euzophora magnolialis* (Capps), usually become established only after a tree has been sufficiently weakened (i.e., scale infestation), and trees may be girdled or killed by heavy infestations. Other lepidopterans, including *Paralobesia liriodendrana* (Kraft) and *Phyllocnistis magnoliella* (Chamberlin), mine the undersides of young leaves, though they rarely kill trees. The *Platypus* beetles are more destructive than other ambrosia beetles because their burrows are more extensive, often penetrating deep into the heartwood of the trees they attack, thus destroying the most valuable timber. However, these beetles seldom attack healthy trees. The larvae of the scarab *Phyllophaga forsteri* (Burmeister) are destructive root feeders in southern nurseries.

The coreid *Leptoglossus fulvicornis* (Westwood) is an herbivorous specialist on the fruits of several magnolia species, including *M. grandiflora* (Mitchell and Mitchell 1983). While it has been collected from other tree species, magnolias are the only known breeding hosts (Mead 1971). In Texas, *L. fulvicornis* becomes active on *M. grandiflora* in late summer, with nymphs first observed in September. Overwintering adults in Pennsylvania appear in mid-June to early July, in late April at Mobile, AL, and in late May at Knoxville, TN (Wheeler and Miller 1990). The late-season development of these coreids is primarily due to their feeding preference on the magnolia fruits, which do not appear until mid to late summer, depending on the region. In laboratory studies by Wheeler and Miller (1990), nymphs and adults were not successfully reared using other foods (green beans or sunflower seeds) or excised magnolia seeds, supporting the knowledge of their specialized feeding habits. Overwintering adult females lay eggs in chain-like masses on the underside of foliage shortly after they become active. Nymphs begin to feed on developing and mature fruits of the magnolia, going through several molts until the adults develop in early August. Second-generation adults remain on the trees and feed until late September, when they seek shelter underneath leaf litter (Wheeler and Stimmel 1988). Most common in the southeastern states, the range of *L. fulvicornis* extends north along the Atlantic coast to New York and Massachusetts, west through Pennsylvania, and south into eastern Texas. Mitchell and Mitchell (1983) also report on

the extension of the range of this hemipteran into central Texas, beyond the range of its host tree. Natural enemies of this ornamental pest include the hymenopteran egg parasitoids *Gryon carinatifrons* (Ashmead) and *Anastatus reduvii* (Howard). Wheeler and Miller (1990) reported *G. carinatifrons* to parasitize several coreid egg masses at a rate of 40%, and also an 18% parasitism rate on the same egg masses by *A. reduvii*. These wasps emerged a few days after *G. carinatifrons*, suggesting that they may be facultative hyperparasitoids. Mitchell and Mitchell (1983) also reported the hymenopteran parasitoids *Gryon pennsylvanicum* (Ashmead) and *A. reduvii* reared from collected eggs of *L. fulvicornis*, with 77% of the egg masses and 31% of the individual eggs parasitized. Other than egg parasitoids, *L. fulvicornis* has few reported natural enemies.

Outbreaks of root feeding insects like mole crickets or scarabaeid larvae can present serious problems to young *M. grandiflora* plantations. Soil surveys were conducted in Tennessee nurseries to determine the presence of entomogenous nematodes (Rueda et. al 1993). The most prevalent and effective infective nematodes collected from magnolia plots were *Heterorhabditis bacteriophora* Poinar and *Steinernema carpocapsae* Weiser. These nematodes can play an important role in regulating populations of soil insect pests in magnolia nurseries.

In addition to insect pests, an unexplained decline and death of southern magnolia in urban areas of the southern U.S. was observed from 1976 to 1985 (McCracken 1985). Defoliation, twig dieback, and malodorous, blue-black necrotic stains of the cambium were observed. In addition, some affected trees had an elongate trunk canker, necrotic roots and a reduced number of feeder roots. Most of the affected trees died within two years of the first appearance of symptoms. The disease occurred in somewhat restricted areas, primarily in west central Mississippi, and it appeared to spread to adjacent trees in the same general location. While many of the affected trees were found near residences, roads or parks, none was found in native stands, suggesting that site-related factors may have contributed to the development of this disease. Although eight different genera of fungi were recovered from diseased tissues, all contributed to the disease in a strictly secondary manner, and no abnormal concentrations of nitrogen, potassium, phosphorus,

calcium, magnesium, iron or manganese were found in the diseased tissues (McCracken 1985). Symptom suppression of affected trees following the soil injection of Oxytetracycline HCL indicated an infectious mycoplasma or bacteria as the cause, but no further work has been done on problem.

Relatively little scientific research has been conducted on the insects associated with southern magnolia, and consequently there exists a general lack of information regarding the insects associated with *M. grandiflora*. Given the importance of this tree to the ornamental nursery industry, to ornamental landscapes around the world, and to the *M. grandiflora*-*Q. virginiana* and *M. grandiflora-Fagus grandifolia* ecosystems, a broader understanding of the insect fauna associated with *M. grandiflora* is needed.

The objectives of this research were: 1) to assess the richness and abundance of the insects associated with southern magnolia in East Tennessee, 2) to compare the insect fauna collected from upper and lower tree canopy levels, 3) to compare the insect fauna collected from pitfall traps at two test sites, 4) to compare the insect fauna collected from pitfall traps and malaise traps at two test sites, and 5) to compare the floral insect visitors of southern magnolia from two years. This study will provide the baseline data to identify pest and beneficial (predators, parasitoids, and pollinators) insects associated with southern magnolia in East Tennessee, facilitating future research conducted on this tree.

Chapter II
Materials and Methods

Six mature southern magnolia trees were non-randomly selected as test trees, four from a mixed hardwood forest site at the University of Tennessee Forestry Experiment Station and Arboretum (Anderson County, TN), and two from an urban site at the University of Tennessee Agriculture campus (Knox County, TN). Malaise/pan traps were suspended from two trees at each site, and pitfall traps were placed in the leaf litter beneath each of these trees. Additionally, direct samples were taken from the flowers of the two trees at the urban site, and the two remaining trees at the forest site were fogged exclusively.

Site Descriptions

The urban site (15.4 ha) contains various tree species including sycamore (*Platanus occidentalis* L.), willow oak (*Quercus phellos* L.), ginkgo (*Ginkgo biloba* L.), and southern magnolia scattered over an open, grassy lawn surrounding the buildings on the University of Tennessee Agriculture campus. This site is maintained (i.e., mowing lawns, mulching of tree bases) by the University of Tennessee Physical Plant staff. A large flower and herb garden, located on the east side of the Agriculture Campus, is maintained by the Department of Plant Sciences and Landscape Systems. The Brehm Animal Science Building houses cows and sheep year-round for research by the Department of Animal Science. The grounds of the urban site undergo periodic construction projects, including the construction of a new biotechnology building on the west side of the Ellington Plant Science Building. Trees one (35^o 56'508"N 83^o 56'346"W, 14 m tall) and two (35^o 56'496"N 83^o 56'362"W, 15 m tall) from the urban site were located within 10 m^2 plots on either side of the walkway to the west entrance of Brehm Animal Science Building.

In contrast, the forest site consists of approximately 915 ha. of managed forest land, 50% of which has always had forest cover. Roughly 80% of the forest is greater than five years old, 15% is less than five years old, and 5% is experimental tree plots and power

line right of ways. Approximately 100 ha. of this forest has been set aside for the Arboretum, which contains more than 800 species of native and exotic woody plants. All four of our test trees were located within 10 m^2 plots, with trees one (36^{o} 59'486"N 84^{o} 13'083"W, 9 m tall) and two (35^{o} 59'509"N 84^{o} 13'124"W, 13.5 m tall) used for trapping, and trees three (35^{o} 59'604"N 84^{o} 13'210"W, 7.5 m tall) and four (35^{o} 59'838"N 84^{o} 12'891"W, 11.5 m tall) used for canopy fogging.

Sampling Methodology

Insect specimens were collected in November and December 2000 with pitfall traps at the forest site, from April 2001 through November 2001 with malaise traps and pitfall traps at both sites, from April 2001 through November 2001 with a canopy fogger at the forest site, and floral samples were conducted from May through July in 2001 and in 2002 at the urban site.

Pitfall trap - Procedures for this collection method followed those outlined by Morrill (1975) and Hylton (1980). Four pitfall/intercept traps were placed under two trees at each site, one trap at each of four corners (North, East, South, and West) within a 10 m radius of the trunk. Each trap included a buried 120 ml specimen cup, with a second 120 ml cup as the inner container placed flush with the soil surface and filled with 30 ml of 50% antifreeze/water solution (Morrill 1975). A plexiglass “intercept trap” lid (20 x 20 x 0.5 cm) with four baffles (4 x 10 x 0.5 cm) was then placed above each cup, with the lid limiting the entry of rain water into the trap and the baffles directing insects into the trap (Hylton 1980). Traps on the North/South sides and East/West sides were activated and emptied once per month each, on alternate collection dates. The inner canister of each trap was removed and a new one inserted, with specimens then labeled and taken to the laboratory for processing.

Malaise/pan trap - Malaise/pan traps were suspended from two trees at each site. Frames (60 x 60 x 60 cm) were constructed with PVC pipe and nylon mesh netting, and plastic containers (0.5 l) were attached to the top of each frame with a plastic funnel. One 120 ml plastic sample cup was attached to each container as a reservoir for insect specimens. One plastic pan was attached to the base of each frame, and frames were

attached to limbs with plastic zip ties and rope at heights representative of the upper and lower canopy of trees one and two from both the urban and forest setting. Each sample cup contained ca. 30 ml of a 50% Sierra antifreeze/water solution, and each pan trap contained ca. 800 ml of solution. Insects captured in these eight traps were collected every two weeks from each site. The combination of the conventional Malaise trap and the pan captured insects that tend to fly up (Malaise) as well as insects that drop (pan). The sample cups with the insect specimens were removed and new cups inserted, while specimens from the pan traps were removed with tweezers. Specimens were then placed into 70% ethanol, labeled, and taken to the laboratory for processing. When the antifreeze solution in the pan degraded due to evaporation or collection of rainwater, pans were emptied and replenished with new solution.

Canopy fogging - Two trees at the forest site were fogged during alternate months (14 May, 11 June, 11 July, 6 August, 5 September, 1 October, and 5 November, 2001). A standard broad-spectrum, synthetic pyrethrum insecticide (Asana Xl, 0.66 emulsifiable concentrate) was dispersed using a modified Dynafog Golden Eagle™ (model 2610) fogger. Formulation for the insecticide was calibrated to the rate of 0.02 ml/liter to generate a fog for six to 10 minutes. A two-month rotation was used to avoid any residual effects of the insecticide. Procedure for this collection technique has been modified from that utilized by Gagne (1979). Plastic tarpaulins (9 x 12 m) were placed on the ground to catch falling insects rather than an elevated canvas sheet, and a modified Dust-Buster™ vacuum was used to collect the insects rather than an aspirator. The plastic tarpaulins were placed around the tree base and under the canopy to catch the fallen insect specimens, which were then collected after two hours using the vacuum, and were labeled and taken to the laboratory for processing.

Floral sampling - Trees located at the forest site produced few flowers, and those that were produced were not accessible for sampling. Five flowers within 2 m of the ground from each of the two trees at the urban site were sampled three days each week from 21 May through 18 July 2001. Each of the 10 flowers per sampling date was sampled using a sweep net (34.3 cm diameter) and ethyl acetate-charged killing jars. During the 30-minute observation time on each sampling date, any insects observed

walking on or flying into the 10 flowers were collected by shaking the flower into the sweep net. Insects were then placed into the killing jar, labeled, and taken to the laboratory for processing.

In the summer of 2002, this study was expanded to include sticky trap sampling with sweep net sampling. From 12 May until 29 June, five flowers selected from the two trees at the urban site were sampled at the beginning of each week at approximately 09:00 am, and five flowers were sampled at the end of each week at approximately 5:00 pm to account for the variable activity time of different insects. These ten flowers selected from the two trees were sampled for three minutes each using a sweep net, with specimens placed in a killing jar, labeled, and taken to the laboratory for processing. After conducting each sweep-net sample, a marker was placed near each flower and Tangle-trap^{R} aerosol spray was sprayed onto the tepal surfaces of each flower. After 24 hours, flowers were examined and insect specimens were collected and placed into vials, labeled, and taken to the laboratory for processing.

Processing of Specimens

Specimens collected from malaise and pitfall traps were stored in 70% alcohol until they were mounted, and all specimens were mounted to observe morphological features as needed for their identification. After identification, specimens were labeled with collection date, site, sampling method and taxonomic information (order, family, genus, species, and author). Voucher specimens were systematically arranged into Cornell drawers for incorporation into the University of Tennessee Insect Museum.

Identification of Specimens

Specimens were identified using standard keys (Table 2) and voucher specimens located in the University of Tennessee Insect Museum. Identifications of specimens in Membracidae (Mark Rothschild, Maryland Department of Agriculture), Tipulidae (Matthew Petersen, University of Tennessee), and Pompilidae (Ian Stocks, Great Smoky Mountains National Park) were provided by specialists. Assistance with and verification of specimens by specialists was provided for the following groups:

Table 2. Summary of papers with keys used to identify insect specimens.

