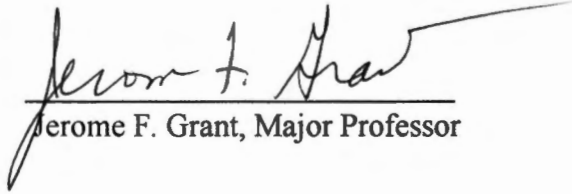
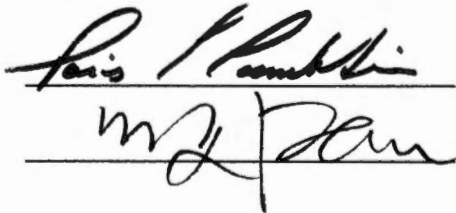


To the Graduate Council:

I am submitting herewith a thesis written by Derek Lee Puckett entitled "Impact of prescribed burning on arthropod communities associated with Eggert's sunflower and the grassland barrens of middle Tennessee". I have examined the final 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.


Jerome F. Grant, Major Professor

We have read this thesis and
recommend its acceptance:



Accepted for the Council:


Associate Vice Chancellor
and Dean of the Graduate School

**IMPACT OF PRESCRIBED BURNING ON ARTHROPOD COMMUNITIES
ASSOCIATED WITH EGGERT'S SUNFLOWER AND THE GRASSLAND
BARRENS OF MIDDLE TENNESSEE**

A Thesis

Presented for the

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Degree

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Derek Lee Puckett

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ABSTRACT

A total of 12,028 specimens was collected in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, in 1997 and 1998. From these specimens, 709 arthropod species, representing 21 orders and 165 families, were identified. Two sites in 1997, burned and non-burned, and three sites in 1998, initial burned, recent burned, and non-burned, were evaluated. Abundance, seasonality, and species composition of insects associated with the barrens, along with the effectiveness of various sampling methods in assessing insect communities, were included in the study. The impact of burning on arthropod communities and incidence of selected arthropods occurring on Eggert's sunflower, *Helianthus eggertii* Small, also were examined.

In regard to arthropods associated with the grassland barrens in middle Tennessee, Coleoptera was the most species-rich order, with 208 species representing 30 families. Diptera (127 species in 33 families) and Hymenoptera (94 species in 27 families) also were well represented. However, the Collembola (31 species in 8 families) contained the most number of individuals collected.

Species richness in the burned sites was slightly higher than in the non-burned sites in both 1997 and 1998. For instance, 185 species were collected in the burned site in 1997 compared to 135 species in the non-burned site. In 1998, 328, 327, and 318 species were collected in the recent burned, initial burned, and non-burned sites, respectively. The variation in species numbers in the burned and non-burned sites may be a result of plant species succession and the influx of many insect species into the burned sites after burning.

During August and September 1998, 67 insect species were collected from Eggert's sunflower. Peduncle collapse, a condition caused by clipped stems, was commonly observed on Eggert's sunflower throughout this study. The incidence of clipped stems was greater in the burned sites than the non-burned site. Spittlebug masses also were encountered throughout the monitoring of Eggert's sunflower. Infestation levels were highest in the burned sites and lowest in the non-burned site. Of all groups collected from Eggert's sunflower in 1998, perhaps no insects affected the plant as much as the beetles. Even though leaf-feeding beetles were found on Eggert's sunflower, the weevils seemed to have the most impact on the plant. Larvae of *Odontocorynus* spp. were found inside the stem of plants, and it is plausible that adult weevils were responsible for the clipped stems often observed on *H. eggertii* in the barrens.

The results of this study provide evidence that burning has a major influence on the presence and persistence of arthropod species in grassland ecosystems. The variation in the burn tolerance of species and the changes in the physical environment, i.e., succession of plant communities, following burning may result in different arthropod communities in frequently burned sites compared to non-burned sites. However, the effects of burning on some plants, such as Eggert's sunflower, presents a paradox. That is, even though burning perpetuates and maintains populations of this plant, it also causes a higher incidence of damage by insects in burned areas. In general, an area (region or landscape) containing sites at different successional stages, and sites varying in the frequency of burning, may support more species than a site protected from burning (non-burned).

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CHAPTER I

LITERATURE REVIEW

Grasslands, perhaps the most well-known of all vegetation types, can be defined as any region where nonwoody or herbaceous plants grow naturally and abundantly (Anderson 1982). Woody plants, such as bushes and trees, are usually absent, but if present, they are in limited numbers. Soil type, along with such factors as climate and low precipitation, account for the restricted growth of shrubs and woody plants from many grasslands. Grassland plants include true grasses and numerous flowering herbaceous plants, known as forbs, that can tolerate soil and climatic conditions that woody plants cannot (Axelrod 1985). These grassland species are able to survive in these areas by: 1) lying dormant for an extended period of time, with most of the plant surviving below ground as a root system until conditions improve, or 2) as seed, ready to germinate whenever favorable conditions occur.

Grasslands occur in many regions, such as the steppes of central Asia, the savannas of Africa, the pampas of Argentina, the grasslands of Australia, and the prairies of North America. About 24% of the vegetation cover in the world today (29 million km²) consists of grasslands (Anderson 1982). Many of the familiar types are of great antiquity, fashioned by the combination of weather and the gradual development of particular soil types. For instance, the North American prairie, grasslands that are found in the central part of the North American continent, are believed to date back to Miocene times, a

geological epoch that began about 35 million years ago and endured for 28 million years (Risser et al. 1981). The Rocky Mountains surfaced during this period and changed the climate by reducing the amount of rainfall available to vast outlying areas (Sauer 1950). As a result, the dry summers and drier winters favored the propagation of grasslands in these regions, and the existing forests gradually disappeared. Similar weather patterns of low rainfall and a short wet season followed by a longer period of drought had similar effects in other lowland areas of the world. The North American prairie forms a more or less continuous, triangular area that extends for approximately 3,870 km from Alberta, Saskatchewan, and Manitoba southward through the Great Plains to southern Texas and adjacent Mexico and approximately 1,612 km from western Indiana westward to the foothills of the Rocky Mountains, covering 2.25 million km² (Fig. 1).

Many grasslands in temperate Europe and North America are of a more recent origin, however, and have been developed largely by the influence of man, who has destroyed the forest cover to provide more cultivating and grazing land for himself and his animals. One of the most characteristic features of grasslands in developed countries is their artificiality. Artificial grasslands are regions that have been converted to cropland, whereas true grasslands are regions that have been left undisturbed by development and progress of mankind. True grasslands are now scarce, and they are becoming more so as additional land is being utilized by man for agricultural purposes, housing development, and industrialization. For example, 60% of Illinois (approximately 9 million ha) was covered with prairie at one time. Today, just over 800 ha remain, less than one-hundredth of one percent. However, not all grasslands are being manipulated by human activity.

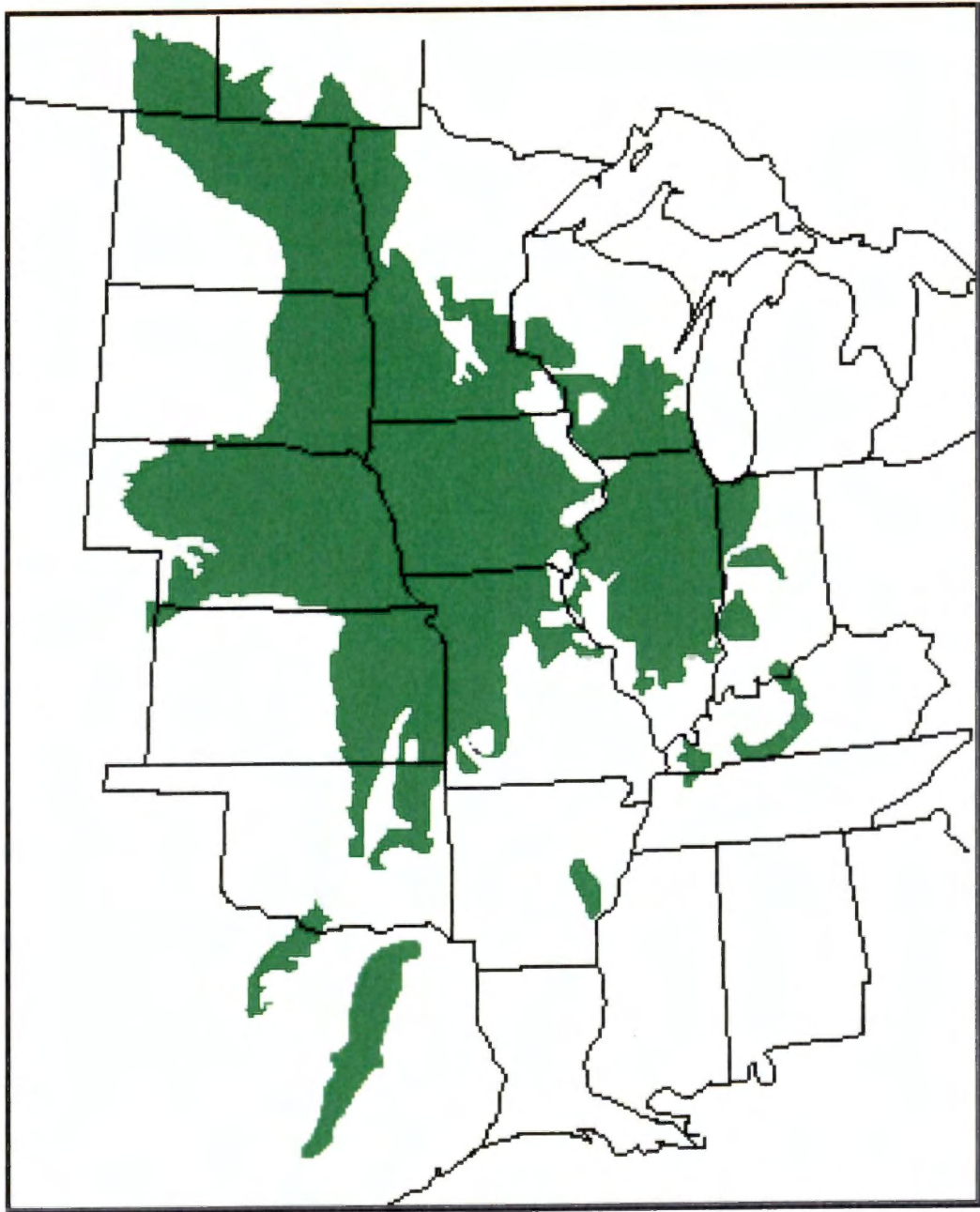


Figure 1. Distribution of the North American Prairie (Robertson 1999).

Many of the world's government-controlled national parks, nature reserves, and military installations include grassland areas that are protected from the depredations of human intruders. There is probably no place in the modern world where one can find either grassland itself, or the wildlife within the grassland, completely unaffected by past or present man.

Barrens are a type of grassland similar to prairies, only differing in the amount of rainfall received, the quality of soil, and the geographical range they cover (Axelrod 1985). Grassland barrens are located throughout the United States, but are often associated with the southeastern United States. The barrens are areas that contain a mixture of forbs and grasses, and other vegetation usually found in prairies. The barrens have been maintained by burning and mowing, as well as by the grazing of herbivorous animals. The exact land coverage of barrens has not been documented; however, a large portion of the grassland barrens is located in the plateau regions of Kentucky, Tennessee, and Alabama (Martin et al. 1993). The plant and animal communities occurring in prairies are similar to those often found in the barrens. However, tallgrass prairies contain a denser ground cover than the barrens, with vegetation reaching 2 m in height. Whether it is the barrens of the southeastern United States, or the tallgrass prairies of the Midwest, biological diversity is perpetuated by the rich flora and fauna that grasslands provide. For example, animals rely on plants for their food source, and plants are dependent upon animals for replenishing the soil through nitrogen-rich wastes and insect pollination (Ehrlich 1988).

Animal life in grasslands can be quite diverse. Mammals are probably the most conspicuous vertebrates of the grasslands. Most of these mammals are grazers and can increase the productivity and diversity of vegetation in grassland ecosystems. Grazing increases growth in grasslands because nitrogen is recycled through the urine and feces of the animals. In addition to the large herbivores present in grasslands, such as bison, antelope, and deer, a varied assortment of small mammals, birds, and insects exist. Small mammals of desert and mountain grasslands and tallgrass prairies are largely grazers or foliage feeders; those of mixed grass prairies are grazers and seed and fruit consumers; and those of shortgrass plains and lowland barrens are grazers. Rodents of semiarid desert grasslands are seed consumers (Lewis 1971). *Lepus* spp. (jackrabbits) are important consumers, ingesting about 6% of their body weight or about 0.45 kg of dry weight forage each day. The proportion of insectivorous to granivorous (seed-eaters) birds in grassland ecosystems is influenced by grazing intensity of herbivorous mammals. The loss of grass cover reduces insect populations and nesting cover, thus reducing the availability of food for insectivorous birds.

Although mammals and birds are often found in grasslands, perhaps the most important and abundant constituents of grasslands are the arthropods, which include insects, millipedes, centipedes, mites, and spiders. Also, grasslands are favorite habitats for terrestrial molluscs, such as slugs and snails. No phylum of multicellular organisms is more durable or more widespread than the Phylum Arthropoda, whose members are found in nearly every type of environment. They live under the snow, in hot springs, in salt lakes, along the sea coast, and within all kinds of living and dead matter. More than 750,000

species of insects have been identified in the world (Arnett et al. 1993). These species include pollinators, decomposers, scavengers, predators, parasites, parasitoids, and herbivores. Virtually every type of flowering plant is used as food by one or more species of insects (Evans and Murdoch 1969).

The insect fauna of grasslands is diverse, but most of the grassland species are relatively small, inconspicuous organisms that are not readily discernible, even to a field biologist. On the other hand, some beautiful insects, such as butterflies and moths (Lepidoptera) and grasshoppers (Orthoptera), are quite noticeable. In the Great Plains of North America, researchers have documented approximately 100 different species of grasshoppers, some of which can do a tremendous amount of damage to crops (Anderson 1964). Nearly one-half of the grasshopper species in the world feed on grasses, whereas the other half specialize on different types of broad-leaved plants that grow only in grasslands; thus, most of the vegetation could be consumed by grasshoppers alone if they were not controlled (Haskell 1970). Margules and Usher (1981) have estimated that when grasshoppers are abundant, about 30/m², they are capable of eating as much vegetation in a season as a buffalo. Fortunately, this type of situation rarely develops because so many birds and small mammals eat the adults, the nymphs (immature stages), and even the eggs (Price 1975).

The most destructive grasshoppers are the migratory species, popularly called locusts (Acrididae). Locusts thrive on every continent, and many areas have suffered from their depredations for thousands of years. In many parts of Africa, a large swarm of the migratory locust, *Locusta migratoria* (Uvarov), may contain up to 100 million insects,

which can consume about 3,000 tons of green food daily (Kemp 1992). In North America, the American grasshopper, *Schistocerca americana* (Drury), and the two-striped grasshopper, *Melanoplus bivittatus* (Say), are common and sometimes destructive migratory species which occur in a variety of situations including the tallgrass prairies of the Great Plains and the grassland barrens of the Central Lowland. They also feed on fruit trees, alfalfa, and other crops. Modern research and control methods have substantially reduced the damage caused by these insects in most of the Western world, but their ability to destroy crops has left an indelible mark on many agricultural communities and natural areas. Although less damaging than it used to be, the locust is still a widespread, fairly common, and hungry inhabitant of grassland areas.

The world of grass-eating insects in grasslands does not entirely consist of grasshoppers. Their near relatives, the katydids and crickets, also are present. Most of the katydids are grass eaters but a few capture grasshoppers and other insects, or eat dead insects, including their own kind. The common meadow katydid, *Orchelimum vulgare* Harris, which ranges from Canada to Georgia and west to Wyoming and Texas, becomes abundant in prairies each fall. Another common species is the broad-winged katydid, *Microcentrum rhombifolium* Saussure, which ranges from New York to Indiana, Colorado, and Kansas, as well as across the southern United States from coast to coast.

On the prairies and other grassland areas, the familiar crickets are known for their chirping and for their affinity for food whether it be plant tissues, or dead insects. Populations of the common field cricket, *Acheta assimilis* (F.), which is found in almost every vegetation type in the United States, peak in grassland ecosystems in autumn

(Farrell and Mitter 1994). Adult crickets, which are omnivorous and feed ravenously on green vegetation or on dead insects, particularly grasshoppers, can eat the equivalent of three-fourths of their own weight each day. Because as many as 4,000/ha may occur, the impact of these insects in grassland systems sometimes equal that of rabbits, mice, and other small mammals that search for vegetable and animal food among the grass stems (Opler 1981).

Many insect species, regardless of whether they are seeking pollen, extracting nectar, or preying on other insects, serve as pollinators in grassland ecosystems. Insect pollinators include such diverse groups as beetles (Coleoptera), butterflies and moths, bees and wasps (Hymenoptera), true bugs (Hemiptera), flies (Diptera), leafhoppers (Homoptera), and walking sticks (Phasmida) (Borror et al. 1992).

Among the most specialized of the pollinators are the butterflies and moths. Although many of these produce larvae with strong jaws and voracious appetites for leaves and other plant organs, the adults are responsible for cross-pollination of many grassland plants. Therefore, they are essential for the production of seeds, fruits, and plants upon which other animals depend, either directly or indirectly.

Grassland butterflies are numerous and exhibit great diversity in size, color, and habits. Many are flower visitors and some of their larvae feed only on certain species of plants. The most widely distributed butterflies are the monarchs, *Danaus plexippus* (L.), which feed primarily on *Asclepias* spp. (milkweed) (Scott 1986), and the viceroys, *Limnitis archippus* (Cramer), which mimic the monarchs. Among the other butterflies common to grassland ecosystems is the American painted lady, *Vanessa virginiensis*

(Drury), which feeds exclusively on composites, such as sunflower (*Helianthus* spp.) and daisies (*Aster* spp.). The larvae of the great spangled fritillary, *Speyeria cybele* (F.), feed on violet leaves which can be abundant in drier grassland regions, and the adults feed on nectar from many species of flowers including milkweed, violet (*Verbena* spp.), dogbane (*Apocynum* spp.), and purple coneflower (*Rudbeckia* spp.).

In early April, the spicebush swallowtail, *Papilio troilus* L., is one of the first butterflies to appear in grassland areas. Their food preferences include milkweed, lantana (*Lantana* spp.), thistles (*Cirsium* spp.), and azalea (*Azalea* spp.). The sleepy orange, *Eurema nicippe* (Cramer), is a common inhabitant of grasslands, where males patrol for females. The females often lay their eggs singly under host plant leaves belonging to the pea family (Fabaceae). Skippers (Hesperiidae) are commonly found in grasslands, where some of their caterpillars feed on plant species of the Fabaceae, and the adults feed on thistles and red clover (*Trifolium* spp.).

The allies of the butterflies are the moths. Hummingbird clearwing moths, *Hemaris thysbe* (F.), and green cloverworm moths, *Plathypena scabra* (F.), are commonly found in the lush vegetation of grasslands. Perhaps no moths are as abundant in these areas as the arctiid moths, especially the banded tiger moth, *Apantesis vittata* (F.), and the banded tussock moth, *Halysidota tessellaris* (J.E. Smith) (Opler 1981).

The bees are the most important pollinators in grassland ecosystems. Many of the Rosaceae, forbs with conspicuous and strongly scented flowers, and most of the legumes are pollinated by bees and wasps, and flies. Bees, along with beetles, pollinate goldenrods (*Solidago* spp.) and other forbs that bloom in late summer and autumn. In addition to bees

and wasps, the ants have varied feeding habits and are concentrated more or less on the surface layer of grasslands. Many ants are carnivorous, but most are phytophagous, feeding on sap, nectar, honeydew, and similar substances.

The direct and indirect effects of ants in grassland ecosystems have been inadequately studied. The most conspicuous signs of ants located within the grassland systems are the large mounds, 15 to 30 cm high and 1 to 2 m diam at the base, of harvester ants, *Pheidole dentata* Mayr. These mounds, which are rather large and usually shaped like a round-topped cone, are generally situated in the center of sparse or open vegetation. Harvester ants maintain their mounds by removing encroaching vegetation, and when the colony prospers the mound may endure for 20 yr.

At harvest time thousands of ants search the grasslands for the seeds they store in chambers or granaries. They may climb plant stems to obtain the ripened seeds of many grasses and forbs, and one colony can collect almost one liter of seeds in a single day (Fanning 1965). In a growing season they exert an important influence on the seed supply of forbs and grasses. The efficacy of the cleared area around the ant mounds has been the subject of speculation by many researchers (Rice 1932, Anderson et al. 1989). Some theorize that the ants remove vegetation to afford protection from enemies (Evans and Murdoch 1969), but since they must travel across a considerable distance of bare space to reach surrounding grassland it appears that they are easily exposed to, rather than protected from, enemies. The absence of plants near the mound does allow the sun to dry the perimeter of the mound after rainstorms, and thus, tends to allay the threat of mold destroying the seeds in the granaries below. The constant removal of vegetation by the

ants prevents the formation of roots which might decay and leave channels in the soil through which rainwater could enter the nest. Furthermore, when fires burn over grasslands, the soil around the mounds is not heated to an intolerable degree, thus the ants are spared and with their stored seeds they are able to live until the grasslands become productive again (Evans 1971).

Even within a relatively small area, the insect community of one grassland area is likely to be considerably different from that of another. An arthropod community in a grassland located in the shale barrens of Oklahoma will be quite different from the arthropods located in the grassland barrens of middle Tennessee, or from the tallgrass prairies of the Midwest, or on coastal sand dunes in Florida (Martin et al. 1993). Each community has its own distinctive species, just as each kind of grassland could be hardly mistaken for one of the others, and, even though the differences are striking, the similarities are apparent as well. The structure of a grassland partly determines the type of fauna within it. For instance, the tall and dense vegetation in most grassland systems contains a series of vertical layers known as microhabitats, where insects with different food requirements live (Morris 1981). This grassland insect world is like that found in a forest, differing only in scale; miniature layers correspond to the forest canopy, the shrub layer, field layer vegetation, and the ground zone, and, each small layer has its own range of microhabitats.

The vertical zonation of microhabitats in taller grasslands is immediately affected when grassland systems are burned or cut (Panzer 1988). These practices remove dead vegetation and prevent the succession of woody plants and shrubs. However, the

reduction in height of the vegetation causes two effects. First, in removing most of the stems, flowers, and seeds, as well as leaves, these management practices kill all but the basal foliage of grasses and the rosettes of other plants, which diminishes potential food material for the insect community. Second, the change in vegetative structure alters the microclimate within the grass; that is, the invertebrates that were confined to the moist, shady zone close to the ground suddenly find themselves exposed to bright light, drying winds, and even more predators than usual. Consequently, life for these animals in those areas subjected to burning or cutting is hindered, and they must move, adapt to the conditions, or die.

Fire as a factor in the origin and maintenance of grasslands has been examined by numerous investigators, and many of the studies have focused on the response of the plant community or individual plant species to burning (Daubenmire 1968). However, arthropod responses to burning have not been well studied. Populations are difficult to census, especially those of species with short flight periods, such as butterflies and specialist bees. The small size of many grassland preserves has limited the areas available for well-replicated studies. A few groups, primarily grasshoppers, have been relatively well-studied, but many taxa have received little or no attention from researchers (Loucks 1970). The responses of grassland arthropods to burning was reviewed and divided into four phases: 1) the preburn phase, 2) the combustion phase (the burn itself), 3) the shock phase (time until regrowth occurs), and 4) the recovery phase (time until the system returns to the original state) (Warren et al. 1987). Fire characteristics, the arthropod species, the timing of the burn relative to arthropod phenology, predator/prey ratios

following the fire, postburn weather, and the direction and extent of postburn succession can influence the response of a species to burning and must be understood to predict this response. The mortality, reproduction, immigration, and emigration of arthropod taxa during each phase determine the species composition of any site.

The insect species composition of grassland areas has been poorly studied. It is especially important now to study these species to determine what factors, other than burning, may increase their diversity. Also, if floristic diversity is not maintained or perpetuated, then insects closely associated with these systems may perish, as a result of inadequate food resources. Grassland sites contain a mixture of rare, threatened, and endangered (RTE) and common insect species including grassland species, woodland species, and widespread species, as observed for bees (Reed 1995); butterflies (Swengel 1996, New 1995); leafhoppers (Hamilton 1995); and grasshoppers, crickets, and katydids (Ballard and Greenlee 1994). Grassland insects that are dependent on vertebrates, such as dung-feeding scarabs, tenebrionids that use animal burrows as shelters, and vertebrate ectoparasites, are often absent from small prairie remnants; consequently, their conservation is of special interest (Opler 1981, Nagel 1979).

Some arthropod species are attracted to heat or smoke. Metallic wood-boring beetles (Buprestidae) and long-horned beetles (Cerambycidae) are most often reported (Evans 1971, Hansen 1986), but some spiders (Reichert and Reeder 1970), carrion beetles (Silphidae) (Evans 1971, Hansen 1986), and platypezids, tabanids, and empidids (all Diptera) (Evans 1971) also have been reported in areas immediately following fire. Mortality and population reduction rates during the burn (combustion phase) vary among

arthropod taxa. Many arthropods die during burning, including the stem-boring larvae of the gall wasp *Anistrophus silphii* Gillette (Fay and Samenus 1993), spider species that were once active on the surface at the time of the burn (Reichert and Reeder 1970), ambush bugs (Hemiptera) (Dana 1991), tenebrionids, carabids, and cutworm larvae (Lepidoptera) (Rice 1932), and adult and nymphal grasshoppers, especially flightless species (Bock and Bock 1991). Only two species of parasitic Hymenoptera (Braconidae) and two species (one each) of predaceous Hymenoptera (Sphecidae and Pompilidae) were collected in malaise traps two weeks after a Utah range fire (Hansen 1986).