Publication	Taxa
Agriculture Canada 1993	Hymenoptera
Agriculture Canada 1981	Diptera
Ashmead 1903	Proctotrypoidea (Hymenoptera)
Blatchley 1926	Heteroptera
Brigham et al. 1982	Gerridae (Hemiptera)
Britton 1923	Hemiptera
Byers 1954	Mecoptera
Chilcott 1960	*Euryomma* (Diptera: Muscidae)
DeLong 1948	Cicadellidae (Homoptera)
Downie and Arnett 1996	Coleoptera
Fattig 1947	Cerambycidae (Coleoptera)
Helfer 1953	Orthoptera
Krombein and Hurd 1979	Hymenoptera
Liljeblad 1945	Mordellidae (Coleoptera)
Marsh 1971	Braconidae (Hymenoptera)
Mead 1971	Coreidae (Hemiptera)
Melander 1918	*Drapetis* (Diptera: Empididae)
Oman 1949	Cicadellidae (Homoptera)
Pate 1947	Tiphiidae (Hymenoptera)
Penny et al. 2000	*Chrysopa* (Neuroptera: Chrysopidae)
Shewell 1961	*Pollenia* (Diptera: Calliphoridae)
Townes 1969	Ichneumonidae (Hymenoptera)
USDA, ARS 1965	Diptera
Van Duzee 1928	*Medeterus* (Diptera: Dolichopodidae)
Vockeroth 1983	Syrphidae (Diptera)

Formicidae (Karen Vail, University of Tennessee), Coleoptera and Apoidea (Adriean Mayor, University of Tennessee), and Diptera (David Paulsen, University of Tennessee).

Data Analysis

Species name, family name, order, site, collection method, collection date, and specimen abundance were entered into a computer database (Biota[R]) and stored on discs. A species list was developed using all of the sampling methods from each site, and an assessment was made of richness of insect families, species and specimens collected from each canopy level and from each site.

Mean diversity and evenness of insects collected from the different canopy levels (upper canopy and lower canopy) of the trees at both sites were compared using the Shannon-Weaver diversity index (Zar 1996). Diversity and evenness levels were also determined for insects from the pitfall trap samples at each site and from combined pitfall and malaise trap samples at each site. The equation for the Shannon-Weaver index (H') is $H' = -\Sigma p_i \log p_i$ where p_i is the number of insects in canopy level 'i' divided by the total number of insects. Evenness (E) was calculated as $J' = H' / H'_{max}$ where $H'_{max} = \log k$ and k is the number of categories, thus expressing the observed diversity as a proportion of the maximum possible diversity.

Determinations of any significant differences in abundance of insect specimens, families and species were made using the Chi-square formula (SAS Institute 1989). The equation for the Chi-square (χ^2) formula is $\chi^2 = {}^{k}\Sigma\, (f_i - f'_i)^2 / f'_i$ where f_i is the frequency observed in class i, f'_i is the frequency expected in class i if the null hypothesis is true, and the summation is performed over all k categories of data. Output values less than 0.05 were considered to be significant. This formula was used to evaluate any difference in the numbers of insects or taxa collected from malaise traps at the two tree canopy levels at both sites, from the pitfall trap samples at each site, and from combined pitfall and malaise trap samples at each site. The Chi-square formula was also used to assess any difference in the number of insect specimens, families, and species collected from floral samples over two years (2001 and 2002). Because of the shorter bloom period in 2002 (seven weeks), only the first seven of the actual nine weeks of data from 2001 were

used for this analysis to assess an equal sampling period. Because of the altered sampling methodology in 2002 which led to one-third fewer flowers sampled per week than in 2001, the numbers of insect specimens, families and species collected each week in 2001 were adjusted by multiplying them by 0.6667 before analysis. The assistance of Michael A. O'Neil of the University of Tennessee Customer Technology Support Department was provided for all of these analyses.

The number of specimens and families within the three major orders (Coleoptera, Diptera, Hymenoptera) was noted for comparison and determination of common insect groups and their guilds. Determinations were also made of the proportions of families that were unique to each site (i.e., only collected at a particular site) vs. common to each site (i.e., collected at both sites). Determinations were made of any coleopteran species that were non-native or with new range extensions into Tennessee, according to species notes from Downie and Arnett (1996) and the list of Coleoptera collected from the Great Smoky Mountains National Park (GRSM) by the Coleoptera Taxonomic Working Group at the Louisiana State Arthropod Museum (LSAM). Coleopteran species were identified as pests or beneficials, and their associations with certain guilds (i.e., plant feeders, predators, parasitoids) were also assessed.

Chapter III
Results and Discussion

From the 5,757 insect specimens collected at both sites by all collection methods, 480 species in 119 families and 12 orders were determined. Shannon-Weaver diversity values were similar for each category tested (Table 3). The canopy levels held the highest diversity and evenness of the three categories tested, inferring that insects were most evenly distributed between the two canopy levels. Several insect species were collected in higher abundance from the upper canopies than the lower canopies, including the sarcophagid *Sarothromyia* sp. (510 specimens in the upper canopy and 267 specimens in the lower canopy) and the calliphorid *Pollenia* sp. (304 specimens in the upper canopy and 167 specimens in the lower canopy). These flies are attracted to decay odors, and may have been more attracted to upper canopy traps due to higher water content and accelerated decay of insects in the malaise traps.

The number of insects collected from the pitfall traps was intermediate in both values (Table 3). This correlation is due in large part to the presence of the carabid *Abacidus atratus* Newman and several ant species including *Aphenogaster lamellidens* Mayr and *Tetramorium bicarinatum* Nylander. While these species were present at the forest site (with the exception of *A. lamellidens*), they were collected in greater abundance from the urban site. With only two species of Carabidae collected from the urban site, and seven collected from the forest site, perhaps lack of competition for resources enables *A. atratus* to exist in higher abundance at the urban site. More specimens (422) and species (11) of ants were collected from pitfall traps at the urban site compared with the forest site (164, 9). These trends are probably due to one of the major macro-environmental differences between the two sites, and the presence of human trash at the urban site. Pavement and fewer trees may contribute to higher temperatures at the urban site, and while people regularly visit the forest site for nature-trail hiking, their impact on the ecosystem is restricted. The urban site, however, is populated with hundreds of students, faculty, staff, and members of construction crews by day. Trash, including discarded food items, can easily be found in parking lots and under bushes alike, providing a food source for

Table 3. Shannon-Weaver diversity (H') and evenness (J') values for upper and lower canopies at both sites, pitfall traps at each site, and pitfall and malaise traps combined at each site.

Collection Category	H' Value	J' Value
Canopy	0.2902	0.9641
Pitfall traps	0.2853	0.9478
All Traps	0.2831	0.9405

animals that is not present at the forest site.

The number of insects collected from pitfall and malaise traps combined at the two sites were compared, and the lowest diversity and evenness of the three categories was found (Table 3). Traps at the urban site collected almost twice as many specimens as traps at the forest site, inferring important differences in the sites. With the warmer climate, and the presence of the livestock barn and human trash as a food source, the urban site may allow for higher insect abundance than the forest site. Aside from the ground-dwelling insects from Carabidae and Formicidae, other insects including Forficulidae, Anthomyiidae, Calliphoridae, and Muscidae that may take advantage of a resource like human trash were more abundant at the urban site than at the forest site. The common earwig *Forficula auricularia* L. was abundant at the urban site, but was not collected at the forest site. These insects are scavengers and will use human trash for a food source, but they also require shelter in trees such as cracks in bark or animal nests, and each tree at the urban site had a squirrel nest, while none of the trees at the forest site had one. When a squirrel nest at the urban site was disturbed on 3 September 2001, dozens of earwigs crawled or fell from the shelter of the leaves. Additionally, the three previously mentioned dipteran families, along with the most abundant family, Sarcophagidae, likely exploited the manure and animal resources present in the livestock barn. The presence of these additional resources may have contributed to the disparity in abundance at the two sites, and the lowest H' and J' values.

Differences in Malaise Traps at Two Canopy Levels at Both Sites

Significantly more insect specimens [$\chi^2 = 204.84$; df = 1; $P < 0.05$ (Table 4)] were collected from the upper canopies of trees at both sites than from the lower canopies. The common earwig, *F. auricularia*, was present in higher abundance in upper canopies than in lower canopies (175 specimens in upper canopies and 91 in lower), but the major contributors to this trend were from the order Diptera (1,535 specimens in the upper canopy and 825 in the lower). The four main families responsible for this significance were the Anthomyiidae (157 specimens in the upper canopy and 99 in the lower), Calliphoridae (393 specimens in the upper canopy and 217 in the lower), Muscidae (377 specimens in the upper canopy and 144 in the lower) and Sarcophagidae (538 specimens in the upper canopy and 291 in the lower). Notable exceptions to this trend include two species from the family Nitidulidae, *Glischrochilus fasciatus* (Olivier) (17 specimens from the upper canopy and 41 from the lower) and *Glischrochilus sanguinolentus* (Olivier) (nine specimens from the upper canopy and 48 from the lower). This trend is again likely attributable to presence of the livestock barn at the urban site, and the decay odors from the upper canopy malaise traps. Family abundance was not significantly different for each canopy level [$\chi^2 = 0.00$; df = 1; $P > 0.05$ (Table 4)], and while more species were collected from upper canopies than lower canopies, the difference was not significant [$\chi^2 = 0.36$; df = 1; $P > 0.05$ (Table 4)].

Table 4. Insect specimen, family and species abundance from malaise traps in the upper and lower tree canopies.

Test category	No. collected in upper canopy	No. collected in lower canopy	Expected[a]	χ^2	SR[b]
Specimens	2,541	1,618	2,079.50	204.84[c]	461.50
Families	85	85	85.00	0.00	0.00
Species	243	230	236.50	0.36	6.50

[a] Based on null hypothesis: no. of insects collected from malaise traps in the upper canopy = no. of insects collected from malaise traps in the lower canopy.
[b] SR, Standardized residual = [(no. observed - no. expected) / no. expected].
[c] Null hypothesis rejected; [χ^2 1, 0.05 = 204.84 ($P < 0.05$)].

Differences in Pitfall Traps at Each Site

Significantly more insect specimens were collected from the pitfall traps at the urban site than at the forest site in 2001 [$\chi^2 = 54.12$; df = 1; $P < 0.05$ (Table 5)]. The carabid beetle *A. atratus* (74 specimens from the urban and four from the forest site) was more abundant at the urban site. The greatest contributors to specimen abundance were in the family Formicidae, with *A. lamellidens* (128 specimens at the urban and zero at the forest site) and *T. bicarinatum* (109 specimens at the urban and 81 at the forest site) collected in larger numbers at the urban site. Site differences, including temperature and food resources, may have contributed to this significance. While greater family diversity was found at the forest site, there was not a significant difference [$\chi^2 = 3.19$; df = 1; $P > 0.05$ (Table 5)]. However, with 27 coleopteran species collected from pitfall traps at the forest site against 12 species at the urban site, and six hemipteran species against zero from the urban site, significantly more species were collected from the forest site in 2001 [$\chi^2 = 8.17$; df = 1; $P < 0.05$ (Table 5)]. This trend was likely due to the greater diversity of plant life and habitat structure at the forest site.

Differences in Pitfall and Malaise Traps Combined at Each Site

Significantly more specimens [$\chi^2 = 400.65$; df = 1 ($P < 0.05$)] were collected from pitfall and malaise traps combined at the urban site than at the forest site in 2001 (Table 6). Several insect groups contributed to an overwhelming significance level, including the carabid *A. atratus* (74 specimens at the urban site and only four at the forest site), the

Table 5. Insect specimen, family and species abundance from pitfall traps at two sites.

Test Category	No. collected at forest site	No. collected at urban site	Expected[a]	χ^2	SR[b]
Specimens	276	478	377.00	54.12[c]	101.00
Families	33	20	26.50	3.19	6.50
Species	66	37	0.04	8.17[d]	14.50

[a] Based on null hypothesis: no. of insects collected from pitfall traps at the forest site = no. of insects collected from pitfall traps at the urban site.
[b] SR, Standardized residual = ((no. observed - no. expected) / no. expected).
[c] Null hypothesis rejected [χ^2 1, 0.05 = 54.12 ($P < 0.05$)].
[d] Null hypothesis rejected [χ^2 1, 0.05 = 8.17 ($P < 0.05$)].

Table 6. Insect specimen, family and species abundance from pitfall and malaise traps combined at the two sites.

Test Category	No. collected at forest site	No. collected at urban site	Expected[a]	χ^2	SR[b]
Specimens	1,755	3,158	2,456.50	400.65[c]	701.50
Families	88	80	84.00	0.38	4.00
Species	272	220	246.09	5.50[d]	26.00

[a] Based on null hypothesis: no. of insects collected from pitfall and malaise traps at the forest site = no. of insects collected from pitfall and malaise traps at the urban site.
[b] SR, Standardized residual = ((no. observed - no. expected) / no. expected).
[c] Null hypothesis rejected [χ^2 1, 0.05 = 400.65 ($P < 0.05$)] .
[d] Null hypothesis rejected [χ^2 1, 0.05 = 5.50 ($P < 0.05$)].

common earwig *F. auricularia* (270 specimens at the urban site and zero at the forest site), and flies from the families Anthomyiidae (211 specimens at the urban site and 46 at the forest site), Calliphoridae (477 specimens at the urban site and 140 specimens at the forest site), Muscidae (383 specimens at the urban site and 142 at the forest site), and Sarcophagidae (581 specimens at the urban site and 249 at the forest site). Additionally, members of the family Formicidae were much more abundant at the urban site (421 specimens and only 164 specimens at the forest site), most notably the ant *A. lamellidens* (128 specimens at the urban site and zero at the forest site). Exceptions included two species of the coleopteran family Nitidulidae, *G. fasciatus* and *G. quadrisignatus*, and a member of the hymenopteran family Halictidae, *Augochlora pura pura* (Say). The nitidulid species are attracted to tree sap, and are especially common on *Quercus* species. Given the importance of various *Quercus* species to the mixed hardwood forest of which the forest site is a part, it is not surprising that these nitidulids were more abundant at this site. The halictid bee *A. pura pura* is a solitary ground nesting bee that may nest close together in aggregations (Goulet 1993). While the forest site is largely left untouched by human intervention, the grounds of the urban site are covered in grass or pavement, are maintained by the staff of the University of Tennessee Physical Plant, and may include less available habitat for the common species of halictid, *A. pura pura.* These site characteristics likely contributed to the difference in the number of specimens collected at each site.