Burn tolerance may depend on burn season; for example, *Hesperia dacotae* (Skinner) and *H. ottoe* Edwards, prairie skippers, showed low larval mortality (5%) in a test burn early in the season when the larvae were in burrows; and, later in the season, burning caused higher mortality (30%) because the larvae had moved to surface shelters (Dana 1991). Savannas and woodlands, and areas of heterogeneous topography, usually contain more unburned patches than more uniform sites, such as prairie restorations on former agricultural fields (Beeler 1999). Unburned patches can allow the survival of arthropods, such as larvae of the Karner blue butterfly, *Lycaeides melissa samuelis* Nabokov (Swengel 1995), chinch bugs (Lygaeidae), cutworm larvae, and centipedes (Rice 1932).

During the shock phase following a burn, soil temperatures are increased, soil moisture is reduced, and litter is reduced (Glenn-Lewin et al. 1990). Diapausing arthropods, such as spiders (Reichert and Reeder 1970) and grasshoppers (Evans 1984), emerge earlier on burned areas. Adult insects that survive the combustion phase may

remain in the area and survive or die, or they may leave the site in search of food, prey, or shelter. For example, rove beetles (Staphylinidae), flower beetles (Cetoniinae), and chinch bugs left an Illinois site following a burn (Rice 1932). Spiders with high moisture requirements and those needing structural support for webs are better able to survive in unburned areas (Reichert and Reeder 1970). Bock and Bock (1991) found that while most grasshopper species declined temporarily following a natural fire in Arizona grassland, a few species that preferred bare ground and herbaceous foods increased immediately after the fire. Shock phase population changes can influence interactions such as predator-prey relationships. Dana (1991) noted that prairie skippers may benefit from the absence of one of their predators, *Phymata* spp., following a burn.

Relative to unburned areas forbs and grasses develop and flower earlier in the season during the first growing season following a spring burn, and vegetation productivity increases (Hulbert 1986). Generalist and specialist phytophagous insects are attracted to the new growth to feed on leaves, sap, or nectar, or for oviposition on plants that serve as a food source for their larvae (Cancelado and Yonke 1970). The number of insects, their biomass, and relative representation of orders and families on small burned sites adjacent to unburned areas return to levels similar to those of unburned areas by the middle or end of the summer following a spring burn (Dunwiddie 1991). Studies of the effects of a single burn on arthropod groups for a single season may differ, but many spider taxa have been found to leave the burned area (Halvorsen and Anderson 1980). Millipedes tend to be more numerous on burned areas compared to unburned areas during the recovery phase (Seastedt et al. 1986). Hemiptera and Homoptera are reduced in

population numbers during the combustion and shock phases but tend to invade recently burned areas where the vegetation is regrowing (Cancelado and Yonke 1970, Anderson et al. 1989). Coleoptera, Diptera, Lepidoptera, and Orthoptera vary among taxa in their responses to burning; however, ants tend to survive burning well (Warren et al. 1987).

Response of arthropods to a spring burn of a tallgrass prairie in Minnesota was investigated (Amburg et al. 1981). Researchers reported that the number of beetles in the families Carabidae, Coccinellidae, Staphylinidae, and Meloidae were significantly ($p \leq 0.05$) more abundant in the burned site (11, 25, 45, and 23, respectively) than the non-burned site (1, 11, 21, and 2, respectively). However, the Chrysomelidae were more numerous in the non-burned site (31) than the burned site (19). Furthermore, three families of Diptera also exhibited a response to burning as significantly ($p \leq 0.05$) greater numbers of Anthomyiidae and Syrphidae were found in the burned site (29 and 36, respectively) than the non-burned site (9 and 14, respectively). However, the Bombyliidae were significantly ($p \leq 0.05$) more abundant in the non-burned site than the burned site (12 and 1, respectively). Few statistically significant observations have been made on other insects; however, their plant associates have received much attention in grassland ecosystems (Howe 1994).

Plants are virtually limitless in most grassland ecosystems. Investigations into plant species diversity often have revolved around prescribed burning and soil composition (Daubenmire 1968). Researchers in the Midwest have been studying the effects of fire on vegetation for years, particularly in Kansas and Missouri (Howe 1994, Daubenmire 1968). Perhaps one reason that might explain their popularity hinges on the fact that plants are

easier to study because they are fixed (immobile) in the environment and are easier to manipulate than insects. Common grassland plants include daisies, milkweed, wild carrot or Queen Anne's Lace (*Daucus carota* L.), tickseed (*Coreopsis* spp.), goldenrod, false indigo (*Amorpha* spp.), bluets (*Houstonia* spp.), Asiatic dayflower (*Commelina communis* L.), loosestrife (*Lythrum* spp.), sunflower, and many others.

One particular species of *Helianthus* that has been the subject of many conservationists is Eggert's sunflower, *H. eggertii* Small. This concern may be in part because of its recent listing on 22 May 1997 as threatened under the Endangered Species Act of 1973. This species is usually associated with Mississippian age formations, mainly limestones, but also may occur on a shale/siltstone base. Soils are generally acidic, silt loams, or sandy loams, and are low in organic matter (Bullington et al. 1998). This species is distributed in a linear fashion through Kentucky, Tennessee, and Alabama (Fig. 2).

Most of the known populations of *H. eggertii* are threatened with destruction or adverse modification of their habitat. More than 50% of the known *H. eggertii* sites are threatened by the encroachment of more competitive herbaceous vegetation and/or woody plants that produce shade and compete with this species for limited water and nutrients. Active management is essential to ensure that Eggert's sunflower continues to survive at all reported locations.

Barrens habitat, which is preferred by this species, is disappearing from the south-central United States at an unprecedented rate (DeSelm 1989). Most of this type of habitat has been converted to croplands, pasture, or has been developed as residential and industrial sites (Bullington et al. 1998). DeSelm (1989), in a study on Tennessee barrens,



Figure 2. Distribution of *Helianthus eggertii* Small (Jones 1991).

reported that all of his study sites were in later stages of succession, with the suppression of fires being the major contributing factor. As its natural habitat disappears, Eggert's sunflower is now located primarily in habitats that replicate the species' ecological requirements. These sites, having the accompanying assortment of weedy vegetation associated with disturbed areas, typically are habitats like roadside right-of-ways, ditches, road cuts, or mounds of soil. Colonization most likely occurs soon after a disturbance to the habitat. This particular sunflower can initially compete with other vegetation. However, as successional stages progress, this species is consequently reduced to vegetative growth from rhizomes and is eventually eliminated. Periodic burning, mowing, or thinning of vegetation at these sites favors the species by lessening competition. This sunflower is persisting at several sites in Coffee County, TN, due to the current burning and mowing regime; however, little information is available on the impact of burning on insects occurring on Eggert's sunflower.

Little doubt exists as to the magnitude of insects found within the plant communities of North American prairies. They perform a variety of tasks from pollination to decomposition. In addition, most research conducted on insect abundance and diversity on prairies in North America has been performed in the Midwest and in the southwestern United States. The practice of prescribed burning has often accompanied these surveys but only a few insect taxa have been studied.

Little information is available on species composition of insects in grasslands, nor on the impact of burning on these insect species, especially in the southeastern United States. In addition, no studies have been located in the literature emphasizing the role of

insects in the population dynamics of Eggert's sunflower. Thus, a research project was initiated in 1997 to determine the diversity of insects in the grassland barrens of Arnold Air Force Base (AFB) in Middle Tennessee. The objectives of this research were to: 1) determine species composition of insects in the grassland barrens of Arnold AFB, 2) assess the impact of burning on insect populations in these barrens, and 3) monitor the incidence of insects associated with Eggert's sunflower in the grassland barrens.

CHAPTER II

ARTHROPODS ASSOCIATED WITH THE GRASSLAND BARRENS IN MIDDLE TENNESSEE

i. Introduction

Barrens are a type of grassland similar to prairies, only differing in the amount of rainfall received, the quality of soil, and the geographical range they cover (Axelrod 1985). Grassland barrens are located throughout the United States, but are often associated with the southeastern United States. The barrens, containing a mixture of forbs and grasses, and other vegetation usually found in prairies, have been maintained by burning and mowing, as well as by the grazing of herbivorous animals. The exact land coverage of barrens has not been documented; however, a large portion of the grassland barrens is located in the plateau regions of Kentucky, Tennessee, and Alabama (Martin et al. 1993). The plant and animal communities occurring in prairies are similar to those often found in the barrens. Whether it is the barrens of the southeastern United States, or the tallgrass prairies of the Midwest, biological diversity is perpetuated by the rich flora and fauna that grasslands provide; that is, animals relying on plants for their food source, and plants dependent upon animals for replenishing the soil through nitrogen-rich wastes and insect pollination (Ehrlich 1988).

Insect species composition of grassland areas has been poorly studied. It is especially important now to study these grasslands to determine species composition and to determine the factors, other than burning, that may impact species diversity. Also, if floristic diversity is not maintained or perpetuated, then insects closely associated with these systems may perish, as a result of inadequate food resources. Thus, the objective of this research was to: 1) determine species composition, abundance, and seasonality of insects associated with the grassland barrens in middle Tennessee, and 2) evaluate the effectiveness of sampling methods in assessing insect communities in the barrens.

ii. Materials and Methods

Description of Study Area

The study area is located within the 15,816-ha Arnold AFB military installation located near Tullahoma in Coffee County, ca. 113 km SE of Nashville, TN. The topography in this region is a rather high, flat zone called the Eastern Highland Rim, just west of the Cumberland Plateau consisting of clay overlain by a thick mantle of wind-blown particles, called loess. The clay, which can become saturated in the winter, is not favorable for the roots of trees, while the mantle of loess is ideal for the more shallow-rooted grassland species (Martin et al. 1993).

The study was conducted in the grassland barrens of Arnold AFB (35°23' 12"N 86°5'30"W) in an area that occupies nearly 100 ha along the airstrip (Fig. 3). The dominant plant species occurring within the study area include big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* Nash), Indian grass (*Sorghastrum nutans* L.), switchgrass (*Panicum virgatum* L.), spikerush (*Eleocharis*

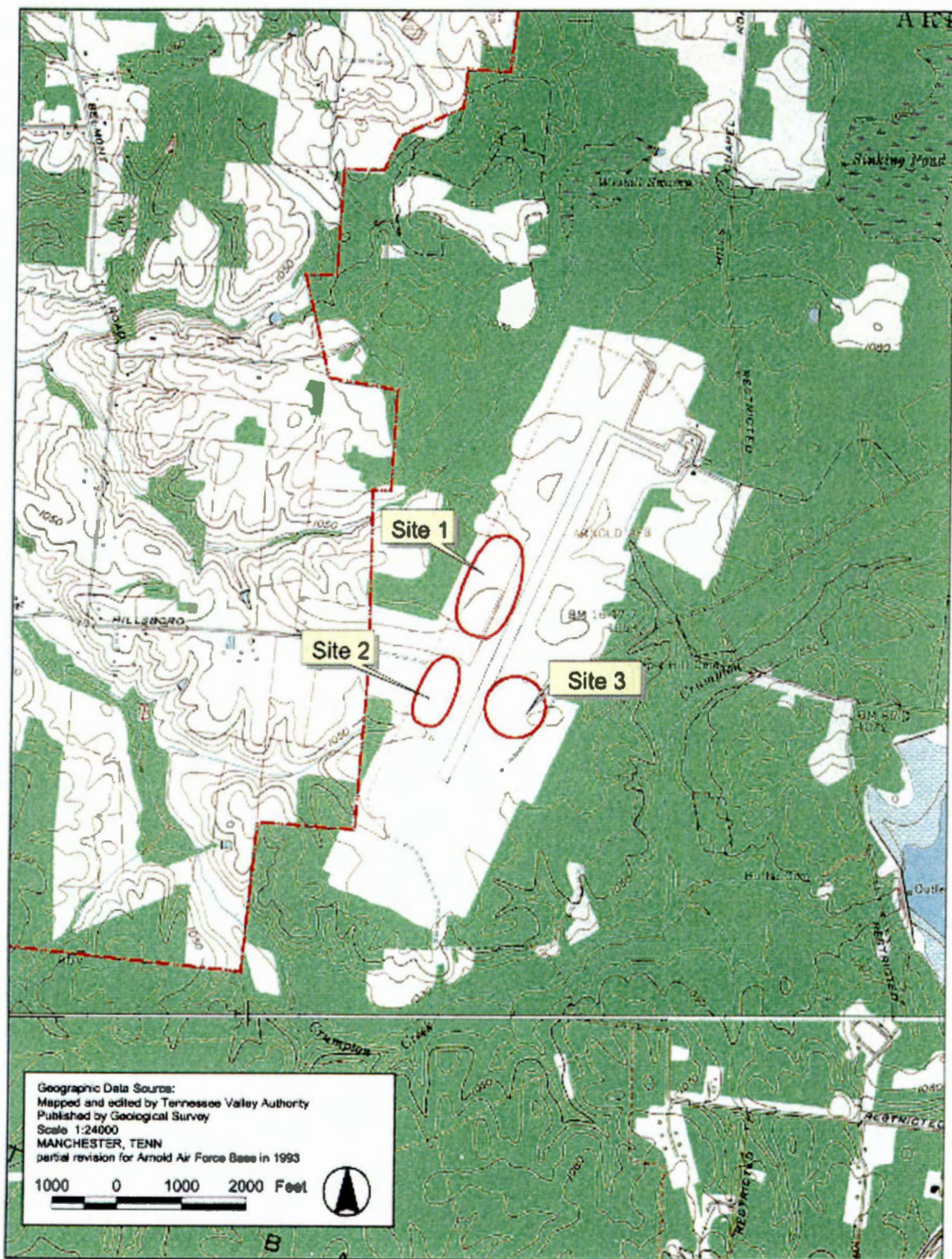


Figure 3. Location of barrens study sites 1, 2, and 3, Arnold Air Force Base, Tullahoma (Coffee Co.), TN.

microcarpa Torrey), dropseed (*Sporobolus cryptandrus* Torrey), wiregrass (*Aristida virgata* Trin.), beardgrass (*Gymnopogon brevifolius* Trin.), and timothy (*Phleum pratense* L.) as dominant grasses. Eggert's sunflower (*Helianthus eggertii* Small), hairy sunflower (*Helianthus hirsutus* Rafinesque), aster (*Aster dumosus* L.), daisy fleabane (*Erigeron annuus* L.), tickseed (*Coreopsis lanceolata* L.), black-eyed Susan (*Rudbeckia hirta* L.), sweet goldenrod (*Solidago odora* Aiton), tall goldenrod (*Solidago altissima* L.), meadow stars (*Potentilla simplex* Michauxii), horsemint (*Pycnanthemum muticum* Michauxii), groundnut [*Apios priceana* (Robinson)], false hoarhound (*Eupatorium rotundifolium* L.), dusty clover (*Lespedeza capitata* Michauxii), greenbrier (*Smilax rotundifolia* L.), wild sarsaparilla (*Smilax glauca* Walter), bull thistle (*Cirsium vulgare* L.), and butterfly weed (*Asclepias tuberosa* L.) are the dominant forbs (DeSelm 1989).

Forested areas occur within 100-150 m of the edge of the study area. The dry, upland forest that borders the barrens contains a mixture of black oak (*Quercus velutina* Lam.), white poplar (*Populus alba* L.), scarlet sumac (*Rhus glabra* L.), sand hickory [*Carya pallida* (Ashe)], blackjack oak (*Quercus marilandica* Muenchh.), willow oak (*Quercus phellos* L.), southern red oak (*Quercus falcata* Michx.), black gum (*Nyssa sylvatica* Marsh.), persimmon (*Diospyros virginiana* L.), winged elm (*Ulmus alata* Michx.), red mulberry (*Morus rubra* L.), and others. The shrubby hazelnut (*Corylus americana* Walt.) and highbush blackberry (*Rubus argutus* Link.) grow above such wildflowers as Indian physic (*Porteranthus trifolius* Britton), lyre-leaved sage (*Salvia lyrata* L.), and may-apple (*Podophyllum peltatum* L.).

Evaluation of Arthropods in the Grassland Barrens

To evaluate insect diversity and abundance in the grassland barrens, samples were collected from two sites in 1997 and three sites in 1998. For purposes of this chapter, all data from all sites in 1997 and 1998 were combined and evaluated for each year. A more detailed description of each site is provided in Chapter III. Sampling methods included beat sheets, direct collecting, leaf-litter samples, light traps, malaise traps, pitfall traps, sticky traps, and sweep-net sampling in 1997. In addition to these sampling methods, a Manitoba trap and intensive sampling of insects from Eggert's sunflower were incorporated into the sampling methods in 1998.

Insect Sampling

Beat-sheet Sampling. Five beat-sheet samples per site were taken weekly during the 1997 and 1998 sampling seasons. Beat-sheet samples were taken using a 100-cm² cloth fitted with wooden dowel rods along opposing sides. The beat sheet was positioned on the ground, and surrounding plants were shaken vigorously to dislodge insects and other arthropods from flowerheads and other plant parts. Specimens that fell onto the sheet were collected, transferred to individual Ziploc plastic bags (900 ml), and taken to the laboratory.

Direct Collecting. Direct collections were made weekly at each site in 1997 and 1998. Samples were collected by netting (for aerial insects) and handpicking directly off the plant. Specimens were placed in BioQuip[®] kill jars, containing ethyl acetate, and upon death, transferred to plastic cups (120 ml) and labeled with the date, plant, plant part, and site collected. Specimens were taken to the laboratory for processing and identification.

Whenever possible, infested plant parts were taken to the laboratory and monitored for occurrence of insect species.

Leaf-Litter Samples. Leaf-litter samples were taken by removing accumulated vegetation (dead) from the surface of the ground. In 1997, five leaf-litter samples were collected weekly at each site, placed into individual Ziploc bags (900 ml), labeled, and taken to the laboratory. In 1998, five leaf-litter samples were collected monthly, placed into Ziploc plastic bags (900 ml), labeled, and taken to the laboratory. Once in the laboratory, the contents were placed into a Tullgren funnel with a fine screen on the bottom (Haarlov 1947). Samples remained in these funnels for 48 hours, and specimens were collected in containers (125 ml) filled with van Torne's solution (Torne 1965). Each sample was placed into a separate funnel. Heat from the overhead light source caused the insects to move from the litter, down through the funnel, and into the solution. The screen inside the funnel prevented most of the litter itself from dropping into the container. Each container of collected insects was then sorted under a dissecting microscope.

Light Traps. Nocturnal insects were collected using modified, battery-operated New Jersey light traps equipped with photoelectric cells. Light traps consisted of a 12-watt, U-shaped blacklight tube and a collecting unit, which held an aluminum funnel that guided insects into a plastic bucket (13.2 L) containing killing agent (ethyl acetate).

One light trap was placed at each site for an overnight period during 1997 and 1998; only one light trap sample was taken in 1997; however, light trap samples were collected generally every two weeks at each site in 1998. These traps are photosensitive and become activated late in the evening. Once these traps were placed at their selected

sites, they were removed the next day. Specimens were collected in Ziploc plastic bags (900 ml) and taken to the laboratory where they were sorted and identified.

Malaise Traps. One malaise trap (60 cm³) with No-see-um netting[®] (73 meshes/6.45 cm²) was placed in the center of each site. The netting intercepted flying insects, which were then directed toward a collecting unit at the top of the trap. This collecting unit consisted of a plastic cup (60 mm x 65 mm; 120 ml vol), which contained approximately 30 ml of 50% propylene glycol and water. The frame of the trap was constructed of PVC (polyvinyl chloride) pipe (2 cm ID). Each trap was positioned at ground level, and samples were removed and collecting units replaced weekly during the 1997 and 1998 sampling seasons. Specimens were taken to the laboratory, sorted, and identified.

Pitfall Traps. In 1997, ten pitfall traps per site were placed into shallow holes dug into the ground to collect ground-dwelling arthropods. In 1998, sampling was reduced to five pitfall traps per site. Traps consisted of two plastic cups, each 60 mm wide and 65 mm deep with a volume of 120 ml. One cup was placed inside the other to reduce flooding by heavy rains. The outer cup contained a drain hole to prevent flooding, and the inner cup was filled with a 50% mixture of propylene glycol and water. These traps were covered with 90° directional fans to guide the arthropods into the pitfall traps while protecting the samples from animals, wind, and rain. Traps were replaced weekly during the 1997 and 1998 sampling seasons. Specimens were taken to the laboratory, sorted, and identified.

Sticky Traps. Plastic sheets (22 cm x 28 cm) coated with Tangle Trap[®] were temporarily attached to both sides of yellow plywood plates measuring 23 cm x 29 cm, which were positioned at the top of PVC pipe (2 cm ID, 1.5 m tall). A short dowel rod (15 cm) was

inserted into the top of the pipe, upon which these sticky traps were attached. In 1997, ten sticky traps were placed at each site and replaced weekly. In 1998, five sticky traps were placed at each site and replaced monthly. These traps were placed in the same location as the pitfall traps, mainly to help identify the location of the pitfall traps. After removal, the plastic sticky sheets were placed into Ziploc plastic bags (3.79 L), taken to the laboratory, and examined for arthropods.

Sweep-net Sampling. Five sweep-net samples were taken weekly at each site during 1997 and 1998. The sweep net consisted of a canvas bag approximately 38 cm in diameter and 82 cm deep. One sweep-net sample contained 20 sweeps; each sweep consisted of traversing an arc of 180° through the vegetation. Once in the net, the sample was transferred to a Ziploc plastic bag (900 ml), placed in an ice chest, and taken to the laboratory, where it was sorted and identified.

Manitoba Traps. Manitoba traps were used only during 1998. These traps consisted of a 2- m² piece of black plastic sheeting (polyethylene) attached medially to a wooden stake approximately 2 m perpendicular to the ground with ropes attached to the four corners that were pulled taut and staked. A plastic collection container (20 cm diameter, 20 cm deep) with killing agent (ammonium carbonate) was affixed to the exterior of the trap top. On the inside of the trap, an inflatable black plastic ball (30 cm diameter) was suspended from the top of the stake with a rope approximately 50 cm from the ground surface. The oscillatory motion of the black ball attracted horseflies, paper wasps, and other insects, which flew upwards and were caught in the collecting apparatus. Samples were removed weekly and taken to the laboratory for identification.

Eggert's Sunflower. Special attention was given to one particular plant species due to the nature of its status under the Endangered Species Act of 1973. In 1998, insects were collected from 30 individual sunflowers in each of the sites (10 per site). Specimens were placed in BioQuip[®] kill jars, containing ethyl acetate, and upon death, transferred to plastic cups (120 ml) and labeled with the date, plant number, plant part, and site collected. These insects were taken to the laboratory and identified. Chapter IV focuses entirely on insect interactions on Eggert's sunflower.

Processing and Identification of Collected Specimens

After sorting all samples taken in 1997 and 1998, arthropods were processed accordingly. The spiders, as well as most soft-bodied insects, were placed into 2-dram vials containing 70% ethanol. These vials were labeled, indicating the date and location where each specimen was collected. Also, identification labels were placed in the vial indicating the genus, and whenever possible, the species to which each specimen belonged (identification keys are provided in Appendix A). All other specimens were pinned and labeled with date and location collected, and the properly identified scientific name, if available. Identification of each specimen was completed by entomological consultants to the project (Table 1). These specimens were then placed into Cornell[®] drawers and stored in the insect museum at The University of Tennessee.

Database Entry and Analysis

All specimens collected during 1997 and 1998 were entered into the Biota[®] database (Colwell 1996). The number of insects collected was computed per date for each site and trap. Once entered, data were analyzed using Statistical Analysis Software (SAS

Table 1. Taxonomic consultants contributing to species identification.

Consultants	Address (taxa identified)
Ernest Bernard	Dept. Entomology & Pl. Pathology, The University of Tennessee, Knoxville, TN 37901 (Collembola, Diplura)
Robert Edwards	Dept. Biology, Natural Sciences Bldg., Western Carolina University, Cullowhee, NC 28723-9051 (Arachnida)
David Etnier	Dept. Evol. Biology & Ecology, The University of Tennessee, Knoxville, TN 37901 (Trichoptera, Ephemeroptera, Plecoptera)
Melinda Gibbs	Dept. Entomology & Pl. Pathol., The University of Tennessee, Knoxville, TN 37901 (Hymenoptera: Formicidae)
George Harp	3206 Maplewood Terrace, Jonesboro, AR 72401-8829 (Odonata)
Adrieen J. Mayor	Dept. Entomology & Pl. Pathol., The University of Tennessee, Knoxville, TN 37901 (Coleoptera, Hemiptera, Homoptera)
Kimberly Norris	Dept. Evol. Biology & Ecology, The University of Tennessee, Knoxville, TN 37901 (Arachnida)
Charles O'Brien	Dept. Entomology-Biocontrol, Florida A&M University Tallahassee, FL 32307-4100 (Coleoptera: Curculionidae)
David Paulsen	Dept. of Entomology & Pl. Pathology, The University of Tennessee, Knoxville, TN 37901 (Diptera, Lepidoptera)
Susan Reichert	Dept. Evol. Biology & Ecology, The University of Tennessee, Knoxville, TN 37901 (Arachnida)
Edward Riley	Dept. Entomology, Texas A&M University, College Station, TX 77843 (Coleoptera: Chrysomelidae)
Mark Rothschild	Maryland Dept. of Agriculture, Plant Protection Section, Salisbury, MD 21801-8437 (Homoptera: Membracidae)

Table 1 (cont.). Taxonomic consultants contributing to species identification.

Consultant	Address (taxa identified)
Paul Skelley	Florida State Collection of Arthropods, University of Florida, Gainesville, FL32614 (Coleoptera: Erotylidae)
John Skinner	Dept. Entomology & Pl. Pathology, The University of Tennessee, Knoxville, TN 37901 (Hymenoptera)
Arnold Stange	Florida State Collection of Arthropods, University of Florida, Gainesville, FL32614 (Hymenoptera)
Michael Thomas	Florida State Collection of Arthropods, University of Florida, Gainesville, FL32614 (Coleoptera: Cucujoidea)
Karen Vail	Dept. Entomology & Pl. Pathol., The University of Tennessee, Knoxville, TN 37901 (Hymenoptera: Formicidae)
Greg Wiggins	Dept. Entomology & Pl. Pathol., The University of Tennessee, Knoxville, TN 37901 (Orthoptera: Acrididae)
Thomas Wood	Dept. Entomology & Applied Ecology, University of Delaware, Newark, DE 19713 (Homoptera: Membracidae)

Institute 1997) to determine frequency of species in each trap type and the frequency of species in each order at each site. These numbers were grouped by species code, order, and family.