Although eight more families were collected from pitfall and malaise traps in 2001 at the forest site, this difference was not significant [$\chi^2 = 0.38$; df = 1; $P > 0.05$ (Table 6)]. However, 52 more species were collected at the forest site than at the urban site, a significant difference [$\chi^2 = 5.50$; df = 1; $P < 0.05$ (Table 6)]. The largest disparity at the species level can be observed within the Coleoptera, with 113 species collected from the forest site and only 60 species from the urban site. Insect families including Carabidae (four species at the urban site and nine species at the forest site) and Cerambycidae (two species at the urban site and 16 species at the forest site) were represented by more species at the forest site. Along with being the largest order of insects, Coleoptera may also be the most diverse in terms of habits and habitats (Downie and Arnett 1996). With the greater diversity of plant life and habitat structure at the forest site, it is not surprising that there would be a greater diversity of Coleoptera at the forest site. The only major exception to this trend exists with the order Hymenoptera, where 51 species were collected from the forest site and 64 species from the urban site. This exception could be due to the presence of the flower and herb garden on the east side of the urban site, which contains many species of flowering plants for the Hymenoptera to exploit.

Differences in Floral Samples From Two Years

After adjusting the data from the first year as stated in the analysis section, significantly more specimens [$\chi^2 = 0.68$; df = 1; $P < 0.05$ (Table 7)], families [$\chi^2 = 9.12$; df = 1; $P < 0.05$ (Table 7)], and species [$\chi^2 = 10.33$; df = 1; $P < 0.05$ (Table 7)] were collected from flowers in 2002 than in 2001. The addition of sticky traps to the sampling methodology may have added more specimens and taxa to the database. Only two specimens of the mordellid *Mordella lunulata* Hellmuth were collected in 2001 floral samples, but in 2002 floral samples, 26 specimens were collected, 24 of which were collected from the sticky traps. Of the families unique to the 2002 floral samples, the dipteran families Scatopsidae and Sciaridae and the hemipteran family Miridae were collected using sticky traps. Some species of insects are nocturnal, and since the sticky traps collected insects for a 24-hour period, those nocturnal species could be collected.

Table 7. Adjusted insect specimen, family, and species abundance from floral samples in 2001 and 2002.

Test Category	No. collected in 2001	No. collected in 2002	Expected[a]	χ^2	SR[b]
Specimens	137	151	144.00	0.68[c]	7.00
Families	29	57	43.00	9.12[d]	14.00
Species	31	62	46.50	10.33[e]	15.50

[a] Based on null hypothesis: no. of insects from floral samples in 2001 = no. of insects collected from floral samples in 2002.
[b] SR, Standardized residual = ((no. observed - no. expected) / no. expected).
[c] Null hypothesis rejected [χ^2 1, 0.05 = 0.68 ($P < 0.05$)].
[d] Null hypothesis rejected [χ^2 1, 0.05 = 9.12 ($P < 0.05$)].
[e] Null hypothesis rejected [χ^2 1, 0.05 = 10.33 ($P < 0.05$)].

Despite the adjustments made to data from 2001 floral samples, several exceptions to these trends existed. Individual species such as *Chauliognathus marginatus* (F.) (31 specimens in 2001 and three in 2002), *P. japonica* (54 specimens in 2001 and 30 in 2002), and *Apis mellifera* L. (31 specimens in 2001 and 10 in 2002), were more abundant in 2001 even after the data adjustment was made. All insect species go through population fluctuations from year to year, and it is possible that 2001 was a better year for abundance of these species in floral samples than 2002 was.

Insect Families in Three Major Orders Unique to and Common to Each Site

Coleoptera was represented by 36 families collected from traps at the forest and urban sites in 2001, with 55% (20) of the families common to both sites (collected at both sites), 31% (11) unique to the forest site (collected only at the forest site), and 14% (5) unique to the urban site (collected only at the urban site) (Figure 1). This trend is due to the differences in plant and habitat diversity between sites, as the forest site is able to support a more diverse range of Coleoptera than the urban site. A variety of guilds (i.e., predators, scavengers, bark tunnelers, wood borers, and plant, pollen and fungus feeders) were present, with several families, including the Chrysomelidae, Curculionidae, Nitidulidae, Scarabaeidae, and Scolytidae, representing important economic pests. Beneficial families, including Cantharidae, Carabidae, and Coccinellidae, were also

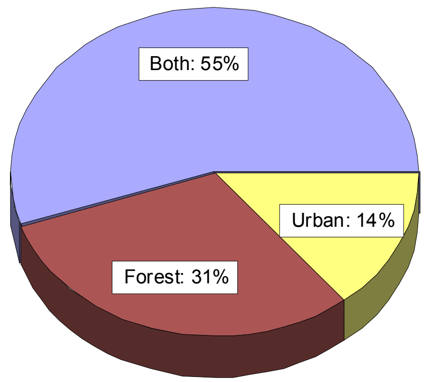

Figure 1. Proportions of families of Coleoptera unique to each site and common to both sites.

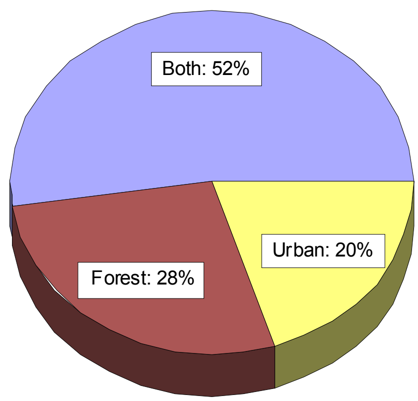

Figure 2. Proportions of families of Diptera unique to each site and common to both sites.

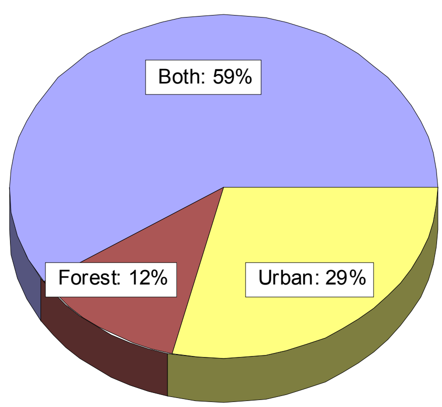

Figure 3. Proportions of families of Hymenoptera unique to each site and common to both sites.

Table. 8. Coleopteran families collected from pitfall and malaise traps at the forest site and at the urban site in 2001, and their associated guilds.

Family	Guild	Abundance forest site	Abundance urban site	Total
Alleculidae	Bark tunnelers	2	3	5
Anobiidae	Bark tunnelers; pests	2	3	5
Anthicidae	Pollen/fungus feeders	2	1	3
Bruchidae	Pollen/seed feeders; pests	0	1	1
Buprestidae	Wood borers	1	0	1
Cantharidae	Predators/pollen feeders	8	9	17
Carabidae	Predators; beneficials	20	77	97
Cephaloidae	Pollen feeders	6	0	6
Cerambycidae	Wood borers	48	7	55
Chrysomelidae	Plant feeders; pests	30	1	31
Cleridae	Predators	9	3	12
Coccinellidae	Predators; beneficials	3	13	16
Curculionidae	Plant feeders; pests	6	3	9
Dascillidae	Plant feeders	1	0	1
Dermestidae	Scavengers; pests	0	3	3
Elateridae	Plant feeders; pests	22	5	27
Erotylidae	Fungi feeders	0	2	2
Eucnemidae	Wood borers	5	0	5
Histeridae	Scavengers	2	0	2
Hydrophilidae	Scavengers	1	0	1
Lagriidae	Plant feeders	2	0	2
Lampyridae	Predators	5	0	5
Leiodidae	Scavengers	2	3	5
Melandryidae	Bark tunnelers	15	6	21
Mordellidae	Pollen/fungi feeders	15	1	16
Mycetophagidae	Fungi feeders	0	1	1
Nitidulidae	Sap/fungi feeders; pests	139	37	176
Ptilodactylidae	Plant/fungi feeders	0	11	11
Rhizophagidae	Bark tunnelers	7	1	8
Scarabaeidae	Plant/dung feeders; pests	34	34	68
Scirtidae	Plant feeders	4	0	4
Scolytidae	Bark tunnelers; pests	6	1	7
Silphidae	Scavengers	5	0	5
Staphylinidae	Predators; beneficials	22	16	38
Tenebrionidae	Scavengers; pests	3	1	4
Trogossitidae	Bark tunnelers; pests	1	0	1
	Totals:	428	243	671

collected (Table 8). Of the families unique to the forest site, three (Buprestidae, Eucnemidae, and Trogossitidae) were associated with wood boring/tunneling guilds. While not present in great abundance, these types of organisms may contribute to a healthy system because they break down dead and decaying wood. Due to recent outbreaks of the southern pine beetle, *Dendroctonus frontalis* Zimmerman, the forest site contains several stands of dead or dying pine trees, along with the normal presence of other dead trees. These dead and dying trees provide abundant habitat for these three families of Coleoptera, along with the most diverse family, the Cerambycidae.

Also unique to the forest site were species in the families Histeridae, Hydrophilidae, and Silphidae. Scavengers are another guild that may contribute to a healthy system, and the forest site had a slightly more diverse representation of coleopteran scavengers, with three of the five families unique to the forest site and a fourth shared between the two sites. The one scavenger family of Coleoptera unique to the urban site was Dermestidae, the members of which are known to be pests of stored grain. With the livestock barn in the Brehm Animal Science Building and its large store of grain, it is likely that the dermestids collected were emanating from these stores. Most notable among the 11 families that included pests are the Curculionidae, Nitidulidae, Scarabaeidae, and Scolytidae. The Curculionidae are the most diverse family of insects, and many of the species contained within can be listed as a pest of some agricultural product, though often not as important in the forest setting. The Nitidulidae, however, are known to vector fungal and viral pathogens to trees, including oak wilt fungus, and may represent important pests to forest systems. Also included in this family is the small hive beetle, *Aethina tumida* Murray, which can severely damage bee hives. The Scarabaeidae are another large family, and include many important pests of turf grass and other plant groups, including the Japanese beetle. There are pest species and beneficial species in this family, with many important pollinators (*Euphoria* spp. and *Cotinus* spp.) and dung recyclers (*Onthophagus* spp. and *Canthon* spp.) in the Scarabaeidae. The Scolytidae have a greater impact economically on the timber-producing forests of North America than any other group of insects. Included in this family are some of the most notorious tree pests, such as the european elm bark beetle, *Scolytus multistriatus* Marsham, and the

southern pine beetle. Although scolytids may be important pests in forest and urban settings, no reports are available for this taxa on *M. grandiflora*. Three species from this family (*D. frontalis, Hypothenemus eruditus* Westwood, and *Scolytus muticus* Say) were collected, none of which is known to damage *M. grandiflora*. Also included in the Coleoptera collected from magnolia are various beneficial families, including the Carabidae and Coccinellidae. Nearly all species of these two families are predaceous, many of them upon destructive pest groups, such as lepidoptera larvae, scales and aphids. There are exceptions in each family, with the seed corn beetle, *Stenolophus lecontei* (Chaudoir), a carabid, and the Mexican bean beetle, *Epilachna varivestis* Mulsant, a coccinellid, important pests of agricultural field crops.

Diptera was represented by 25 families collected from traps in 2001, and was slightly more evenly distributed between sites than the Coleoptera, with 52% (13) of the families common to both sites, 28% (7) unique to the forest site, and 20% (5) unique to the urban site (Figure 2). Included in this order were guilds such as scavengers, fungus feeders, blood feeders, predators, and parasitoids. While three families (Calliphoridae, Culicidae, and Muscidae) represented important pests, nine others were beneficial predators or parasitoids that attack pests like foliage feeders and wood borers (Table 9). Of the seven families unique to the forest site, three were predators or parasitoids, including the Pallopteridae and Pipunculidae. Larvae of the Pallopteridae are predatory on the larvae of wood-boring beetles, which were also more abundant at the forest site, and Pipunculidae parasitize leafhoppers and planthoppers, which include pests of agricultural crops and trees alike. Additionally, the Sciomyzidae were unique to the forest site, and are known for their predation of snails (Agriculture Canada 1981). The four most abundant families of Diptera (Anthomyiidae, Calliphoridae, Muscidae, and Sarcophagidae) were present at both sites. However, in each case they were more abundant in pitfall and malaise traps at the urban site, possibly due to the presence of the livestock barn, as each of these families include members that utilize manure and livestock. The Calliphoridae and Muscidae in particular also include important pests of livestock, including screworms, faceflies, and hornflies, which could present disease problems to the livestock held in the Brehm Animal Science Building.

Table. 9. Dipteran families collected from malaise and pitfall traps at the forest site and at the urban site in 2001, and their associated guilds.

Family	Guild	Abundance forest site	Abundance urban site	Total
Anthomyiidae	Scavengers	47	211	258
Calliphoridae	Scavengers; pests	140	477	617
Chironomidae	Scavengers	1	0	1
Culicidae	Blood feeders; pests	1	3	4
Dolichopodidae	Predators; beneficials	25	27	52
Drosophilidae	Scavengers	1	0	1
Empididae	Predatory; beneficials	1	1	2
Lauxaniidae	Fungus feeders	2	1	3
Lonchaeidae	Scavengers	0	11	11
Muscidae	Scavengers/blood feeders; pests	142	383	525
Mycetophilidae	Fungus feeders	0	2	2
Otitidae	Scavengers	0	5	5
Pallopteridae	Predatory; beneficials	4	0	4
Pipunculidae	Parasitoids; beneficials	1	0	1
Platystomatidae	Scavengers	1	8	9
Sarcophagidae	Scavengers	249	580	829
Scatopsidae	Scavengers	0	2	2
Sciaridae	Fungus feeders	3	0	3
Sciomyzidae	Predators	1	0	1
Stratiomyidae	Predators; beneficials	2	4	6
Syrphidae	Predators; beneficials	19	3	22
Tachinidae	Parasitoids; beneficials	2	7	9
Therevidae	Predators	0	3	3
Tipulidae	Scavengers	5	1	6
Xylophagidae	Predators; beneficials	1	0	1
	Totals:	648	1729	2377

Hymenoptera was represented by 17 families collected from traps in 2001, with 59% (10) common to both sites, 12% (2) unique to the forest site, and 29% (5) unique to the urban site (Figure 3). This is the only one of the three major orders that had more families unique to the urban site, and it also had the largest percentage of families common to both sites. Guilds of the Hymenoptera collected included pollen feeders, predators, parasitoids, and wood borers, and while nine families are considered to be beneficial pollinators or parasitoids of pest insects, only one of the families, Tenthredinidae, is considered to be a pest (Table 10). Only two families (Scelionidae and Xiphydriidae) were unique to the forest site. The Scelionidae are beneficial parasitoids of the eggs of Diptera and Lepidoptera, while the Xiphydriidae are wood borers (Goulet 1993). As with the Coleoptera, wood-boring insects can be expected to be more abundant at the forest site due to the abundance of dead or dying wood. Of the five families unique to the urban site, two were beneficial parasitoids, including the Braconidae, which will attack all life stages of hosts and have been of considerable value in the control of insect pests from the orders Coleoptera, Diptera, Hemiptera, and Lepidoptera. The Evaniidae are parasitoids of the egg capsules of cockroaches, which were also collected from the urban site (Goulet 1993). Sawflies in the family Tenthredinidae were present at both sites, and include important tree pests such as the yellowheaded spruce sawfly, *Pikonema alaskensis* (Rohwer), and the redheaded pine sawfly, *Neodiprion lecontei* (Fitch), but none has been reported to attack magnolia. Aside from the ants, the most abundant shared families of Hymenoptera were the Halictidae and the Vespidae. Both of these families will forage for food resources including flower nectar and other sweet-smelling substances, and the antifreeze solution used in the traps could be responsible for attracting large numbers of these insects into the traps. The presence of the flower and herb garden on the east side of the urban site may provide pollen and nectar resources for a larger diversity of Hymenoptera at this site.

Table. 10. Hymenopteran families collected from pitfall and malaise traps at the forest site and at the urban site in 2001, and their associated guilds.

Family	Guild	Abundance forest site	Abundance urban site	Total
Andrenidae	Pollen feeders; beneficials	5	9	14
Anthophoridae	Parasitoids	1	2	3
Apidae	Pollen feeders; beneficials	5	19	24
Braconidae	Parasitoids; beneficials	0	2	2
Chrysididae	Parasitoids	0	3	3
Colletidae	Pollen feeders; beneficials	0	1	1
Evaniidae	Parasitoids; beneficials	0	1	1
Formicidae	Predators, scavengers	164	422	586
Halictidae	Pollen feeders; beneficials	211	22	233
Ichneumonidae	Parasitoids; beneficials	21	18	39
Megachilidae	Pollen feeders; beneficials	2	4	6
Pompilidae	Parasitoids	12	17	29
Scelionidae	Parasitoids; beneficials	6	0	6
Sphecidae	Predators	0	7	7
Tenthredinidae	Plant feeders; pests	2	3	5
Vespidae	Predators	62	47	109
Xiphydriidae	Wood borers	1	0	1
	Totals:	492	577	1069

Species of Coleoptera Collected from Magnolia

In studies conducted at the GRSM in eastern Tennessee and western North Carolina, 1,103 coleopteran species in 86 families have been recorded as of 23 April 2002 at LSAM. The list of Coleoptera compiled by LSAM provides some interesting information when compared with the list of Coleoptera found on magnolia, since their list was recorded only 70 km from our urban site and 100 km from our forest site. All 40 of the coleopteran families collected from magnolia were recorded in the GRSM, while 58 of the 147 coleopteran species collected from magnolia were recorded from the GRSM and 32 of the 147 species were recorded from Tennessee in Downie and Arnett (1996) (Table 11).

Of the 147 species of Coleoptera collected through all collection methods, eight species were non-native. The coccinellid *Coccinella septempunctata* (L.), commonly known as the seven-spotted lady beetle, has been repeatedly introduced into North

Table 11. Coleopteran species collected from *Magnolia grandiflora* L. at both sites with all methods in 2000-2002.

Family	Species	Distribution*	Abundance
Alleculidae	*Hymenorus discretus* Casey	MA, RI, NY, PA, IN, VA, FL	1
	Hymenorus obscurus (Say)	NY, NJ, PA, MD, IN, VA, FL	4
Anobiidae	*Trichodesma klagesi* Fall	CT, DC, OH, IN, KY	2
Anthicidae	*Tomoderus constrictus* (Say)	NY, NJ, MD, PA, OH, IN, IL, WI, VA, SC, FL, LA, AR	3
Bruchidae	*Amblycerus robiniae* F.	NY, IN, PA, MD, VA, GA, FL, TN	2
Buprestidae	*Agrilus sayi* Saunders	ME, MA, CT, NY, NJ, PA, NH, VA, FL	7
	Brachys aerosus rufescens Nicolay & Weiss	NY, PA, MD, VA, FL, TN	1
Cantharidae	*Cantharis bilineatus* Say	ME, MI, IL, IN, MA, NJ, PA, MD, VA, NC, SC, GA	1
	Cantharis longulus LeConte	MA, NJ, VA, NC	2
	Chauliognathus marginatus (F.)	IL, MA, FL, TN	61
	Silis bidentatus (Say)	NY, IN, VA, GA, FL, MS, TN	1
	Tytthonyx erythrocephalus (F.)	IL, IN, OH	1
Carabidae	*Abacidus atratus* Newman	IN, OH, PA, WV, TN	78
	Agonum punctiforme (Say)	IN, DE, SC, GA, AL, TN	1
	Amara crassispina LeConte	MA, SC	1

*Distributions as determined by Downie and Arnett (1996) and by the Louisiana State Arthropod Museum.

Table 11. (cont.)

Family	Species	Distribution	Abundance
Carabidae	*Calleida viridipennis* (Say)	DE, SC, FL, AL	2
	Cyclotrachelus sodalis LeConte	NY, VT, WI, MI, IL, IN, OH, PA, NJ, KY, TN,	1
	Dicaelus ambiguus LaFerte-Senectere	IL, IN, OH, PA, DC, KY, TN, NC, GA, FL, AR, AL	1
	Harpalus fulgens Csiki	IN, SC, LA, TN	1
	Poecilus lucublandus (Say)	NY, IN, PA, DE, SC, TN	3
	Pterostichus coracinus Newman	NH, WI, IN, PA, MD, VA, TN, NC, SC	5
	Scarites subterraneus F.	IN, PA, DE, SC, FL, TN	1
	Sphaeroderus lecontei Dejean	NY, IN, PA, SC, GA, TN	2
	Stenolophus ochropezus (Say)	NY, IN, RI, PA, DE, SC, FL, TN	2
Cephaloidae	*Cephaloon lepturides* Newman	MA, NY, PA, IN, VA, NC	6
Cerambycidae	*Astylopsis macula* (Say)	WI, MI, NY, VT, ME, MA, CT, RI, IL, IN, OH, PA, NJ, MD, WV, VA, TN, NC, SC, GA, FL, AL, MS	1
	Clytoleptus albofasciatus (Castelneau & Gory)	MI, NY, IN, OH, PA, MD, VA, GA, FL	1
	Cyrtophorus verrucosus (Olivier)	NY, MI, IN, OH, PA, MD, VA, GA, FL, TN	8
	Elaphidion mucronatum (Say)	NY, NJ, PA, MD, OH, MI, IN, IL, VA, NC, SC, GA, FL, AL, LA, TN, KY	6

Table 11. (cont.)

Family	Species	Distribution	Abundance
Cerambycidae	*Euderces picipes* (F.)	MA, CT, NY, NJ, PA, MD, OH, MI, IN, IL, VA, NC, SC, GA, FL, AL, AR, TN, KY	2
	Necydalis mellita (Say)	NY, MI, IN, OH, PA, MD, VA, GA, FL	1
	Neoclytus acuminatus (F.)	NY, IN, OH, PA, AL, AR	1
	Phymatodes amoenus (Say)	NY, MI, OH, IN, FL	1
	Stenocorus cinnamopterus (Randall)	MA, PA, OH, IN, GA, AL	4
	Strangalepta abbreviata (Germar)	TN	2
	Strangalia bicolor (Swederus)	NY, PA, NJ, OH, IN, VA, WV, KY, AL, GA	1
	Strangalia famelica solitaria (Haldeman)	IL, IN, OH, KY, TN, AL, LA	7
	Strangalia luteicornis (F.)	NH, MA, CT, NY, NJ, MD, PA, OH, MI, IN, IL, VA, WV, NC, SC, GA, FL, AL, MS, AR, TN, KY	18
	Tilloclytus geminatus (Haldeman)	NY, IN, OH, PA, MD	1
	Typocerus velutinus (Olivier)	NY, PA, MD, VA, WV, NC, SC, TN, GA, MS, AR	2
	Urgleptes querci (Fitch)	WI, MI, NY, PA, OH, MD, VA	2
	Xylotrechus colonus (F.)	WI, MI, NY, VT, NH, ME, IL, IN, OH, PA, MA, CT, RI, MD, DE, WV, VA, NC, SC, GA, FL, MS, LA, TN	1

Table 11. (cont.)

Family	Species	Distribution	Abundance
Chrysomelidae	*Colaspis brunnea* (F.)	VT, MA, NY, NJ, PA, OH, IN, MI, KY, TN, NC, FL, VA, AL, MS, LA, AR	1
	Cryptocephalus quadruplex Newman	NH, CT, RI, MA, NY, NJ, DE, MD, PA, OH, IN, IL, MI, WI, VA, NC, GA, AL, WV, KY, LA, AR, TN	1
	Demotinus modestus Baly	TN	1
	Diabrotica undecimpunctata Newman	ME, WI, MI, NY, IL, IN, OH, PA, NJ, MD, VA, NC, SC, GA, FL, TN	5
Cleridae	*Cymatodera undulata* (Say)	NY, NJ, MD, OH, IN, IL, WI, SC, AL, FL, AR, KY	3
	Phlogistosternus dislocatus (Say)	NY, NJ, PA, OH, IN, IL, WI, GA, SC, WV	3
	Phyllobaenus humeralis Say	ME, MA, NY, NJ, OH, IN, IL, SC, FL	4
	Placopterus thoracicus (Olivier)	IL, IN, OH, PA, NY, NJ, MD, VA, NC, SC, GA, FL	7
	Thanasimus dubius (F.)	ME, NY, IN, VA, NC, SC, LA, TN	2
Coccinellidae	*Chilocorus stigma* Say	WI, MI, NY, VT, NH, ME, MA, CT, RI, IL, IN, OH, PA, NJ, MD, WV, VA, NC, SC, GA, FL, AL, MS, LA, AR	9
	Coccinella septempunctata (L.)	Throughout eastern U.S., Europe	1

Table 11. (cont.)

Family	Species	Distribution	Abundance
Coccinellidae	*Didion punctatum* (Melsheimer)	ME, WI, MI, NY, VT, NH, MA, CT, RI, IL, IN, OH, PA, NJ, MD, DC, WV, VA, NC, SC, GA, FL, AL, MS, AR, LA	1
	Diomus myrmidon Mulsant	NY, NJ, VA, NC	1
	Harmonia axyridis (Pallas)	Throughout eastern U.S., Asia	16
	Psyllobora vigintimaculata (Say)	OH, WI, MI, NY, VT, NH, MA, RI, IL, IN, OH, PA, NJ, MD, WV, VA, KY, NC, SC, TN, GA, AL, MS, LA, AR	2
	Scymnus loewii Mulsant	NC, FL	1
Curculionidae	*Conotrachelus anaglypticus* (Say)	ME, CT, MA, NY, NJ, PA, MD, DE, DC, OH, MI, IN, IL, WI, WV, VA, NC, SC, GA, FL, AL, MS, LA, AR, KY, TN	1
	Cyrtepistomis castaneus (Roelofs)	CT, NY, NJ, PA, DC, MD, OH, IN, VA, WV, NC, SC, GA, AL, FL, MS, LA, TN, KY, AR, Asia	2
	Eubulus obliquus (Say)	NJ, VA, NC, SC, FL, AL, LA	1
	Hypera punctata (F.)	WI, MI, NY, ME, VT, NH, MA, CT, RI, IL, IN, OH, PA, NJ, MD, WV, VA, NC, TN, SC, Europe	4
	Madarellus undulatus (Say)	CT, MA, NY, NJ, PA, MI, IN, VA, NC, SC, GA, FL	2

Table 11. (cont.)