Insect diversity for each site was determined by using Shannon-Weiner index (Smith 1980). The diversity index considers the number of species as well as their relative abundance. Species evenness and richness also were determined for each site in 1997 and 1998. Evenness values range from zero to one (one representing the most even value). Species richness is the number of species occurring at a particular location or habitat. This number was calculated for each sampling method and site by adding the number of species collected in each sampling method and the total collected in each site, respectively.

iii. Results and Discussion

A total of 12,028 specimens was collected in the grassland barrens at Arnold AFB in 1997 and 1998. From these specimens, 709 arthropod species, representing 21 orders and 165 families were identified and entered into the database (Appendix B, Table 2). The highest number of species were identified in Coleoptera (208 species in 30 families), Diptera (127 species in 33 families), and Hymenoptera (94 species in 27 families). Other orders well represented included Hemiptera (53 species from 13 families), Lepidoptera [52 species in 14 families; mainly tiger moths (Arctiidae) and brush-footed butterflies (Nymphalidae)], Homoptera [42 species in 7 families; mainly leafhoppers (Cicadellidae)], Orthoptera (36 species in 7 families; mainly *Melanoplus* spp.), and Collembola (31 species in 8 families). More individuals of Collembola were collected than any other order.

Table 2. Taxonomic classification and relative abundance of arthropods collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, in 1997 and 1998.

Order	Family	Species	Abundance
Araneae	Araneidae	9	11
	Dictynidae	1	1
	Gnaphosidae	2	5
	Linyphiidae	1	1
	Liocranidae	1	1
	Lycosidae	6	7
	Philodromidae	1	1
	Salticidae	6	8
	Theridiidae	2	2
	Thomisidae	4	7
Blattaria	Blattellidae	5	90
Coleoptera	Anthicidae	1	1
	Anthribidae	1	1
	Bruchidae	1	7
	Buprestidae	3	4
	Cantharidae	6	1057
	Carabidae	27	375
	Cerambycidae	10	28
	Chrysomelidae	48	488
	Cicindelidae	2	7
	Coccinellidae	7	31
	Curculionidae	32	150
	Dermestidae	1	1
	Dryopidae	1	10
	Dytiscidae	3	8
	Elateridae	4	12
	Eucinetidae	1	1
	Halipidae	1	1
	Heteroceridae	2	7
	Histeridae	3	59
	Hydrophilidae	3	67
	Languriidae	2	12
	Leptodiridae	2	2
	Meloidae	6	39
	Mordellidae	2	3
	Nitidulidae	1	1
	Oedomeridae	1	1
	Rhipiphoridae	1	5

Table 2 (cont.). Taxonomic classification and relative abundance of arthropods collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, in 1997 and 1998.

Order	Family	Species	Abundance
Coleoptera	Scarabaeidae	20	392
	Silphidae	2	11
	Staphylinidae	14	186
Collembola	Brachystomellidae	1	1
	Entomobryidae	6	52
	Hypogastruridae	1	91
	Isotomidae	8	125
	Neanuridae	3	28
	Onychiuridae	4	19
	Sminthuridae	6	80
	Tomoceridae	2	3145
Dermaptera	Labiidae	1	5
Diplura	Japygidae	1	1
Diptera	Agromyzidae	1	3
	Anthomyiidae	7	17
	Asilidae	6	50
	Bibionidae	2	31
	Bombyliidae	4	4
	Calliphoridae	2	8
	Ceratopogonidae	1	1
	Chironomidae	1	33
	Chloropidae	10	202
	Culicidae	1	4
	Dolichopodidae	8	73
	Drosophilidae	2	16
	Empididae	3	30
	Ephydriidae	3	11
	Lauxaniidae	1	1
	Milichiidae	1	1
	Muscidae	5	27
	Mycetophilidae	3	39
	Mydidae	1	1
	Otitidae	3	22
	Phoridae	2	62
	Pipunculidae	2	5
	Platystomatidae	1	5
	Sarcophagidae	8	10
	Sciaridae	5	699

Table 2 (cont.). Taxonomic classification and relative abundance of arthropods collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, in 1997 and 1998.

Order	Family	Species	Abundance
Diptera	Sciomyzidae	2	49
	Sphaeroceridae	1	1
	Stratiomyidae	2	4
	Syrphidae	7	22
	Tabanidae	10	36
	Tachinidae	16	43
	Tephritidae	5	8
	Tipulidae	1	11
Hemiptera	Alydidae	2	71
	Coreidae	4	29
	Corimelaenidae	3	43
	Cydnidae	3	24
	Lygaeidae	15	289
	Miridae	3	215
	Nabidae	1	2
	Pentatomidae	10	130
	Phymatidae	4	9
	Reduviidae	3	10
	Rhopalidae	3	45
	Scutelleridae	1	3
	Tingidae	1	2
Homoptera	Acanaloniidae	1	10
	Cercopidae	5	124
	Cicadellidae	22	136
	Cicadidae	1	1
	Dictyopharidae	4	16
	Issidae	3	7
	Membracidae	6	91
Hymenoptera	Andrenidae	1	1
	Anthophoridae	3	5
	Aphelinidae	1	1
	Apidae	3	12
	Braconidae	3	10
	Ceraphronidae	1	1
	Chalcididae	2	4
	Chrysididae	1	14
	Diapriidae	1	3
	Encyrtidae	1	1

Table 2 (cont.). Taxonomic classification and relative abundance of arthropods collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, in 1997 and 1998.

Order	Family	Species	Abundance
Hymenoptera	Eucoilidae	1	1
	Eulophidae	1	8
	Eumenidae	1	12
	Eupelmidae	1	1
	Formicidae	30	988
	Halictidae	3	113
	Ichneumonidae	4	6
	Megachilidae	3	14
	Pamphiliidae	1	1
	Platygastridae	1	1
	Pompilidae	1	1
	Pteromalidae	1	1
	Scelionidae	2	2
	Sphecidae	15	73
	Tenthredinidae	2	5
	Tiphiidae	2	8
	Vespidae	8	13
Isoptera	Rhinotermitidae	1	20
Lepidoptera	Arctiidae	10	34
	Geometridae	5	6
	Hesperiidae	4	13
	Libytheidae	1	1
	Megalopygidae	2	3
	Noctuidae	4	19
	Notodontidae	2	5
	Nymphalidae	11	32
	Papilionidae	2	2
	Pieridae	3	4
	Saturniidae	2	3
	Satyridae	1	1
	Sphingidae	4	9
	Thyrididae	1	3
Mantodea	Mantidae	2	8
Mecoptera	Panorpidae	1	1
Neuroptera	Chrysopidae	2	9
Odonata	Gomphidae	1	1
	Lestidae	2	3
	Libellulidae	4	4

Table 2 (cont.). Taxonomic classification and relative abundance of arthropods collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, in 1997 and 1998.

Order	Family	Species	Abundance
Orthoptera	Acrididae	17	497
	Decticinae	1	1
	Gryllacrididae	3	7
	Gryllidae	5	213
	Gryllotalpidae	1	1
	Tetrigidae	3	15
	Tettigonidae	6	338
Phasmida	Heteronemiidae	1	3
Psocoptera	Psocidae	1	1
Thysanoptera	Phlaeothripidae	1	1
Trichoptera	Hydropsychidae	2	2
	Leptoceridae	6	32
	Polycentropodidae	2	2

Several insect species were commonly collected from the grassland barrens during the two-year study (Table 3). The most abundant species included: the collembolan *Tomocerus flavescens* Tullberg, the coleopterans *Chauliognathus pennsylvanicus* (DeGeer) and *Abacidus atratus* Newman, the dipterans *Corynoptera* spp., the hemipteran *Lygus lineolaris* (Palisot de Beauvois), the hymenopteran *Pheidole dentata* Mayr, and the orthopterans *Orchelimum vulgare* Harris, *Melanoplus* spp. and *Melanoplus femurrubrum propinquus* DeGeer.

Overall diversity for arthropods in the grassland barrens was 4.219 (maximum value = 6.561) with an overall evenness value of 0.643 (maximum value = 1). Species diversity increases as the number of individuals in the total populations are more evenly distributed among them. The more equitable the distribution of individuals among species, the greater the evenness (Smith 1980). The maximum diversity rating obtainable for the number of species collected was 6.561. For simplicity, species diversity, abundance and seasonality of arthropods, and the effectiveness of each sampling method, for each year are examined in the following sections. Also, disjunct species of Coleoptera occurring in the barrens at Arnold Air Force Base are discussed. Detailed information on the impact of burning on insect populations is provided in Chapter III.

1997

Species Diversity. A total of 3,127 specimens, representing 243 species, 87 families, and 15 orders, was identified from the barrens in 1997 (Appendix B). The diversity rating for arthropods in 1997 was 3.397 (maximum value = 5.063) with an overall evenness value of 0.673 (maximum value = 1). The Coleoptera and Diptera produced the greatest number of

Table 3. Most abundant species collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, during 1997 and 1998.

Order	Family	Genus	Species/Subspecies Author	Abun. ^a
Coleoptera	Carabidae	<i>Abacidus</i>	<i>atratus</i> Newman	221
	Cantharidae	<i>Chauliognathus</i>	<i>pennsylvanicus</i> (DeGeer)	988
	Chrysomelidae	<i>Diabrotica</i>	<i>undecimpunctata howardi</i> Barber	139
	Chrysomelidae	<i>Luperaltica</i>	<i>nigripalpis</i> (LeConte)	72
	Curculionidae	<i>Pantomorus</i>	<i>tessellatus</i> (Say)	60
	Histeridae	<i>Hister</i>	<i>fungicola</i> Schaeffer	56
	Hydrophilidae	<i>Berosus</i>	<i>infuscatus</i> LeConte	65
	Scarabaeidae	<i>Bolbocerosoma</i>	<i>bruneri</i> Dawson & McColloch	133
	Scarabaeidae	<i>Bolbocerosoma</i>	<i>farctum</i> (F.)	80
	Scarabaeidae	<i>Popillia</i>	<i>japonica</i> Newman	81
Collembola ^b	Hypogastruridae	<i>Hypogastrura</i>	species 1	91
	Isotomidae	<i>Folsomia</i>	<i>duodecimoculata</i> Ford	66
	Tomoceridae	<i>Tomocerus</i>	<i>flavescens</i> Tullberg	3114
Diptera	Chloropidae	<i>Apallates</i>	spp.	89
	Sciaridae	<i>Corynoptera</i>	spp.	684
Hemiptera	Alydidae	<i>Alydus</i>	<i>eurinus</i> (Say)	50
	Lygaeidae	<i>Malezonotus</i>	<i>sodalicius</i> (Uhler)	52
	Lygaeidae	<i>Orthaea</i>	<i>basalis</i> (Dallas)	58
	Miridae	<i>Lygus</i>	<i>lineolaris</i> (Palisot de Beauvois)	204
Homoptera	Cercopidae	<i>Philaenus</i>	<i>leucophthalmus</i> L.	74
	Membracidae	<i>Spissistilus</i>	<i>festinus</i> (Say)	58
Hymenoptera	Formicidae	<i>Aphaenogaster</i>	<i>treatae</i> Forel	128
	Formicidae	<i>Dolichoderus</i>	<i>mariae</i> Forel	103
	Formicidae	<i>Formica</i>	<i>schaufussi schaufussi</i> Mayr	137
	Formicidae	<i>Pheidole</i>	<i>dentata</i> Mayr	175
	Formicidae	<i>Tapinoma</i>	<i>sessile</i> (Say)	123
	Halictidae	<i>Dialictus</i>	species 1	90
Orthoptera	Acrididae	<i>Melanoplus</i>	<i>femurrubrum propinquus</i> DeGeer	144
	Acrididae	<i>Melanoplus</i>	spp.	229
	Gryllidae	<i>Acheta</i>	<i>assimilis</i> (F.)	102
	Tettigoniidae	<i>Orchelium</i>	<i>vulgare</i> Harris	258
Lepidoptera	Nymphalidae	<i>Phyciodes</i>	<i>tharos</i> (Drury)	15
	Noctuidae	<i>Plathypena</i>	<i>scabra</i> (F.)	14

^a Number of individuals collected

^b Numbers of Hypogastruridae and Isotomidae are from 1997; Tomoceridae are mostly from 1998.

species (51 and 43, respectively) and yielded 38.7% ($n = 94$) of the 243 species recorded. About 34.2% ($n = 83$) of all species were found in the Collembola (31), Araneae (27), and Hymenoptera (25). The remaining orders produced 27.1% ($n = 66$) of all species collected.

Arthropod Abundance and Seasonality. More species ($n = 96$) were prevalent during the week of 1 October than at any other time in 1997 (Fig. 4A). The number of species began to decline from 15 to 29 October and increased slightly by 5 November. The inadequate supply of plants may be one explanation for these trends. Furthermore, the number of individuals collected in 1997 were most abundant during the week of 26 September (Fig. 4B). Incidentally, most of these individuals were soldier beetles, *C. pennsylvanicus* (DeGeer), collected from sticky traps.