Family	Species	Distribution	Abundance
Curculionidae	*Mecinus pyraster* (Herbst)	NY, NJ, MD, VA, FL, Eurasia	1
	Myrmex chevrolati (Horn)	CT, NY, NJ, DC, RI, PA, IN, MI, NC, GA, VA	1
	Naupactus leucoloma Boheman	S. America	2
	Rhyssomatus annectans (Casey)	NY, MD, OH, IN, IL, SC	2
	Sitona hispidula F.	Throughout eastern U.S.	5
Dascillidae	*Eurypogon niger* Melsheimer	NY, PA	1
Dermestidae	*Attagenus elongatulus* Casey	NY, PA	1
	Trogoderma teukton Beal	IL, IN	2
Elateridae	*Agriotes oblongicollis* (Melsheimer)	ME, VT, NH, MA, CT, NY, NJ, PA, OH, IN, IL, VA, WV, NC, SC, GA, TN	3
	Ampedus sellatus (DeJean)	NY, OH, IN, GA, FL	1
	Conoderus lividus (DeGeer)	NY, IN, PA, MD, FL, TN	2
	Ctenicera pyrrhos (Herbst)	MA, NY, CT, VA, TN, GA	2
	Glyphonyx helix Smith & Balsbaugh	OH, AR, FL, LA, TN	17
	Melanotus americanus (Herbst)	CT, RI, MA, NY, NJ, MD, DE, OH, IN, IL, WV, NC, SC, GA	3
	Melanotus morosus Candeze	NH, MA, CT, NY, NJ, PA, MD, DC, OH, IN, IL, VA, NC, SC, GA, AL, FL, MS, AR, TN	5

Table 11. (cont.)

Family	Species	Distribution	Abundance
Elateridae	*Melanotus pertinax* (Say)	ME, NH, VT, MA, CT, NY, PA, IN, IL, WI, NC, SC, GA	5
Erotylidae	*Tritoma humeralis* F.	WI, MI, NY, NH, MA, CT, IL, IN, OH, PA, NJ, MD, DC, WV, VA, NC, SC, TN, KY, GA, MS, LA, AR	2
Eucnemidae	*Dromaeolus calceatus* (Say)	WI, MI, NY, VT, NH, ME, MA, AR, GA	1
	Isorhipis obliqua (Say)	NY, VT, NH, ME, MA, CT, RI, IL, IN, OH, PA, NJ, MD, DC, KY, VA, NC, GA, SC	3
	Melasis pectinicornis Melsheimer	NY, NH, MA, IL, IN, IH, PA, NJ, MD, DC, KY, VA, NC, LA, AL, GA, SC, FL	1
Histeridae	*Hister dispar* LeConte	IL, GA	1
	Platysoma basale (LeConte)	OH, IN, MI	1
Lagriidae	*Arthromacra aenea aenea* (Say)	ME, NH, VT, MA, CT, NY, NJ, MD, DE, PA, OH, IN, MI, VA, WV, TN, NC	5
Lampyridae	*Lucidota punctata* LeConte	NY, IN, VA	2
	Photinus pyralis (L.)	NY, NJ, PA, MD, OH, IN, IL, VA, WV, KY, TN, NC, GA, FL, AL, LA, MS	1
	Photuris cinctipennis Barber	DE	2
	Pyractomena borealis (Randall)	ME, NH, MA, CT, NY, NJ, PA, OH, MI, IN, IL, WI, DC, MD, VA, KY, TN, NC, SC, GA, FL, AL, MS	2

Table 11. (cont.)

Family	Species	Distribution	Abundance
Leiodidae	*Colenis impunctata* LeConte	IN, MI, LA, FL, TN	5
Melandryidae	*Eustrophus tomentosus* Say	MI, NY, MA, IN, VA, AL	19
	Hallomenus debilis LeConte	IN	3
Melyridae	*Attalus pallifrons* Motschulsky	CT, NY, DC, IN	1
	Melyrodes basalis LeConte	WI, FL	1
	Melyrodes cribrata LeConte	NY, IN, VA, FL	2
Mordellidae	*Mordella atrata* Melsheimer	AL	1
	Mordella lunulata Hellmuth	MA, CT, NY, NJ, PA, MD, MI, OH, IN, IL	2
	Mordellistena hebraica LeConte	PA, MD, OH, IN, MI, IL, NH, VA, NC, AL, KY, MS, GA	1
	Mordellistena ornata (Melsheimer)	ME, MA, NY, PA, MD, OH, IN, MI, IL, FL	1
	Mordellistena pubescence (F.)	ME, MA, NY, NJ, CT, MD, PA, OH, IN, IL, VA, NC, TN, AL, FL	13
	Mordellistena smithi Dury	IN, IL, OH, MD, VA, AR	1
	Tomoxia fascifera (LeConte)	DC, NC, FL	1
	Tomoxia lineella LeConte	ME, NY, MD, PA, OH, IN, IL, MI, GA	4
	Tomoxia triloba (Say)	VT, NY, PA, MD, OH, MI, IN, IL, AL, FL	1
Mycetophagidae	*Litargus tetraspilotus* LeConte	WI, MI, NY, IL, VA, WV, TN, NC, SC, GA, FL, LA	1

Table 11. (cont.)

Family	Species	Distribution	Abundance
Nitidulidae	*Amphicrossus ciliatus* (Olivier)	IN, FL, TN	8
	Carpophilus corticinus Erichson	IN, NY, PA, GA, TN	4
	Carpophilus sayi Parsons	IN, NY, MD, GA	2
	Colopterus maculatus (Erichson)	NY, PA, VA, GA, FL	8
	Colopterus niger (Say)	IL, IN, IA, MD, DC, WV, NC, FL, AR, LA	1
	Cryptarcha ampla Erichson	NY, WI, MI, IL, IN, PA, MD, WV, NC, FL, TN	5
	Glischrochilus fasciatus (Olivier)	IN, OH, FL, TN	58
	Glischrochilus quadrisignatus Say	WI, IN, OH, MD, NC, FL, TN	9
	Glischrochilus sanguinolentus (Olivier)	WI, IN, PA, WV, FL, TN	57
	Stelidota geminata (Say)	MA, WV, NC, FL, TN	8
	Stelidota octomaculata (Say)	MA, WI, MI, IN, NC, FL, TN	18
Rhizophagidae	*Bactridium ephippigerum* (Guerin)	NY, MD, IN, LA	8
Scarabaeidae	*Anomala marginata* (F.)	WI, MI, NY, MA, PA, MD, VA, GA, FL	1
	Cloeotus globosus (Say)	NY, IN, FL, AL, LA	3
	Cotinus nitida (L.)	IN, NY, CT, FL, LA	3
	Cyclocephala hirta LeConte	IN	1

Table 11. (cont.)

Family	Species	Distribution	Abundance
Scarabaeidae	*Euphoria fulgida* (F.)	CT, MI, IN	2
	Euphoria inda (L.)	CT, NY, IN, FL, TN	9
	Euphoria sepulchralis (F.)	IL, IN, FL, LA, TN	2
	Glaphyrocanthon viridis (Beavois)	NY, PA, MD, VA, NC, SC, GA, FL	1
	Gnorimella maculosa (Knoch)	NY, IN, MD, GA, AL, FL, TN	2
	Macrodactylus angustatus Beauvois	PA, IN, MD, VA, GA, FL	1
	Onthophagus nuchicornis (L.)	WI, NY, IN, VA, Europe	1
	Osmoderma eremicola (Knoch)	WI, MI, NY, CT, IN, NC, TN	1
	Popillia japonica Newman	NY, MA, IL, IN, OH, PA, NJ, VA, TN, Japan	86
	Serica iricolor Say	NH, MA, MD, GA	16
	Serica sericea (Illiger)	MA, IN, MD, FL, TN	24
Scirtidae	*Cyphon ruficollis* Say	NY, CT, IN, GA, TN	4
Scolytidae	*Dendroctonus frontalis* Zimmerman	PA, DC, WV, VA, NC, SC, GA, FL, AL, LA, AR, TN	1
	Hypothenemus eruditus Westwood	NH, NY, NJ, PA, MD, IL, IN, WV, VA, TN, NC, SC, GA, AL	1
	Scolytus muticus Say	CT, NJ, PA, OH, IN, KY, WV, MS, SC, FL	5

Table 11. (cont.)

Family	Species	Distribution	Abundance
Silphidae	*Necrophila americana* (L.)	NH, VT, MA, CT, RI, WI, MI, IL, IN, OH, NY, PA, NJ, DE, MD, KY, WV, TN, AR, AL, SC, GA, FL	2
	Nicrophorus pustulatus Herschel	ME, NH, CT, RI, WI, MI, IL, IN, NY, PA, NJ, MD, DC, WV, VA, TN, NC, GA, FL, AR	3
Tenebrionidae	*Meracantha contracta* (Beauvois)	NY, CT, IN, TN	3
Throscidae	*Aulonothroscus convergens* Horn	NY, DC, NC, SC, FL, LA, TN	1
Trogossitidae	*Tenebroides corticalis* Melsheimer	Throughout eastern U.S.	1

America from Europe for the biological control of various aphids. Established in the early 1970s in New Jersey, it has since spread naturally and is now found throughout the eastern U.S. *C. septempunctata* may be a more effective predator than some native lady beetle species, displacing them in some areas (Hoffman and Frodsham 1993). Another coccinellid, *Harmonia axyridis* (Pallas), or the Asian multi-colored lady beetle, was introduced from Asia into the U.S. many times during the twentieth century, both purposefully for classical biological control of arthropod pests and accidently. It finally became established and quickly spread over the entire U.S. sometime in the late 1980s and early 1990s. Now considered a minor pest species due to congregation in homes during winter months, these lady beetles are also more effective predators than native species, and can often be seen feeding on the same insects and at the same sites as *C. septempunctata* (Hoffman and Frodsham 1993). This trend is supported by the fact that both of these species were collected from the same fog sample on 11 June 2001.

Another four non-native species of Coleoptera collected from magnolia were in the family Curculionidae. The Asiatic oak weevil, *Cyrtepistomis castaneus* (Roelofs), is a minor foliage pest of *Quercus* spp., and has been reported throughout much of the eastern United States. This Asian weevil is also known to invade homes in winter months (Downie and Arnett 1996). The clover leaf weevil, *Hypera punctata* (F.), is European in origin, but has become an important pest of clover and alfalfa crops throughout the eastern and midwestern U.S. (Roberts and Pausch 1982). The weevil *Mecinus pyraster* (Herbst), of Eurasian origin, has been previously recorded along the east coast of the U.S. While it can be a seed pest of *Plantago* spp., successful biological control by three hymenopteran parasitoids has been reported (Norowi et al. 2000). Whitefringed beetle, *Naupactus leucoloma* (Boheman), is a native of South America and was first reported in Florida in 1936. Now spread throughout the southeastern United States, *N. leucoloma* can damage root and tuber crops grown in this region (Zehnder et al. 1998). None of these insects was collected in great abundance from magnolia.

Along with the Coccinellidae and Curculionidae, two non-native species from the family Scarabaeidae were collected. With a wide natural distribution in Europe and central Asia, *Onthophagus nuchicornis* (L.) was introduced on both coasts of North America around the year 1945, and can be found burying pads of dung in cow and horse pastures. While it is an exotic-invasive insect, *O. nuchicornis* has been shown to be effective at reducing populations of horn f ly, a medically important livestock pest, due to its ability to bury dung pads (Macqueen 1975). Perhaps the most notorious of these non-native species, the Japanese beetle was first reported in New Jersey in 1916, possibly imported from Japan as grubs in the soil of irises. This beetle has now spread throughout most of the eastern U.S., and is considered the country's most widespread and destructive pest of turfgrass, landscape and nursery crops. Larvae of the Japanese beetle can seriously damage turf grass, and the adults attack the foliage, flowers, and fruits of more than 300 ornamental and agricultural plants, including *M. grandiflora*. More than 450 million dollars is spent each year for control costs and for renovating damage to turf and ornamental plants. Despite these ongoing efforts, the Japanese beetle remains a threat as an invasive species (Potter and Held 2002). Only one specimen of *P. japonica* was

collected from the forest site, and of the 85 specimens collected from the urban site, 84 were collected from the flowers in direct samples. Japanese beetles were observed feeding on pollen and tepals of the flowers, with up to 12 specimens collected from a single flower (27 June 2001).

Along with *P. japonica*, several other species of Coleoptera were collected in high abundance on southern magnolia. The cantharid *C. marginatus* has been reported as a biological control agent of a variety of pest insects, including corn rootworms (*Diabrotica* spp.) in the family Chrysomelidae (Kuhlmann and van der Burgt 1998). It is also an important pollinator of many types of flowering plants (Primack and Silander 1975), and probably filled this role on *M. grandiflora*. Of the 61 total specimens collected, 49 were collected by sweep net from flowers, inferring the importance of this insect to magnolia pollination at the urban site. The carabid *A. atratus* was the most abundant beetle collected in pitfall traps, and in overall abundance was second only to *P. japonica*. This ground beetle is an important predator of pests such as scarab grubs, and can be a beneficial biological control agent in agricultural fields (Hylton 1980). The cerambycid *Strangalia luteicornis* (F.) is widespread throughout the eastern U.S., and can be commonly seen on flowers and foliage (Downie and Arnett 1996). It has also been noted as an important pollinator of *M. grandiflora* (Thien 1974). Although this cerambycid was not collected in our floral sampling at the urban site, 18 specimens were collected from malaise traps at the forest site, making up part of the high overall abundance and diversity of the family Cerambycidae at that site. Two nitidulid species, *G. fasciatus* and *G. sanguinolentus*, have been recorded throughout the western and midwestern U.S., and are primary vectors of the oak wilt pathogen, *Ceratocystis fagacearum* (Bretz). This disease occurs in 22 states and is considered the most important forest disease problem in Minnesota, Wisconson, Illinois, and Iowa, causing mortality in thousands of native oaks annually across the Midwest. Transmission by *G. fasciatus* and *G. sanguinolentus* is the most significant means of vectoring the disease, as they are attracted to sap flowing from wounds of diseased trees, pick up the spores, and transmit them to fresh wounds on healthy trees (Cease and Juzwik 2001). Both species were extremely abundant at the forest site, and given the importance of oaks to the forest

site ecosystem, represent a significant problem should this disease become prevalent in eastern Tennessee. Another nitidulid, *Stelidota octomaculata* (Say), is an important pest of red oak seedlings and acorns, and can hinder red oak regeneration (Williams et al. 1995). While not as abundant as other members of its family, *S. octomaculata* may represent an important pest species to the red oaks at the forest site.

Chapter IV
Conclusions

Significantly more ($P < 0.05$) insect specimens were collected from the upper canopy malaise traps than from the lower canopy malaise traps. This difference in the number of specimens collected could be the result of structural differences of the trees at the two canopy levels. The malaise/pan traps in the upper canopy may have had less canopy density and area to shelter them from the rain, and as a result may have collected more rain water than the traps in the lower canopy. During the two weeks in which insects were allowed to accumulate in traps between collection dates, a larger amount of water in the trap could have contributed to more rapid and advanced decay of the insects. The insects that caused the disparity in number of specimens collected from the two canopy levels were Diptera from the families Anthomyiidae, Calliphoridae, Muscidae, and Sarcophagidae, primarily from insects collected from the urban site. Due to the presence of the livestock barn in the Brehm Animal Science Building, these Diptera were more abundant at the urban site. These families of Diptera are attracted to decay and fecal waste, and may have been more abundant in traps in the upper canopy than those in the lower canopy due to the accelerated rate of decay of insects in those traps.

Significantly more ($P < 0.05$) insect specimens were collected from pitfall traps at the urban site than from pitfall traps at the forest site in 2001. The presence of paved roads, parking lots, and walkways around the buildings at the urban site, and fewer large trees to provide shade, may have allowed for higher temperatures at the soil surface of the urban site. Higher temperatures may have resulted in increased levels of insect activity, which could account for the higher numbers of insect specimens collected from the urban site. Significantly more ($P < 0.05$) insect species were collected from pitfall traps at the forest site than from pitfall traps at the urban site in 2001. A more diverse and abundant representation of plants, along with the presence of dead trees and a more complex habitat structure in general, may have allowed for this trend.

Significantly more ($P < 0.05$) insect specimens were collected from pitfall and malaise traps combined at the urban site than at forest site in 2001. In addition to the

previously mentioned climatic differences, the presence of the livestock barn and human trash may have contributed to a more abundant representation of insects at the urban site. Significantly more ($P < 0.05$) insect species were collected from pitfall and malaise traps combined at the forest site than at the urban site in 2001, again likely due to the more diverse and abundant representation of plants, along with the presence of dead trees and a more complex habitat structure in general, at the forest site.

Significantly more ($P < 0.05$) specimens, families, and species were collected from flowers in 2002 than in 2001. While this trend is likely due in part to the addition of the sticky traps to the sampling methodology, it is also likely due to the adjustments made to the data from 2001, as listed in the methodology section. Two coleopteran species, *C. marginatus* and *P. japonica*, and the honeybee *A. mellifera*, were collected in greater abundance in 2001 despite the data adjustment. This trend could be an indication of variable insect abundance from year to year for these species, but future studies should include consistent sampling methodology from year to year to avoid the necessity of data adjustment.

Of the 480 species collected, 285 species were represented by only one or two specimens, indicating that they may not be associated with magnolia. Other taxa, including the nitidulids, formicids, halictids, and vespids, are attracted to sweet-smelling substances and may have been attracted to the pitfall and malaise traps by the anti-freeze solution.

Eight exotic species of Coleoptera were collected from southern magnolia during this study, six of which are potentially destructive. The species with the greatest potential for impacting southern magnolia is the Japanese beetle, which was collected with floral samples in both 2001 and 2002. The two exotic coccinellid species considered as beneficial were intentionally introduced by entomologists for control of pest species.

From this study, new information was gained concerning the insect fauna associated with southern magnolia in eastern Tennessee, including a species list. Data collected from this study may be useful to propagators and owners of southern magnolia in assessing potential pest species (*P. japonica*, *G. fasciatus*, and *G. sanguinolentus*), potentially beneficial species for biological control (*C. marginatus*, *A. atratus*, *H.

axyridis, and *C. septempunctata*), or pollination studies (*C. marginatus*, *S. luteicornis*, and *P. japonica*). These data may be compared to new data collected after a possible defoliation or dieback event (i.e., McCracken 1985) in east Tennessee to determine any significant differences in insect communities. A greater understanding of these insect communities associated with southern magnolia may provide scientists the information necessary to combat future problems with non-native insects, pollination problems, or diseases.

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Appendix

Appendix A.

Order	Family	Species	Method*
Blattaria	Blattelidae	*Ischnoptera deropeltiformis* Brunner	M, P, Fg
Blattaria	Blattellidae	*Parcoblatta bolliana* Brunner	M, P
Blattaria	Blatellidae	*Parcoblatta virginica* Brunner	Fg
Orthoptera	Acrididae	sp.	P
Orthoptera	Gryllidae	*Acheta assimilis* (F.)	P
Orthoptera	Gryllidae	*Orocharis saltator* Uhler	M, P
Orthoptera	Gryllacrididae	*Camptonotus carolinensis* (Gerstaeker)	Fg
Orthoptera	Gryllacrididae	*Ceuthophilus brevipes* Scudder	P
Orthoptera	Tettigoniidae	*Pyrgocorypha uncinata* (Harris)	M, Fg
Orthoptera	Tettigoniidae	*Pterophylla* sp.	M, Fg
Dermaptera	Forficulidae	*Forficula auricularia* L.	M, P, Fl
Psocoptera	Liposcelidae	sp. 1	M, P, Fg
Psocoptera	Liposcelidae	sp. 2	P
Psocoptera	Pachytroctidae	sp. 1	M, Fg
Psocoptera	Pachytroctidae	sp. 2	Fl
Psocoptera	Pachytroctidae	sp. 3	Fg
Psocoptera	Pachytroctidae	sp. 4	Fg
Homoptera	Acanaloniidae	*Acanalonia* sp.	M
Homoptera	Cercopidae	*Aphrophora parallela* Say	Fg
Homoptera	Cicadidae	*Tibicen* sp.	M
Homoptera	Cicadellidae	*Aulacizes irrorata* (F.)	Fg
Homoptera	Cicadellidae	*Graphocephala versuta* (Say)	M
Homoptera	Cicadellidae	*Idiocerus verticis* (Say)	P
Homoptera	Cicadellidae	*Phlepsius collitus* Ball	M, Fg
Homoptera	Cicadellidae	*Jassus olitorius* Say	M, Fg
Homoptera	Cicadellidae	*Oncometopia undata* (F.)	Fg
Homoptera	Cicadellidae	*Oncopsis distinctus* (Van Duzee)	Fg
Homoptera	Cicadellidae	*Phlepsius collitus* Ball	Fg
Homoptera	Cicadellidae	*Scaphoideus auronitens* Provancher	P
Homoptera	Cixiidae	*Cixius miscellus* Van Duzee	Fg
Homoptera	Cixiidae	*Oliarus* sp.	M
Homoptera	Cixiidae	*Oliarus quinquelineatus* (Say)	M
Homoptera	Flatidae	*Anormenis chloris* (Melichar)	M, Fg
Homoptera	Flatidae	*Ormenis pruinosa* (Say)	M, Fl
Homoptera	Membracidae	*Atymna querci* (Fitch)	Fg

*M = Malaise, P = Pitfall, Fg = Fog, and Fl = Floral samples

Appendix A. (cont.)

Order	Family	Species	Method
Homoptera	Membracidae	*Cyrtolobus arcuatus* (Emmons)	M, Fg
Homoptera	Membracidae	*Glossonotus acuminatus* (F.)	M, Fg
Homoptera	Membracidae	*Ophiderma salamandra* Fairmaire	M
Homoptera	Membracidae	*Platycotis vittata* (F.)	M
Homoptera	Membracidae	*Telamona monticola* (F.)	M, Fg
Homoptera	Psyllidae	*Psylla* sp.	Fl
Hemiptera	Coreidae	*Acanthocephala terminalis* (Dallas)	M, Fg
Hemiptera	Cydnidae	*Pangaeus bilineatus* (Say)	P
Hemiptera	Cydnidae	*Sehirus cinctus* Palisot de Beauvois	Fg, Fl
Hemiptera	Lygaeidae	*Myodocha serripes* Olivier	P
Hemiptera	Miridae	*Platytylellus circumcinctus* (Say)	Fl
Hemiptera	Miridae	sp. 1	Fg
Hemiptera	Miridae	sp. 2	Fg
Hemiptera	Miridae	sp. 3	M, Fg
Hemiptera	Miridae	sp. 4	Fl
Hemiptera	Miridae	sp. 5	Fl
Hemiptera	Pentatomidae	*Apateticus cynicus* (Say)	Fg
Hemiptera	Pentatomidae	*Euschistus tristigmus* (Say)	Fg
Hemiptera	Pentatomidae	*Brochymena arborea* (Say)	M
Hemiptera	Reduviidae	*Pselliopus barberi* Davis	M
Hemiptera	Reduviidae	*Sinea spinipes* (Herrich-Schaeffer)	M
Hemiptera	Reduviidae	sp.	Fl
Hemiptera	Rhopalidae	*Boisea trivittatus* (Say)	Fg
Hemiptera	--	sp. 1	M
Hemiptera	--	sp. 2	M
Hemiptera	--	sp. 3	P
Hemiptera	--	sp. 4	P
Hemiptera	--	sp. 5	M
Hemiptera	--	sp. 6	P
Hemiptera	--	sp. 7	P
Hemiptera	--	sp. 8	M
Hemiptera	--	sp. 9	Fg
Hemiptera	--	sp. 10	M
Hemiptera	--	sp. 11	Fg
Neuroptera	Hemerobiidae	*Hemerobius stigma* Stephens	M

Appendix A. (cont.)

Order	Family	Species	Method
Neuroptera	Chrysopidae	*Chrysopa quadripunctata* Burmeister	M, Fg
Coleoptera	Alleculidae	*Hymenorus obscurus* (Say)	M
Coleoptera	Alleculidae	*Hymenorus discretus* Casey	M
Coleoptera	Anobiidae	*Oligomerus* sp.	M
Coleoptera	Anobiidae	*Trichodesma klagesi* Fall	M
Coleoptera	Anthicidae	*Tomoderus constrictus* (Say)	M
Coleoptera	Bruchidae	*Amblycerus robiniae* (F.)	M, Fl
Coleoptera	Buprestidae	*Agrilus bilineatus* (Weber)	M
Coleoptera	Buprestidae	*Agrilus sayi* Saunders	Fg
Coleoptera	Buprestidae	*Anthaxia* sp.	Fg
Coleoptera	Buprestidae	*Brachys aerosus rufescens* Nicolay & Weiss	Fg
Coleoptera	Buprestidae	sp. 1	Fg
Coleoptera	Buprestidae	sp. 2	Fg
Coleoptera	Cantharidae	*Cantharis bilineatus* Say	M
Coleoptera	Cantharidae	*Cantharis longulus* LeConte	M
Coleoptera	Cantharidae	*Cantharis* sp.	Fg
Coleoptera	Cantharidae	*Chauliognathus marginatus* (F.)	M, P, Fg, Fl
Coleoptera	Cantharidae	*Silis bidentatus* (Say)	Fg
Coleoptera	Cantharidae	*Tytthonyx erythrocephalus* (F.)	M
Coleoptera	Carabidae	*Abacidus atratus* Newman	P
Coleoptera	Carabidae	*Amara crassispina* LeConte	P
Coleoptera	Carabidae	*Calleida viridipennis* (Say)	M
Coleoptera	Carabidae	*Cyclotrachelus sodalis* LeConte	P
Coleoptera	Carabidae	*Cymindus* sp.	Fg
Coleoptera	Carabidae	*Dicaelus ambiguous* LaFerte-Senectere	P
Coleoptera	Carabidae	*Harpalus fulgens* Csiki	M
Coleoptera	Carabidae	*Poecilus lucublandus* (Say)	P
Coleoptera	Carabidae	*Pterostichus coracinus* Newman	P
Coleoptera	Carabidae	*Scarites subterraneus* F.	P
Coleoptera	Carabidae	*Sphaeroderus lecontei* Dejean	M, P
Coleoptera	Carabidae	*Stenolophus ochropezus* (Say)	M
Coleoptera	Cephaloidae	*Cephaloon lepturides* Newman	M
Coleoptera	Cerambycidae	*Astylopsis macula* (Say)	M
Coleoptera	Cerambycidae	*Clytoleptus albofasciatus* (Laporte & Gory)	M
Coleoptera	Cerambycidae	*Cyrtophorus verrucosus* (Olivier)	M

Appendix A. (cont.)