Effectiveness of Sampling Methods. Pitfall traps and sweep-net sampling produced the greatest number of arthropod species (79 and 73, respectively) (Fig. 5A). Pitfall sampling collected 32.5% of all species, while sweep-net sampling collected 30.0% of all species. About 24.7% and 21.4% of all species were collected using beat sheet ($n = 60$) and leaf-litter ($n = 52$) samples, respectively. Although sticky traps did not produce many species during 1997, they yielded more individuals (33.9% of the total) than any other sampling method (Fig. 5B). Nearly all of these insects were soldier beetles and were so abundant probably due to the presence of goldenrod in the barrens. Pitfall traps yielded about 33.7% of all individuals due to the abundance of ground-dwelling arthropod assemblages, such as ground beetles and scarabs. It is noteworthy that sweep-net sampling produced such a low

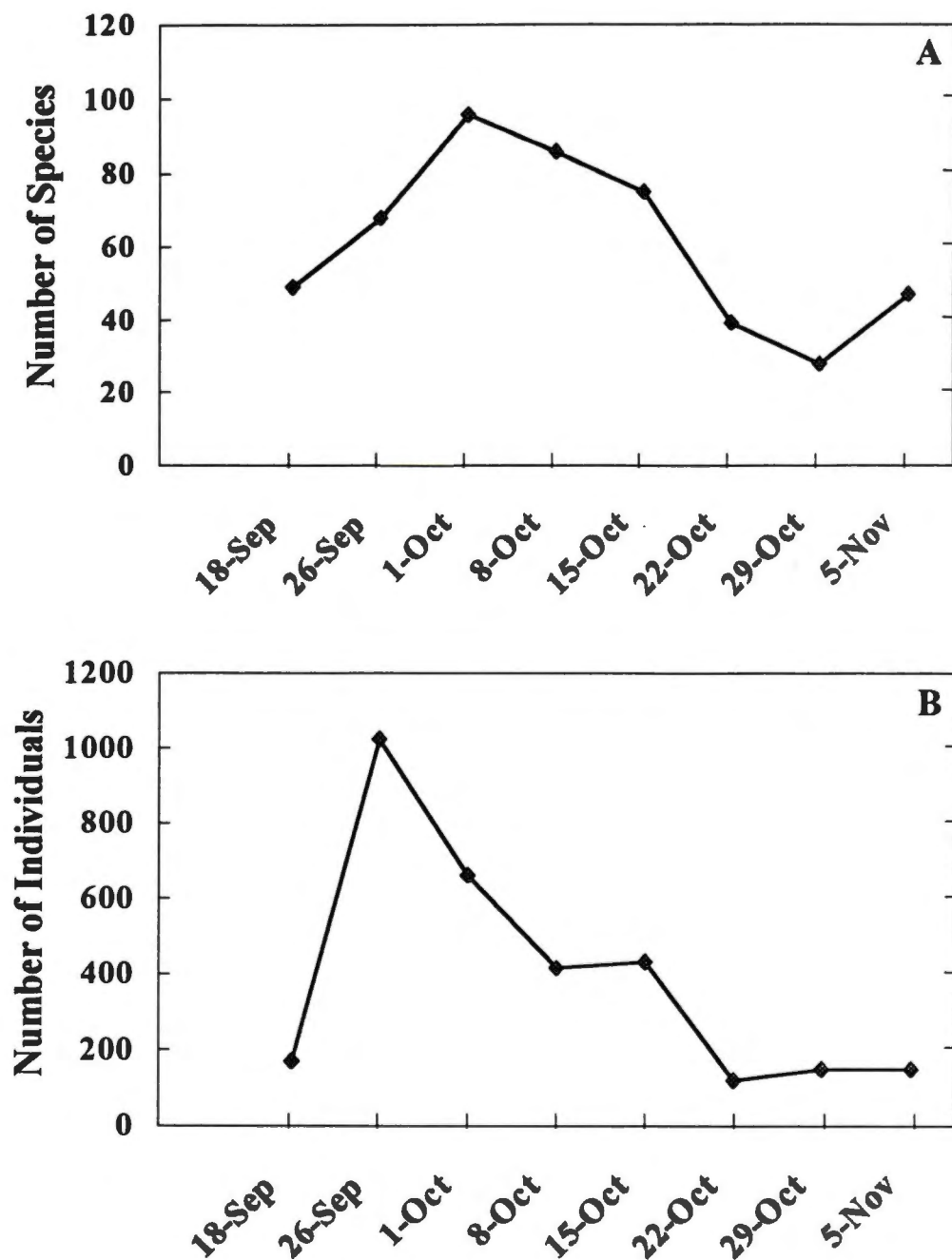


Figure 4. Seasonality of all species (A) and individuals (B) collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

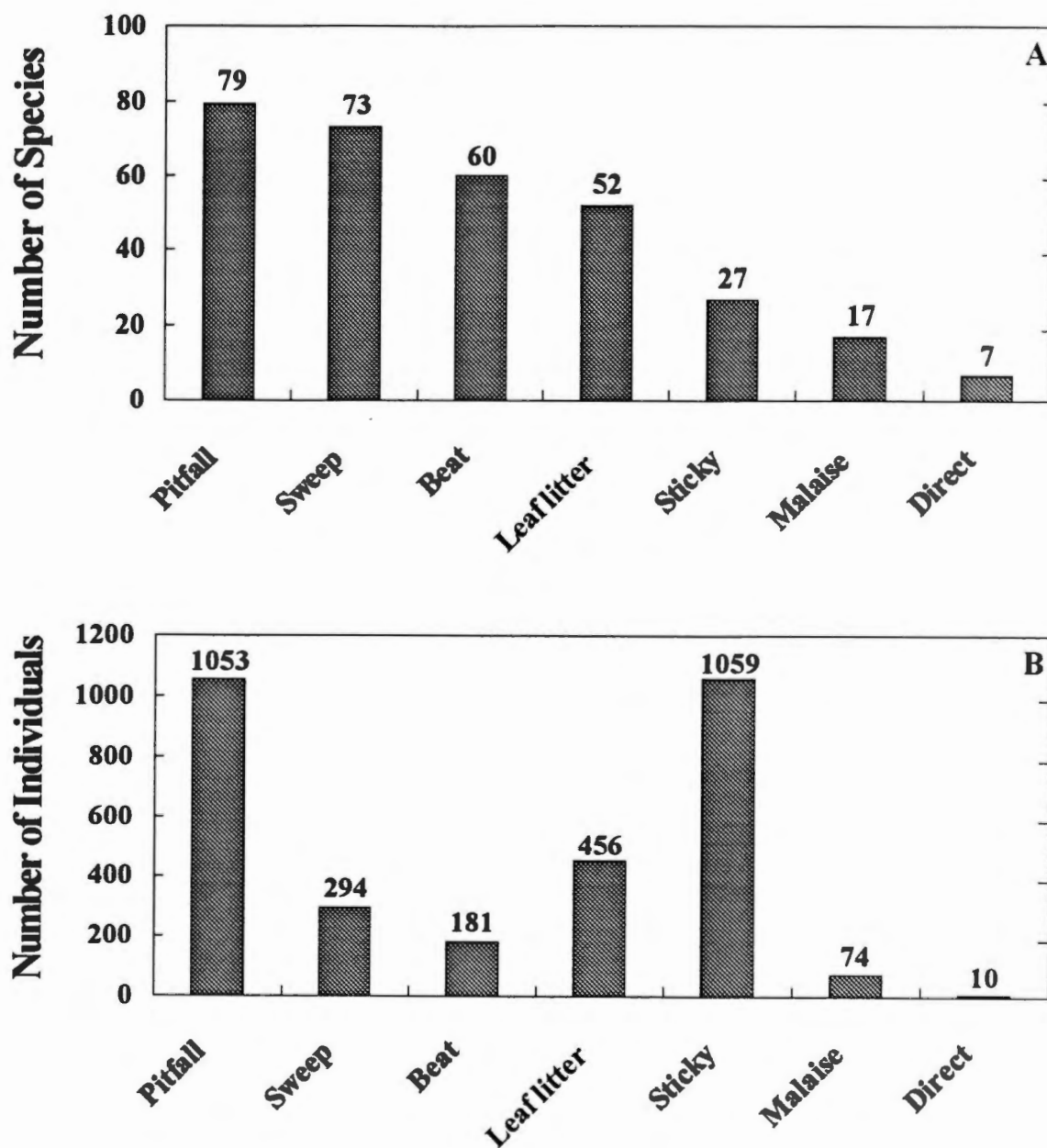


Figure 5. Number of species (A) and individuals (B) collected from each sampling method in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

number of individuals, but such a high number of species. Therefore, this method is effective in sampling a diverse fauna.

1998

Species Diversity. A total of 8,901 specimens, representing 601 species, 143 families, and 19 orders, was identified from the barrens in 1998 (Appendix B). The diversity rating for arthropods in 1998 was 3.720 (maximum value = 5.782) with an overall evenness value of 0.643 (maximum value = 1). The Coleoptera and Diptera produced the greatest number of species (191 and 114, respectively). These two orders yielded 50.7% ($n = 305$) of the 601 species recorded in 1998. About 31.1% ($n = 187$) of all species were found in the Hymenoptera ($n = 90$), Hemiptera ($n = 49$), and Lepidoptera ($n = 48$). The remaining orders accounted for 18.1% of all species collected. Only a single species of Collembola was identified (*Tomocerus flavescens* Tullberg); however, most of the litter-inhabiting insects, as well as the spiders, were not identified in 1998.

Diversity indices, with regard to the various sampling methods, for all arthropods collected in 1997 and 1998 are illustrated in Table 4 for both the 1997 and 1998 samples (overall H' value ranging from 1.690 to 4.454). Diversity indices were lowest for collections from the sticky traps (1.690) and Manitoba traps (2.845); and highest for collections from direct sampling (4.250), malaise traps (4.231), and sweep-net sampling (4.454). When combining all sampling methods for both years, an average evenness value of 0.729 was obtained, which indicates a uniform collection of species using the various sampling methods. Species evenness was greatest for direct sampling (0.949) and malaise

Table 4. Diversity indices, species evenness, and richness for all arthropod species collected (n = 709) in 1997 and 1998 in each sampling site, Arnold Air Force Base, Tullahoma, TN.

Sampling Method	Shannon-Wiener		Species Evenness	Species Richness	Percent Total Species
	H'	H max			
Beat sheet	3.960	4.938	0.802	139	19.61
Direct	4.250	4.478	0.949	88	12.41
Eggert	3.393	4.143	0.819	63	8.89
Light	3.002	4.344	0.691	77	10.86
Leaf litter	2.971	4.075	0.729	59	8.32
Malaise	4.231	4.989	0.848	147	20.73
Manitoba	2.845	3.662	0.777	39	5.50
Pitfall	2.337	5.193	0.450	179	25.25
Sticky	1.690	3.867	0.437	48	6.77
Sweep net	4.454	5.652	0.788	285	40.20

^a Shannon-Wiener formula:

$$H' = -\sum_{i=1}^s (p_i)(\log p_i)$$

Where H = diversity index

s = species number

p_i = proportion of the ith species in the total sample.

^b Species evenness = H' / H max, therefore, maximum = 1.

traps (0.848) and lowest for sticky traps (0.437) and pitfall traps (0.450); however, species richness (179 species) was high in pitfall traps, second only to the sweep nets (285 species). The malaise and beat sheet methods also yielded high numbers of species (147 and 139, respectively).

Arthropod Abundance and Seasonality. When all arthropod species collected in 1998 at all sites were combined, more than 250 species were found in July (Fig. 6A). The numbers of arthropod species collected in the barrens exhibited their highest levels in the middle of summer before declining as cooler weather and fewer resources became prevalent. In addition, the number of individuals collected in 1998 were most abundant during August (Fig. 6B), indicating insects were more abundant during the middle of summer than at any other time.

Effectiveness of Sampling Methods. Sweep-net sampling produced the greatest number of arthropod species (258) and collected 42.9% of all species (Fig. 7A). Pitfall and malaise traps collected similar numbers of species (143, and 136, respectively). Approximately 16.5%, 14.0%, and 12.6% of all species were collected in beat sheet ($n = 99$), direct sampling ($n = 84$), and light traps ($n = 76$), respectively.

Pitfall traps alone yielded 2X as many individuals as sweep-net sampling (Fig. 7B). About 22.6% of all individuals were collected through sweep-net sampling. The remaining sampling methods accounted for 30.4% of all individuals collected. As observed in 1997, the majority of these arthropods were ground-dwelling beetles (carabids and scarabs). Sweep-net sampling and pitfall traps were the most optimal sampling methods employed in this arthropod study; both from a species standpoint, as well as abundance.

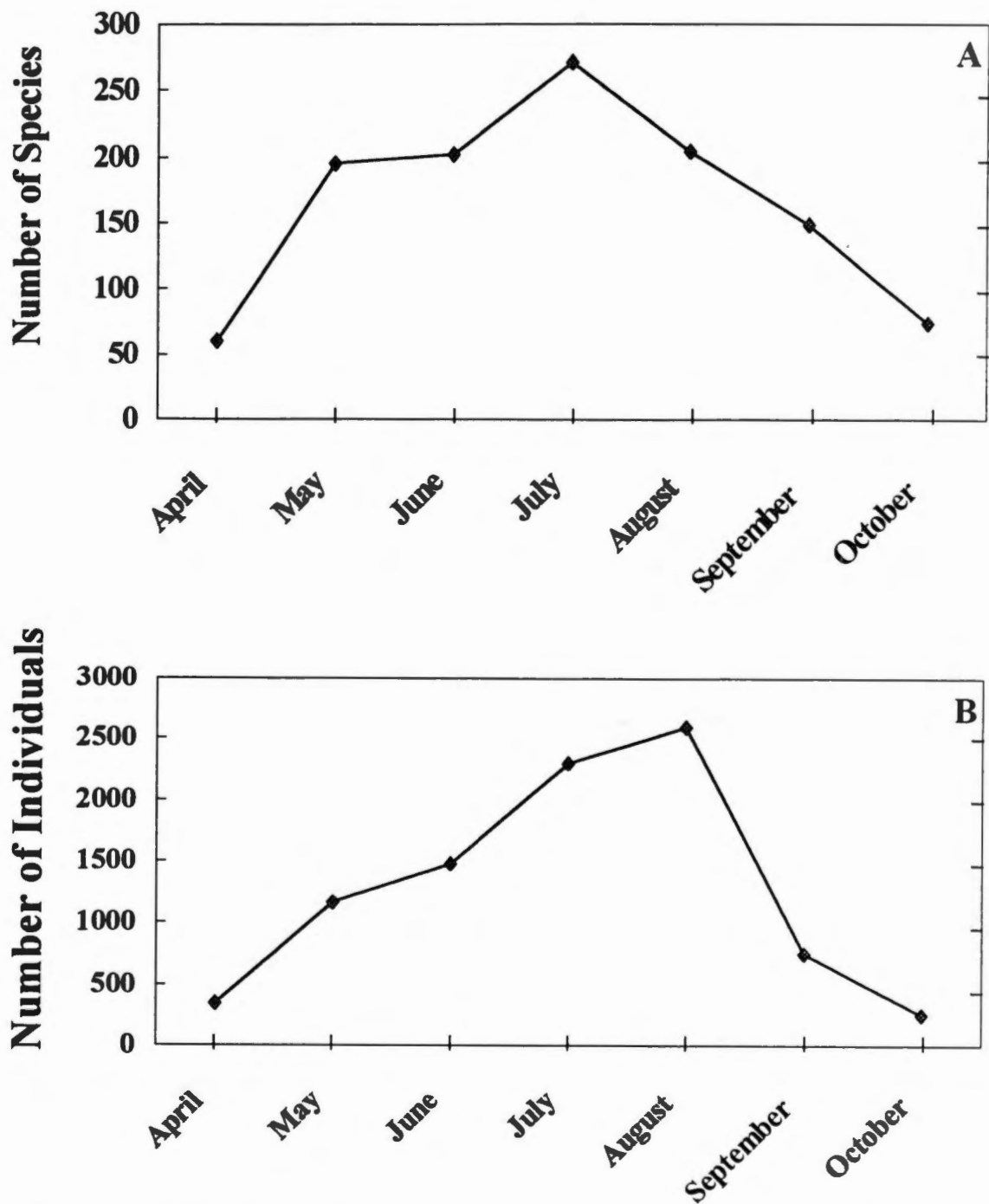


Figure 6. Seasonality of all species (A) and individuals (B) collected from the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

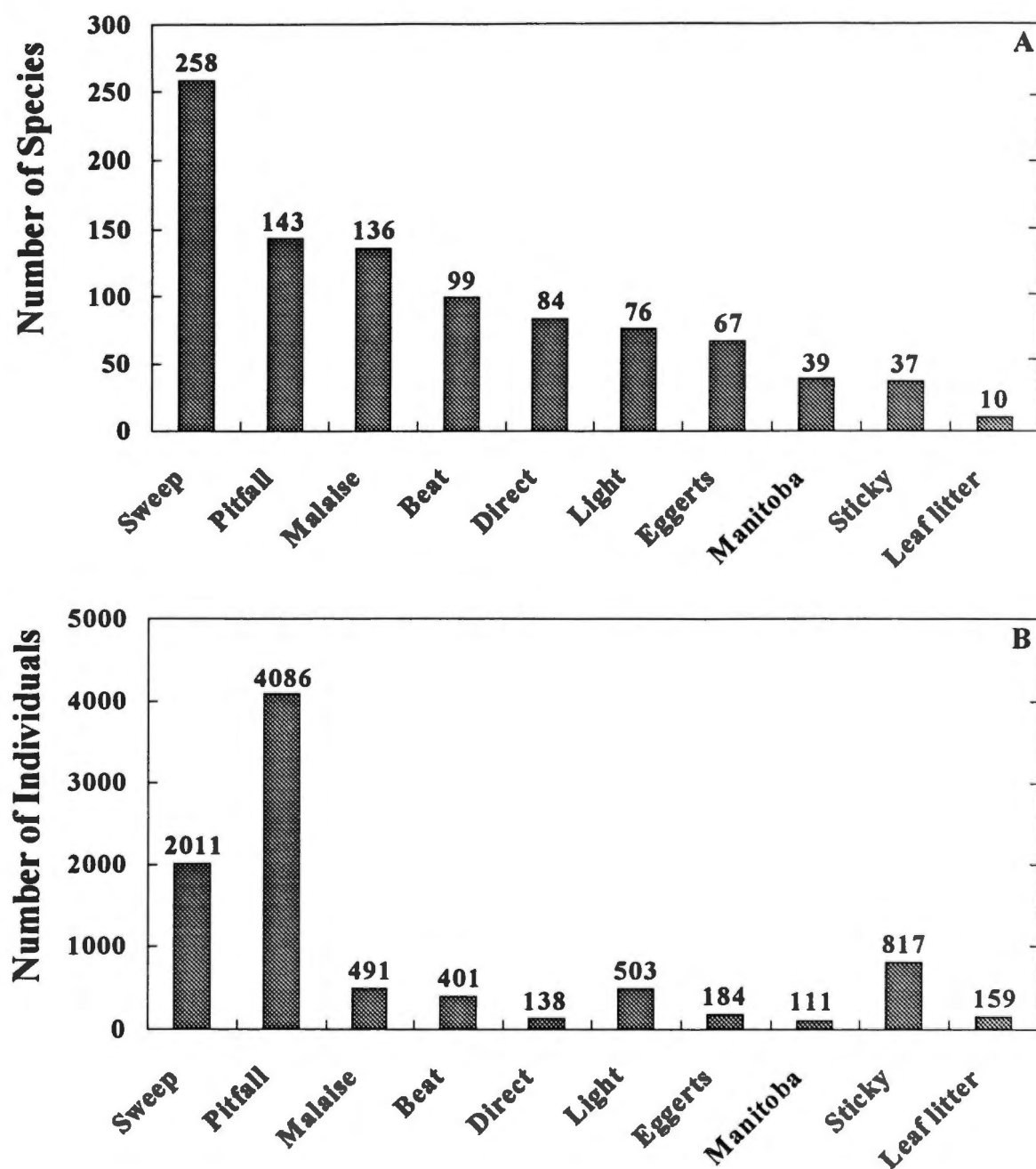


Figure 7. Number of species (A) and individuals (B) collected from each sampling method in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

Disjunct Species

Because of the availability of updated taxonomic keys (Downie and Arnett 1996), only the disjunct species of Coleoptera are discussed. This reference provides useful information about all North American beetles that have been identified and also provides taxonomic keys to species, as well as their range.

Investigations of disjunct species in Tennessee have not been extensive, even though their range may have included the state at one time. Twelve beetle species collected in the grassland barrens may be disjunct and may represent new state records for Tennessee (Table 5). The ground beetle *Myas cyanescens* Dejean, a forest species, was collected in the barrens and has been recorded from the northeastern United States. The distribution of the click beetle *Aeolus mellillus* (Say), which was attracted to lights, ranges from the southwest to the northeastern United States. The margined blister beetle, *Epicauta pestifera* Werner, may be a disjunct species, and is often considered a pest of potatoes. Little information is available in the literature for the other beetles that are considered disjunct from their range.

iv. Summary

Abundance, seasonality, and species composition of insects associated with the grassland barrens in middle Tennessee were examined during 1997 and 1998. Also, the effectiveness of various sampling methods in assessing insect communities in the barrens was evaluated. A total of 12,028 specimens was collected in the grassland barrens at Arnold AFB in 1997 and 1998. From these specimens, 709 arthropod species, representing 21 orders and 165 families, were identified (more arthropods were identified

Table 5. Disjunct species of Coleoptera occurring in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997 and 1998.

Family	Genus	Species/Subspecies	Author	Range*
Carabidae	<i>Myas</i>	<i>cyanescens</i>	Dejean	MA, WI, MI
Curculionidae	<i>Anthonomus</i>	<i>molochinus</i>	Dietz	MT, ND, NH, MA, CT, TX, MN
	<i>Odontocorynus</i>	<i>illini</i>	Casey	IL
	<i>Odontocorynus</i>	<i>iowensis</i>	Casey	IA
	<i>Tachyerges</i>	<i>salicis</i> (L.)		IL, DC, IN, MI, NJ, NY, WI, CA, ID, NV, OR, WA, MT
Elateridae	<i>Aeolus</i>	<i>mellillus</i>	(Say)	IN, PA, MD, TX, AZ
Eucinetidae	<i>Eucinetus</i>	<i>terminalis</i>	LeConte	NY, VT, MI, IN, IL, ID, OR, WA
Melandryidae	<i>Epicauta</i>	<i>pestifera</i>	Werner	NY, IL, IN, OH, PA, WY, CO, NE, IA
Mordellidae	<i>Mordellistena</i>	<i>divisa</i>	LeConte	LA
Staphylinidae	<i>Hommaeotarsus</i>	<i>pimerianus</i>	(LeConte)	IN, TX, AZ, CA, IA
	<i>Staphylinus</i>	<i>maculosus</i>	(Gravenhorst)	NY, IN
	<i>Sunius</i>	<i>confluentus</i>	(Say)	CT, NY, IN, MN

* As provided by Downie and Arnett (1996).

in 1998 than in 1997 due to the shorter sampling period in 1997). The collembolan *T. flavescens* was the most abundant species collected (3,114 individuals). Pitfall traps and sweep-net sampling were the most effective sampling methods and accounted for more of the total species collected and individuals collected in 1997 and 1998. Although sticky traps did not produce many species during 1997, they yielded more individuals (33.9% of the total) than any other sampling method. Furthermore, diversity indices were lowest for collections from the sticky traps and Manitoba traps and highest for collections from direct sampling, malaise traps, and sweep-net sampling.

Coleoptera was the most species-rich order, with 208 species representing 30 families. Diptera (127 species in 33 families) and Hymenoptera (94 species in 27 families) also were well represented. These three orders constituted 61.9% of all species collected in 1997 and 1998.

In general, more species were prevalent during the week of 1 October than at any other time sampled (from September to November) in 1997. Also, the number of individuals collected in 1997 were most abundant during the week of 26 September. When all arthropod species collected in 1998 at all sites were combined, more than 250 species were found in July. In addition, the number of individuals collected in 1998 were most abundant during August.

The grassland barrens in middle Tennessee provide habitat for a diverse arthropod fauna. Little information, however, is available on the impact of management strategies on insect species composition in grassland ecosystems. By determining which species are

present in these grassland ecosystems, researchers may be able to predict what factors affect species diversity, abundance, and seasonality.

CHAPTER III

IMPACT OF PRESCRIBED BURNING ON ARTHROPOD POPULATIONS IN THE GRASSLAND BARRENS OF MIDDLE TENNESSEE

i. Introduction

Fire is an important ecological factor in many of the world's grasslands, particularly in semi-arid regions where burning, annually or every few years, is a well-established practice (Hulbert 1986). Burning is conducted for one or more of the following purposes: to remove accumulated, inedible grass; to stimulate the growth of succulent and nutritious new grass; to influence the distribution and abundance of animals; to remove a fire hazard, especially in areas which contain forests; to prepare a seedbed for natural or artificial seeding of desired forage species; to stimulate range grasses to produce seed; and to encourage the growth of native legumes for forage and soil improvement.

The use of fire as a tool in the management of grassland and forest ecosystems has acquired an impressive acceptance within the past decade. A large amount of literature has been generated by numerous studies, usually concerning the response of vegetation to fire (Daubenmire 1968). Relatively few studies have examined the effect of burning upon other components of the ecosystem, such as soil flora and fauna, or above-ground arthropods. Literature becomes even more scant when considering a particular type of ecosystem or geographical area (Vogel 1974).

The effect of prairie burning on insect populations in Missouri was reported by Cancelado and Yonke (1970). They compared populations of some Hemiptera and Homoptera on prairie grassland, part of which had been burned in spring, with untreated areas located in the same vicinity. They found statistically significant ($p \leq 0.05$) differences between trap collections for Hemiptera and Homoptera in general and for the families Lygaeidae and Cicadellidae, with the greatest number of insects in each group coming from the burned area. The Miridae also were more numerous in the burned area, especially later in the season, and the authors suggested that near the middle of the growing season the ecology of the burned area offers conditions for a fast accumulation of certain species of Miridae and other taxa, while later in the season some condition of equilibrium returned. Unfortunately, no attempt has been made to explain these differences in terms of biology and ecological requirements of the species concerned.