Order	Family	Species	Method
Coleoptera	Cerambycidae	*Elaphidion mucronatum* (Say)	M
Coleoptera	Cerambycidae	*Euderces picipes* (F.)	Fg
Coleoptera	Cerambycidae	*Molorchus bimaculatus* Say	M, Fg
Coleoptera	Cerambycidae	*Necydalis mellita* (Say)	M
Coleoptera	Cerambycidae	*Neoclytus acuminatus* (F.)	M
Coleoptera	Cerambycidae	*Phymatodes amoenus* (Say)	M
Coleoptera	Cerambycidae	*Stenocorus cinnamopterus* (Randall)	M, Fg
Coleoptera	Cerambycidae	*Strangalepta abbreviata* (Germar)	M
Coleoptera	Cerambycidae	*Strangalia bicolor* (Swederus)	M
Coleoptera	Cerambycidae	*Strangalia luteicornis* (F.)	M
Coleoptera	Cerambycidae	*Strangalia famelica solitaria* (Haldeman)	M, Fg
Coleoptera	Cerambycidae	*Tilloclytus geminatus* (Haldeman)	M
Coleoptera	Cerambycidae	*Typocerus velutinus* (Olivier)	M
Coleoptera	Cerambycidae	*Urgleptes querci* (Fitch)	M
Coleoptera	Cerambycidae	*Xylotrechus colonus* (F.)	M
Coleoptera	Chrysomelidae	*Colaspis brunnea* (F.)	Fg
Coleoptera	Chrysomelidae	*Cryptocephalus quadruplex* Newman	Fg
Coleoptera	Chrysomelidae	*Demotinus modestus* Baly	M
Coleoptera	Chrysomelidae	*Diabrotica undecimpunctata* Barber	Fl
Coleoptera	Chrysomelidae	*Paria* sp. 1	M, P, Fg
Coleoptera	Chrysomelidae	*Paria* sp. 2	M, P
Coleoptera	Chrysomelidae	*Paria* sp. 3	M
Coleoptera	Chrysomelidae	sp.	Fg
Coleoptera	Cleridae	*Cymatodera undulata* (Say)	M, P, Fg
Coleoptera	Cleridae	*Phlogistosternus dislocates* (Say)	M
Coleoptera	Cleridae	*Phyllobaenus humeralis* (Say)	M, Fg
Coleoptera	Cleridae	*Placopterus thoracicus* (Olivier)	M, Fg
Coleoptera	Cleridae	*Thanasimus dubius* (F.)	M
Coleoptera	Coccinellidae	*Chilocorus stigma* (Say)	M, Fg. Fl
Coleoptera	Coccinellidae	*Coccinella septempunctata* (L.)	Fg
Coleoptera	Coccinellidae	*Didion punctatum* (Melsheimer)	Fg
Coleoptera	Coccinellidae	*Diomus myrmidon* Mulsant	M
Coleoptera	Coccinellidae	*Harmonia axyridis* (Pallas)	M, Fg

Appendix A. (cont.)

Order	Family	Species	Method
Coleoptera	Coccinellidae	*Psyllobora vigintimaculata* (Say)	Fg
Coleoptera	Coccinellidae	*Scymnus loewii* Mulsant	Fg
Coleoptera	Cucujidae	sp.	P
Coleoptera	Curculionidae	*Bagous* sp.	P
Coleoptera	Curculionidae	*Conotrachelus anaglypticus* (Say)	M
Coleoptera	Curculionidae	*Cyrtepistoma castaneus* (Roelofs)	Fg
Coleoptera	Curculionidae	*Eubulus obliquus* (Say)	P
Coleoptera	Curculionidae	*Hypera punctata* (F.)	P
Coleoptera	Curculionidae	*Madarellus undulates* (Say)	M, Fg
Coleoptera	Curculionidae	*Mecinus pyraster* (Herbst)	M
Coleoptera	Curculionidae	*Myrmex chevrolati* (Horn)	Fg
Coleoptera	Curculionidae	*Naupactus leucoloma* Boheman	Fg
Coleoptera	Curculionidae	*Sitona hispidula* F.	P
Coleoptera	Curculionidae	*Rhyssomatus annectans* (Casey)	M
Coleoptera	Curculionidae	sp.	M
Coleoptera	Dascillidae	*Eurypogon niger* Melsheimer	M
Coleoptera	Dermestidae	*Trogoderma teukton* Beal	M
Coleoptera	Dermestidae	*Attagenus elongatulus* Casey	M
Coleoptera	Elateridae	*Agriotes oblongicollis* (Melsheimer)	M
Coleoptera	Elateridae	*Ampedus sellatus* (DeJean)	M
Coleoptera	Elateridae	*Ampedus* sp. 1	M
Coleoptera	Elateridae	*Ampedus* sp. 2	M
Coleoptera	Elateridae	*Conoderus lividus* (DeGeer)	Fg
Coleoptera	Elateridae	*Ctenicera pyrrhos* (Herbst)	M
Coleoptera	Elateridae	*Glyphonyx helix* Smith &Balsbaugh	M, Fg
Coleoptera	Elateridae	*Melanotus americanus* (Herbst)	M
Coleoptera	Elateridae	*Melanotus morosus* Candeze	M
Coleoptera	Elateridae	*Melanotus pertinax* (Say)	M, Fg
Coleoptera	Eucnemidae	*Dromaeolus calceatus* (Say)	M
Coleoptera	Eucnemidae	*Isorhipis oblique* (Say)	M
Coleoptera	Eucnemidae	*Melasis pectinicornis* Melsheimer	M
Coleoptera	Erotylidae	*Tritoma humeralis* F.	P
Coleoptera	Histeridae	*Hister dispar* LeConte	P
Coleoptera	Histeridae	*Platysoma basale* (LeConte)	M

Appendix A. (cont.)

Order	Family	Species	Method
Coleoptera	Hydrophilidae	*Cercyon* sp.	M
Coleoptera	Lagriidae	*Arthromacra aenea aenea* (Say)	M, Fg
Coleoptera	Lampyridae	*Lucidota punctata* LeConte	P, Fg
Coleoptera	Lampyridae	*Photinus pyralis* (L.)	Fg
Coleoptera	Lampyridae	*Photuris cinctipennis* Barber	M
Coleoptera	Lampyridae	*Pyractomena borealis* (Randall)	M
Coleoptera	Leiodidae	*Colenis impunctata* LeConte	M, P
Coleoptera	Melandryidae	*Eustrophus tomentosus* Say	M
Coleoptera	Melandryidae	*Hallomenus debilis* LeConte	M, Fg
Coleoptera	Melyridae	*Attalus pallifrons* (Motschulsky)	Fl
Coleoptera	Melyridae	*Melyrodes basalis* LeConte	Fg
Coleoptera	Melyridae	*Melyrodes cribrata* LeConte	Fg
Coleoptera	Mordellidae	*Mordella atrata* Melsheimer	M
Coleoptera	Mordellidae	*Mordella lunulata* Hellmuth	Fl
Coleoptera	Mordellidae	*Mordellistena hebraica* LeConte	M
Coleoptera	Mordellidae	*Mordellistena ornata* (Melsheimer)	M
Coleoptera	Mordellidae	*Mordellistena pubescence* (F.)	M, Fg, Fl
Coleoptera	Mordellidae	*Mordellistena smithi* Dury	M
Coleoptera	Mordellidae	*Mordellistena* sp. 1	M
Coleoptera	Mordellidae	*Mordellistena* sp. 2	M
Coleoptera	Mordellidae	*Mordellistena* sp. 3	Fg
Coleoptera	Mordellidae	*Tomoxia fascifera* (LeConte)	M
Coleoptera	Mordellidae	*Tomoxia lineella* LeConte	M
Coleoptera	Mordellidae	*Tomoxia triloba* (Say)	Fg
Coleoptera	Mordellidae	sp.	Fl
Coleoptera	Mycetophagidae	*Litargus tetraspilotus* LeConte	M
Coleoptera	Nitidulidae	*Amphicrossus ciliatus* (Olivier)	M
Coleoptera	Nitidulidae	*Carpophilus corticinus* Erichson	M
Coleoptera	Nitidulidae	*Carpophilus sayi* Parsons	M
Coleoptera	Nitidulidae	*Colopterus maculatus* (Erichson)	M
Coleoptera	Nitidulidae	*Colopterus niger* (Say)	M
Coleoptera	Nitidulidae	*Cryptarcha ampla* Erichson	M

Appendix A. (cont.)

Order	Family	Species	Method
Coleoptera	Nitidulidae	*Glischrochilus fasciatus* (Olivier)	M
Coleoptera	Nitidulidae	*Glischrochilus quadrisignatus* (Say)	M
Coleoptera	Nitidulidae	*Glischrochilus sanguinolentus* (Olivier)	M
Coleoptera	Nitidulidae	*Stelidota geminata* (Say)	M, P
Coleoptera	Nitidulidae	*Stelidota octomaculata* (Say)	M, P
Coleoptera	Nitidulidae	sp.	Fl
Coleoptera	Ptilodactilidae	*Ptilodactila* sp.	M, P
Coleoptera	Rhizophagidae	*Bactridium ephippigerum* (Guerin)	M
Coleoptera	Scarabaeidae	*Anomala marginata* (F.)	M
Coleoptera	Scarabaeidae	*Cloeotus globosus* (Say)	M, Fg
Coleoptera	Scarabaeidae	*Cotinus nitida* (L.)	M
Coleoptera	Scarabaeidae	*Cyclocephala hirta* LeConte	P
Coleoptera	Scarabaeidae	*Euphoria fulgida* (F.)	M
Coleoptera	Scarabaeidae	*Euphoria inda* (L.)	M
Coleoptera	Scarabaeidae	*Euphoria sepulchralis* (F.)	M
Coleoptera	Scarabaeidae	*Glaphyrocanthon viridis* (Beauvois)	Fg
Coleoptera	Scarabaeidae	*Gnorimella maculosa* (Knoch)	M
Coleoptera	Scarabaeidae	*Macrodactylus angustatus* Beauvois	Fg
Coleoptera	Scarabaeidae	*Popillia japonica* Newman	M, Fg, Fl
Coleoptera	Scarabaeidae	*Onthophagus nuchicornis* (L.)	P
Coleoptera	Scarabaeidae	*Osmoderma eremicola* (Knoch)	M
Coleoptera	Scarabaeidae	*Serica iricolor* Say	M
Coleoptera	Scarabaeidae	*Serica sericea* (Illiger)	M, P
Coleoptera	Scirtidae	*Cyphon ruficollis* Say	M, P
Coleoptera	Scolytidae	*Dendroctonus frontalis* Zimmerman	M
Coleoptera	Scolytidae	*Hypothenemus eruditus* Westwood	M
Coleoptera	Scolytidae	*Scolytus muticus* Say	M
Coleoptera	Silphidae	*Necrophila Americana* (L.)	M
Coleoptera	Silphidae	*Nicrophorus pustulatus* Herschel	M

Appendix A. (cont.)

Order	Family	Species	Method
Coleoptera	Staphylinidae	sp. 1	P
Coleoptera	Staphylinidae	sp. 2	P
Coleoptera	Staphylinidae	sp. 3	M, P
Coleoptera	Staphylinidae	sp. 4	M, P, Fg
Coleoptera	Staphylinidae	sp. 5	M
Coleoptera	Staphylinidae	sp. 6	P
Coleoptera	Staphylinidae	sp. 7	P
Coleoptera	Staphylinidae	sp. 8	Fg
Coleoptera	Staphylinidae	sp. 9	Fl
Coleoptera	Staphylinidae	sp. 10	P
Coleoptera	Staphylinidae	sp. 11	M
Coleoptera	Staphylinidae	sp. 12	M
Coleoptera	Staphylinidae	sp. 13	M
Coleoptera	Staphylinidae	sp. 14	P
Coleoptera	Staphylinidae	sp. 15	P
Coleoptera	Staphylinidae	sp. 16	P
Coleoptera	Tenebrionidae	*Meracantha contracta* (Beauvois)	P
Coleoptera	Tenebrionidae	sp.	M
Coleoptera	Trogossitidae	*Tenebroides corticalis* Melsheimer	M
Hymenoptera	Andrenidae	*Andrena imitatrix imitatrix* Cresson	M
Hymenoptera	Andrenidae	*Andrena imitatrix profunda* Viereck	M
Hymenoptera	Anthophoridae	*Nomada perplexa* Cresson	M
Hymenoptera	Anthophoridae	*Nomada electella* Cockerell	M
Hymenoptera	Apidae	*Apis mellifera* L.	M, Fl
Hymenoptera	Apidae	*Bombus impatiens* Cresson	M
Hymenoptera	Apidae	*Bombus perplexus* Cresson	M
Hymenoptera	Braconidae	sp. 1	Fg
Hymenoptera	Braconidae	sp. 2	Fg
Hymenoptera	Braconidae	sp. 3	M
Hymenoptera	Braconidae	sp. 4	M
Hymenoptera	Braconidae	sp. 5	P
Hymenoptera	Chrysididae	sp.	M
Hymenoptera	Colletidae	*Hylaeus teleporus* Lovell	M
Hymenoptera	Diapriidae	sp.	Fg
Hymenoptera	Evaniidae	sp.	M
Hymenoptera	Formicidae	*Amblyopone* sp.	M

Appendix A. (cont.)

Order	Family	Species	Method
Hymenoptera	Formicidae	*Aphenogaster lamellidens* Mayr	P
Hymenoptera	Formicidae	*Camponotus castaneus* (Latreille)	M, P, Fg
Hymenoptera	Formicidae	*Camponotus ferrugineus* (F.)	M, P, Fg
Hymenoptera	Formicidae	*Camponotus nearcticus* Emery	M, P, Fg
Hymenoptera	Formicidae	*Camponotus pennsylvanicus* (DeGeer)	M, P, Fg
Hymenoptera	Formicidae	*Crematogaster minutissima* Mayr	P
Hymenoptera	Formicidae	*Crematogaster pilosa* Emery	Fg
Hymenoptera	Formicidae	*Crematogaster* sp.	M, P, Fg
Hymenoptera	Formicidae	*Lasius alienus* Emery	M, P
Hymenoptera	Formicidae	*Monomorium destructor* (Jerdon)	P, Fl
Hymenoptera	Formicidae	*Pheidole dentata* Mayr	P
Hymenoptera	Formicidae	*Pheidole tysoni* Forel	P
Hymenoptera	Formicidae	*Prenolepis imparis* (Say)	M, P, Fg
Hymenoptera	Formicidae	*Tetramorium bicarinatum* (Nylander)	M, P
Hymenoptera	Formicidae	sp.	M
Hymenoptera	Halictidae	*Augochlora pura pura* (Say)	M
Hymenoptera	Halictidae	*Lasioglossum coeruleus* Robertson	M
Hymenoptera	Halictidae	*Lasioglossum* sp.	M, Fg
Hymenoptera	Ichneumonidae	sp. 1	M, P
Hymenoptera	Ichneumonidae	sp. 2	M
Hymenoptera	Ichneumonidae	sp. 3	M
Hymenoptera	Ichneumonidae	sp. 4	Fg
Hymenoptera	Ichneumonidae	sp. 5	M
Hymenoptera	Ichneumonidae	sp. 6	M
Hymenoptera	Ichneumonidae	sp. 7	M
Hymenoptera	Ichneumonidae	sp. 8	M
Hymenoptera	Ichneumonidae	sp. 9	M
Hymenoptera	Ichneumonidae	sp. 10	M
Hymenoptera	Ichneumonidae	sp. 11	M
Hymenoptera	Ichneumonidae	sp. 12	M
Hymenoptera	Ichneumonidae	sp. 13	M
Hymenoptera	Ichneumonidae	sp. 14	M
Hymenoptera	Ichneumonidae	sp. 15	P
Hymenoptera	Ichneumonidae	sp. 16	Fg

Appendix A. (cont.)

Order	Family	Species	Method
Hymenoptera	Ichneumonidae	sp. 17	M
Hymenoptera	Ichneumonidae	sp. 18	M
Hymenoptera	Ichneumonidae	sp. 19	M
Hymenoptera	Ichneumonidae	sp. 20	Fg
Hymenoptera	Ichneumonidae	sp. 21	M
Hymenoptera	Ichneumonidae	sp. 22	M
Hymenoptera	Ichneumonidae	sp. 23	M
Hymenoptera	Ichneumonidae	sp. 24	M
Hymenoptera	Ichneumonidae	sp. 25	M
Hymenoptera	Ichneumonidae	sp. 26	M
Hymenoptera	Ichneumonidae	sp. 27	M
Hymenoptera	Ichneumonidae	sp. 28	Fg
Hymenoptera	Ichneumonidae	sp. 29	Fg
Hymenoptera	Megachilidae	*Heriades carinata* Cresson	M
Hymenoptera	Megachilidae	*Osmia felti* Cockerell	M
Hymenoptera	Megachilidae	*Osmia pumila* Cresson	M
Hymenoptera	Megachilidae	*Osmia subfasciata* Cresson	M
Hymenoptera	Mutillidae	*Dasymutilla occidentalis* (L.)	Fg
Hymenoptera	Pompilidae	*Auplopus mellipes* (Say)	M
Hymenoptera	Pompilidae	*Auplopus nigrellus* (Banks)	M
Hymenoptera	Pompilidae	*Dipogon pulchripennis* (Cresson)	M
Hymenoptera	Pompilidae	*Dipogon sayi* Banks	M
Hymenoptera	Pompilidae	*Dipogon* sp.	P
Hymenoptera	Pompilidae	*Priocnemis germana* (Cresson)	M
Hymenoptera	Pompilidae	*Priocnemis hestia* (Banks)	M
Hymenoptera	Pompilidae	*Priocnemis minorata* (Banks)	M
Hymenoptera	Pompilidae	sp. 1	M
Hymenoptera	Pompilidae	sp. 2	M
Hymenoptera	Pompilidae	sp. 3	M
Hymenoptera	Pompilidae	sp. 4	M
Hymenoptera	Pompilidae	sp. 5	M
Hymenoptera	Pompilidae	sp. 6	M
Hymenoptera	Scelionidae	sp. 1	M, P
Hymenoptera	Scelionidae	sp. 2	P
Hymenoptera	Scelionidae	sp. 3	P
Hymenoptera	Sphecidae	*Chlorion* sp.	M
Hymenoptera	Sphecidae	*Podalonia* sp.	M
Hymenoptera	Sphecidae	*Rhopalum* sp.	M
Hymenoptera	Sphecidae	sp. 1	M

Appendix A. (cont.)

Order	Family	Species	Method
Hymenoptera	Sphecidae	sp. 2	M
Hymenoptera	Sphecidae	sp. 3	M
Hymenoptera	Tenthredinidae	sp.	M
Hymenoptera	Tiphiidae	*Tiphia* sp.	Fg
Hymenoptera	Vespidae	*Dolichovespula maculata* L.	M
Hymenoptera	Vespidae	*Monobia quadridens* (L.)	M
Hymenoptera	Vespidae	*Vespa crabro* L.	M
Hymenoptera	Vespidae	*Vespula maculifrons* Buysson	M, P
Hymenoptera	Vespidae	*Vespula vidua* (Saussure)	M, P, Fg
Hymenoptera	Vespidae	sp.	M
Hymenoptera	Xiphydriidae	*Xiphydria* sp.	M
Hymenoptera	--	sp. 1	M
Hymenoptera	--	sp. 2	M
Hymenoptera	--	sp. 3	Fg
Hymenoptera	--	sp. 4	Fg
Hymenoptera	--	sp. 5	Fg
Lepidoptera	Geometridae	*Itame pustularia* (Guenee)	Fg
Lepidoptera	Geometridae	*Tetracis crocallata* (Guenee)	M
Lepidoptera	Noctuidae	*Catocala ilia* (Cramer)	M
Lepidoptera	Noctuidae	sp. 1	M
Lepidoptera	Noctuidae	sp. 2	M
Lepidoptera	Noctuidae	sp. 3	M
Lepidoptera	Noctuidae	sp. 4	M
Lepidoptera	Noctuidae	sp. 5	M
Lepidoptera	Nymphalidae	*Asterocampa celtis* (Boisduval & LeConte)	M
Lepidoptera	--	sp. 1	M
Lepidoptera	--	sp. 2	M
Lepidoptera	--	sp. 3	M
Lepidoptera	--	sp. 4	M
Lepidoptera	--	sp. 5	M
Lepidoptera	--	sp. 6	M, P
Lepidoptera	--	sp. 7	M
Mecoptera	Panorpidae	*Panorpa* sp.	M, P, Fg
Diptera	Anthomyiidae	*Egle* sp.	M
Diptera	Anthomyiidae	sp. 1	M, Fg
Diptera	Anthomyiidae	sp. 2	M
Diptera	Anthomyiidae	sp. 3	M, P
Diptera	Anthomyiidae	sp. 4	M

Appendix A. (cont.)

Order	Family	Species	Method
Diptera	Asilidae	*Atomosia* sp.	Fg
Diptera	Bibionidae	*Bibio* sp.	Fg
Diptera	Calliphoridae	*Bellardia* sp.	M, Fg
Diptera	Calliphoridae	*Bufolucillia* sp.	M, P
Diptera	Calliphoridae	*Lucillia illustris* (Meigen)	P
Diptera	Calliphoridae	*Pollenia rudis* Robineau-Desvoidy	M, P
Diptera	Calliphoridae	*Pollenia* sp.	M, P, Fg
Diptera	Calliphoridae	*Phaenicia* sp.	M
Diptera	Calliphoridae	*Phormia* sp.	M
Diptera	Calliphoridae	sp.	M
Diptera	Chironomidae	*Diamesa* sp.	M
Diptera	Chironomidae	sp.	Fl
Diptera	Culicidae	*Toxorhynchites rutilus* (Coquillet)	M
Diptera	Culicidae	sp.	M
Diptera	Dolichopodidae	*Condylostylus patibulatus* (Say)	M, Fg, Fl
Diptera	Dolichopodidae	*Medetera* sp.	M, P
Diptera	Dolichopodidae	*Neurigona* sp.	M
Diptera	Dolichopodidae	sp.	Fl
Diptera	Drosophilidae	*Drosophila* sp.	M
Diptera	Empididae	*Allanthalia pallida* (Zetterstedt)	Fg
Diptera	Empididae	*Drapetis* sp.	M, Fg
Diptera	Empididae	*Hilara* sp.	Fg
Diptera	Empididae	*Rhamphomyia* sp.	Fg
Diptera	Lauxaniidae	sp. 1	M
Diptera	Lauxaniidae	sp. 2	M
Diptera	Lonchaeidae	*Earomyia* sp.	M, Fg
Diptera	Lonchaeidae	*Protearomyia* sp.	M
Diptera	Muscidae	*Euryomma peregrinum* Meigen	P
Diptera	Muscidae	*Euryomma* sp.	M, P, Fg
Diptera	Muscidae	*Coenosia* sp.	M, Fg
Diptera	Muscidae	*Piezura* sp.	M
Diptera	Muscidae	*Synthesiomyia nudiseta* (Wulp)	M, Fl
Diptera	Muscidae	sp. 1	M
Diptera	Muscidae	sp. 2	M
Diptera	Muscidae	sp. 3	M
Diptera	Muscidae	sp. 4	M

Appendix A. (cont.)

Order	Family	Species	Method
Diptera	Muscidae	sp. 5	M
Diptera	Muscidae	sp. 6	M
Diptera	Muscidae	sp. 7	M, P
Diptera	Muscidae	sp. 8	M, P
Diptera	Muscidae	sp. 9	M
Diptera	Muscidae	sp. 10	M
Diptera	Muscidae	sp. 11	M
Diptera	Muscidae	sp. 12	M
Diptera	Muscidae	sp. 13	M
Diptera	Muscidae	sp. 14	M, P, Fg
Diptera	Muscidae	sp. 15	M
Diptera	Muscidae	sp. 16	M
Diptera	Muscidae	sp. 17	M
Diptera	Muscidae	sp. 18	Fl
Diptera	Muscidae	sp. 19	M
Diptera	Muscidae	sp. 20	M
Diptera	Muscidae	sp. 21	M
Diptera	Mycetophilidae	*Synapha* sp.	M
Diptera	Otitidae	*Delphinia picta* (F.)	Fg
Diptera	Otitidae	*Myrmecothea myrmecoides* (Loew)	M
Diptera	Pallopteridae	*Toxoneura superba* (Loew)	M
Diptera	Phoridae	*Metopina subarcuata* Borgmeier	P
Diptera	Pipunculidae	*Pipunculus* sp.	M, Fg
Diptera	Platysomatidae	*Rivellia* sp.	M
Diptera	Sarcophagidae	*Boettcheria* sp.	M
Diptera	Sarcophagidae	*Microcerella*sp.	M
Diptera	Sarcophagidae	*Sarothromyia* sp.	M, Fg
Diptera	Scathophagidae	*Paralleloma vittatum* (Meigen)	P
Diptera	Scatopsidae	*Anapausis* sp.	Fg
Diptera	Scatopsidae	*Colobostema* sp.	M, P
Diptera	Scatopsidae	sp.	Fl
Diptera	Scenopinidae	*Scenopinus fenestralis* (L.)	Fg
Diptera	Sciaridae	*Bradysia* sp.	M, P
Diptera	Sciaridae	sp.	Fl
Diptera	Sciomyzidae	*Limnia* sp.	M, Fg
Diptera	Stratiomyidae	*Actina viridis* (Say)	M, P
Diptera	Stratiomyidae	*Allognosta* sp.	M, Fg

Appendix A. (cont.)

Order	Family	Species	Method
Diptera	Stratiomyidae	*Gowdeyana punctifera* (Malloch)	Fg
Diptera	Stratiomyidae	*Merosargus* sp.	M
Diptera	Syrphidae	*Chrysogaster* sp.	M, Fl
Diptera	Syrphidae	*Ferdinandea* sp.	M
Diptera	Syrphidae	*Mallota* sp.	M
Diptera	Syrphidae	*Myolepta* sp.	M
Diptera	Syrphidae	*Spilomyia* sp.	M
Diptera	Syrphidae	*Syrphus ribesii* L.	Fg, Fl
Diptera	Syrphidae	*Toxomerus* sp.	M, Fl
Diptera	Syrphidae	sp.	Fl
Diptera	Tachinidae	*Archytas* sp.	M
Diptera	Tachinidae	*Paradidyma* sp.	Fg
Diptera	Tachinidae	*Trochilodes* sp.	M, Fg
Diptera	Tachinidae	sp.	M
Diptera	Tachinidae	sp.	M
Diptera	Therevidae	*Ozodiceromya* sp.	M
Diptera	Therevidae	sp.	M
Diptera	Tipulidae	*Ctenophora nubecula* Osten Stacken	M
Diptera	Tipulidae	*Epiphragma solatrix* Osten Stacken	M
Diptera	Tipulidae	*Metalimobia immatura* Osten Stacken	M
Diptera	Tipulidae	*Metalimobia cinctipes* Say	M
Diptera	Tipulidae	*Tipula dietziana* Alexander	M, Fg
Diptera	Tipulidae	*Ula* sp.	P
Diptera	Xylophagidae	*Rachicerus* sp.	M
Diptera	Xylophagidae	*Xylophagus nitidus* Adams	Fg
Diptera	--	sp.	Fl

Vita

Christopher Thomas Werle was born in Hartford, CT on 2 October, 1976. He was raised in Burlington, CT and graduated from Lewis S. Mills H.S. in June 1994, where he was a member of the baseball team and the jazz ensemble. In May 1996, he received his Associate Degree in Liberal Arts from the Naugatuck Valley Community College in Waterbury, CT, where he was recognized with several awards as a member of the baseball team and the jazz ensemble, including the Scholar-Athlete Award in 1996 and Jazz Musician of the Year in 1995. In May 2000, he received his Bachelor of Science in Wildlife Ecology from the University of Maine in Orono, ME, where he was active in the University Jazz Ensemble, the University Orchestra, the Student Body of The Wildlife Society, and the Alpha Gamma Rho professional agricultural fraternity. After acceptance into the University of Tennessee Department of Entomology and Plant Pathology, he became active in the University Jazz Ensemble and the Linnaean Games Team, and joined the Entomological Society of America. Upon graduation, the author will be starting his career in Buffalo, NY, with USDA-APHIS.