To date, little research has been performed regarding the effects of burning on insect abundance and diversity in Tennessee. Because fire is such a practical means of managing selected ecosystems, it is important to study the impact it has on animals within the system being burned; in this case, insects. Conservation biologists at AFB have been conducting prescribed burning and rotational mowing for several years, and the main objectives of such practices are to maintain the barrens from forest succession and to compare which management tool, fire or mowing, generates the greatest diversity among plant community types (Bynum 1996). The purpose of this study was to investigate the effects of prescribed burning on arthropod species and populations occurring in the grassland barrens in middle Tennessee.

ii. Materials and Methods

The study area and sampling methods were outlined in general in Chapter II. Collected specimens also were processed and identified as described in Chapter II. The following descriptions contain additional information related to evaluating the impact of burning on arthropod populations.

1997

From 17 September to 5 November 1997, two sites were evaluated to assess the influence of burning on insect diversity and abundance in the grassland barrens of Arnold AFB. These two sites were: 1) burned (ca. 28 ha), and 2) non-burned (ca. 14 ha) (Fig. 3). The burned site was burned in April 1997 and remained the same throughout the project, and the non-burned site was burned on 30 October 1997 (sampling did continue in this site even after the burn). Sampling methods included beat sheets, direct collecting, leaf-litter samples, light traps, malaise traps, pitfall traps, sticky traps, and sweep-net sampling. In addition to these sampling methods, direct sampling from flowerheads and aerial insects were included in the collection process.

1998

Three sites were further evaluated to assess the influence of burning on insect diversity and abundance in the barrens of Arnold AFB. These three sites were: 1) initial burned (ca. 28 ha), 2) recent burned (ca. 14 ha), and 3) non-burned (ca. 12.5 ha) (Fig. 3). During September to November 1997, Site 2 served as the non-burned site until 30 October 1997, when it was reclassified as the recent burned site. A new non-burned site (Site 3) was established in April 1998. All three sites were sampled from April through

October in 1998. Insect diversity and abundance among the sites were assessed using the same sampling techniques during 1997, except with the addition of the Manitoba trap and intensive sampling of insects from Eggert's sunflower in 1998.

Database Entry and Analysis

All specimens collected during 1997 and 1998 were entered into the Biota[®] database (Colwell 1996). The number of insects collected was tabulated per date for each site and trap. Once entered, data were analyzed using Statistical Analysis Software (SAS Institute 1997) to determine frequency of species in each trap type and the frequency of species in each order at each site. These numbers were grouped by species code, order, and family. Insect diversity for each site was determined by using the Shannon-Weiner index (Smith 1980).

iii. Results and Discussion

The influence of burning on numbers of each taxon and their distribution among sites in 1997 and 1998 are presented. Several taxa showed biological differences among each site, specifically, the raw number of individuals occurring in certain taxa varied among sites. Selected taxa are discussed according to the most apparent differences occurring among the sites. Due to the short sampling period in 1997, comparisons of sampling methods between the initial burned and non-burned sites are limited.

1997

Species Diversity. More species were collected from the burned site than the non-burned site (185 and 135 spp., respectively). One family of Coleoptera and three families of

Collembola showed a response to burning. The Cantharidae were 3.2X more abundant in the burned site than the non-burned site (Table 6). It is likely that the presence of goldenrod accounts for these high numbers. The Isotomidae and Tomoceridae were 6.4X and 3.1X, respectively, more numerous in the non-burned site than the burned site. Conversely, the Hypogastruridae were 3.7X greater in the burned site than the non-burned site. Their abundance in the burned site is unusual since most of the ground cover had been removed from burning earlier in the year.

In the burned site, 1,778 specimens representing 185 species, 68 families, and 12 orders were identified (Table 6). Of the total number of arthropods collected, 170 species were insects and 15 were spiders. Nine orders were represented by eight species or more (Fig. 8A), and three orders were represented by fewer than 8 species including: Blattaria (2), Neuroptera (1), and Phasmida (1). More than 50% of all species in the burned site in 1997 were represented by three insect orders: Coleoptera (41), Diptera (30), and Hymenoptera (22). Lepidoptera was represented by only eight species or 4.3% of the total number of species identified.

In the non-burned site, 1,349 specimens representing 135 species, 60 families, and 12 orders were identified (Table 6). Of these species, 121 were insects and 14 were spiders. Eight orders were represented by seven or more species, and four orders were represented by less than seven species including: Blattaria (2), Mantodea (1), Thysanoptera (1), and Diplura (1) (Fig. 8B). More than 66% of all species identified in the non-burned site were represented by the Coleoptera, Collembola, Diptera, and Hymenoptera (Fig. 8B). Species of Hemiptera, Orthoptera, and Homoptera represented

Table 6. Total number of arthropods collected from each family in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

Order	Family	Burned	Non-burned
Araneae	Araneidae	5	6
	Dictynidae	1	0
	Gnaphosidae	0	1
	Linyphiidae	1	0
	Liocranidae	0	1
	Lycosidae	2	2
	Philodromidae	1	0
	Salticidae	5	3
	Theridiidae	1	1
	Thomisidae	3	4
Blattaria	Blattellidae	21	15
Coleoptera	Cantharidae	651	202
	Carabidae	112	130
	Chrysomelidae	62	47
	Coccinellidae	6	5
	Curculionidae	34	15
	Histeridae	4	0
	Leptodiridae	2	0
	Meloidae	2	0
	Scarabaeidae	27	11
	Staphylinidae	0	2
Collembola	Brachystomellidae	1	0
	Entomobryidae	11	41
	Hypogastruridae	70	19
	Isotomidae	17	108
	Neanuridae	2	26
	Onychiuridae	0	19
	Sminthuridae	20	60
	Tomoceridae	84	257
Diplura	Japygidae	0	1
Diptera	Anthomyiidae	5	3
	Asilidae	1	1
	Bibionidae	0	8
	Bombyliidae	0	1
	Calliphoridae	0	2
	Chironomidae	0	11
	Chloropidae	24	54
	Culicidae	4	0

Table 6 (cont.). Total number of arthropods collected from each family in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

Order	Family	Burned	Non-burned
Diptera	Dolichopodidae	8	0
	Drosophilidae	2	0
	Empididae	12	2
	Ephydriidae	0	1
	Muscidae	9	2
	Mycetophilidae	29	4
	Otitidae	2	0
	Phoridae	45	0
	Sarcophagidae	2	0
	Sciaridae	2	6
	Sciomyzidae	1	10
	Syrphidae	1	0
	Tabanidae	0	1
	Tachinidae	0	1
	Tipulidae	4	3
Hemiptera	Alydidae	33	5
	Cydnidae	14	2
	Lygaeidae	13	5
	Miridae	34	9
	Pentatomidae	7	0
	Phymatidae	0	2
	Rhopalidae	8	4
	Scutelleridae	0	2
Homoptera	Acanaloniidae	2	2
	Cercopidae	6	0
	Cicadellidae	23	9
	Issidae	2	1
	Membracidae	22	8
Hymenoptera	Apidae	2	1
	Eucoilidae	1	0
	Formicidae	177	148
	Halictidae	2	0
	Megachilidae	1	0
	Sphecidae	0	1
	Vespidae	0	1
Lepidoptera	Hesperiidae	4	0
	Libytheidae	1	0
	Nymphalidae	4	0

Table 6 (cont.). Total number of arthropods collected from each family in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

Order	Family	Burned	Non-burned
Lepidoptera	Pieridae	2	0
Mantodea	Mantidae	0	1
Neuroptera	Chrysopidae	1	0
Orthoptera	Acrididae	25	21
	Decticidae	1	0
	Gryllacrididae	1	0
	Gryllidae	33	21
	Tetrigidae	0	1
	Tettigonidae	62	18
Phasmida	Heteronemiidae	1	0
Thysanoptera	Phlaeothripidae	0	1

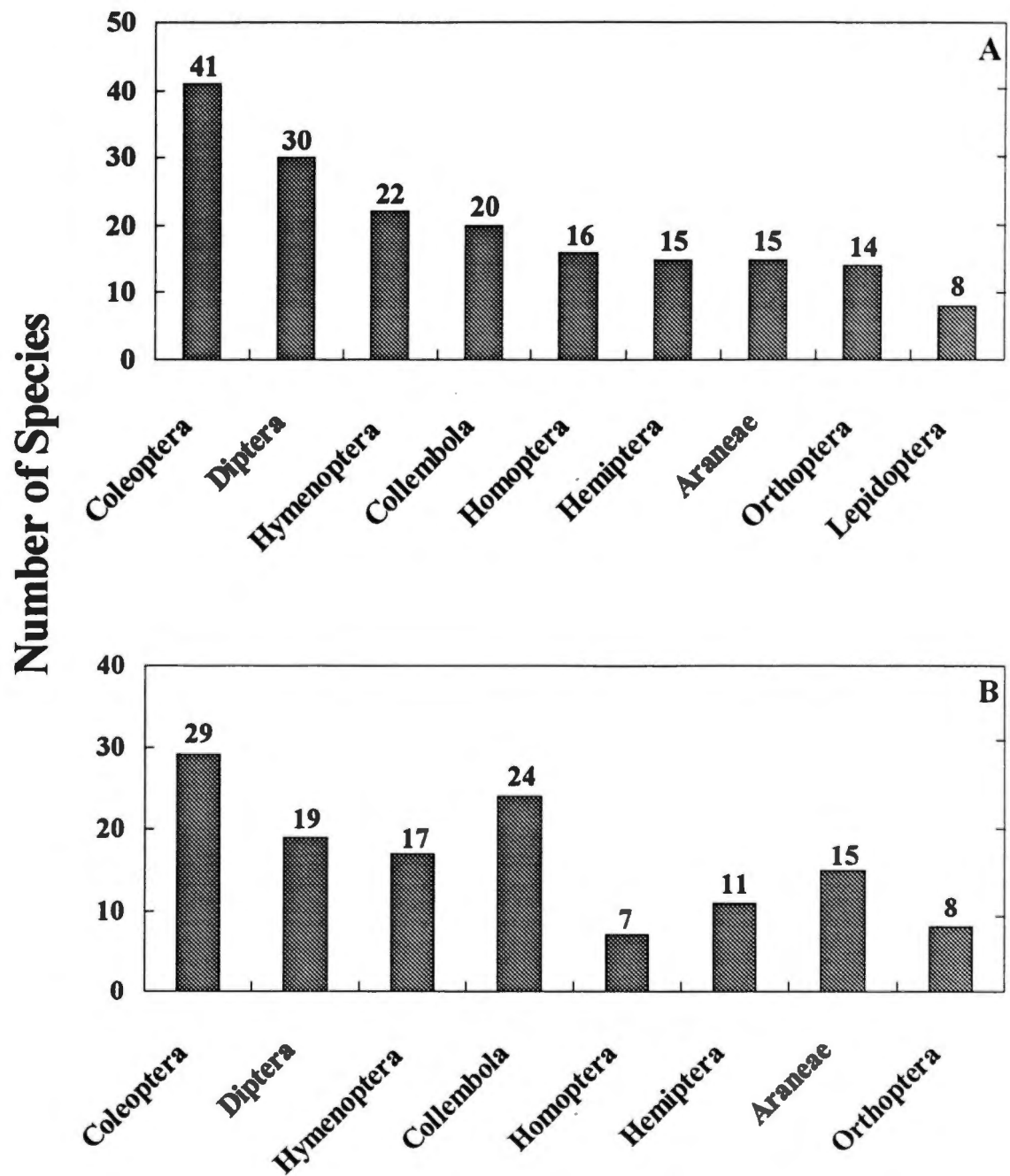


Figure 8. Number of species collected from each order in the burned (A) and non-burned (B) sites in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

only about 19.3% of all species. No species of Lepidoptera were collected at this site in 1997, possibly due to the lack of suitable food resources, such as flowering plants, late in the season when sampling began.

Abundance and Seasonality of Arthropods. In the burned site, numbers of species of Coleoptera, Diptera, and Hymenoptera peaked from 1 to 8 October before declining; however, numbers of species of Coleoptera increased sharply on the last sampling date (5 November) (Fig. 9). In the non-burned site, species of Coleoptera peaked on 15 October (Fig. 10), but did not exhibit the increase in numbers late in the season. Species of Diptera, Hymenoptera, and Orthoptera peaked on 26 September in the non-burned site. These data suggest that species, with the exception of ground-dwelling arthropods, such as springtails and beetles, become more stable later in the year, in the non-burned site because most plants have senesced. Most species of Collembola were recorded on 15 October in both the burned (Fig. 9) and non-burned (Fig. 10) sites.

More individuals also were collected from the burned site than the non-burned site (1,778 and 1,349, respectively). Of the 1,778 specimens collected in the burned site, the beetles comprised more than one-half of all specimens (900) (Fig. 11A). In fact, more than twice as many beetles were found in the burned site than in the non-burned site (412) (Fig. 11B). Nearly all of these individuals, primarily the cantharid *C. pennsylvanicus*, were collected on 26 September from sticky traps (Fig. 12). Likewise in the non-burned site, this species represented the most individuals as well, but reached their highest level one week later on 1 October (Fig. 13).

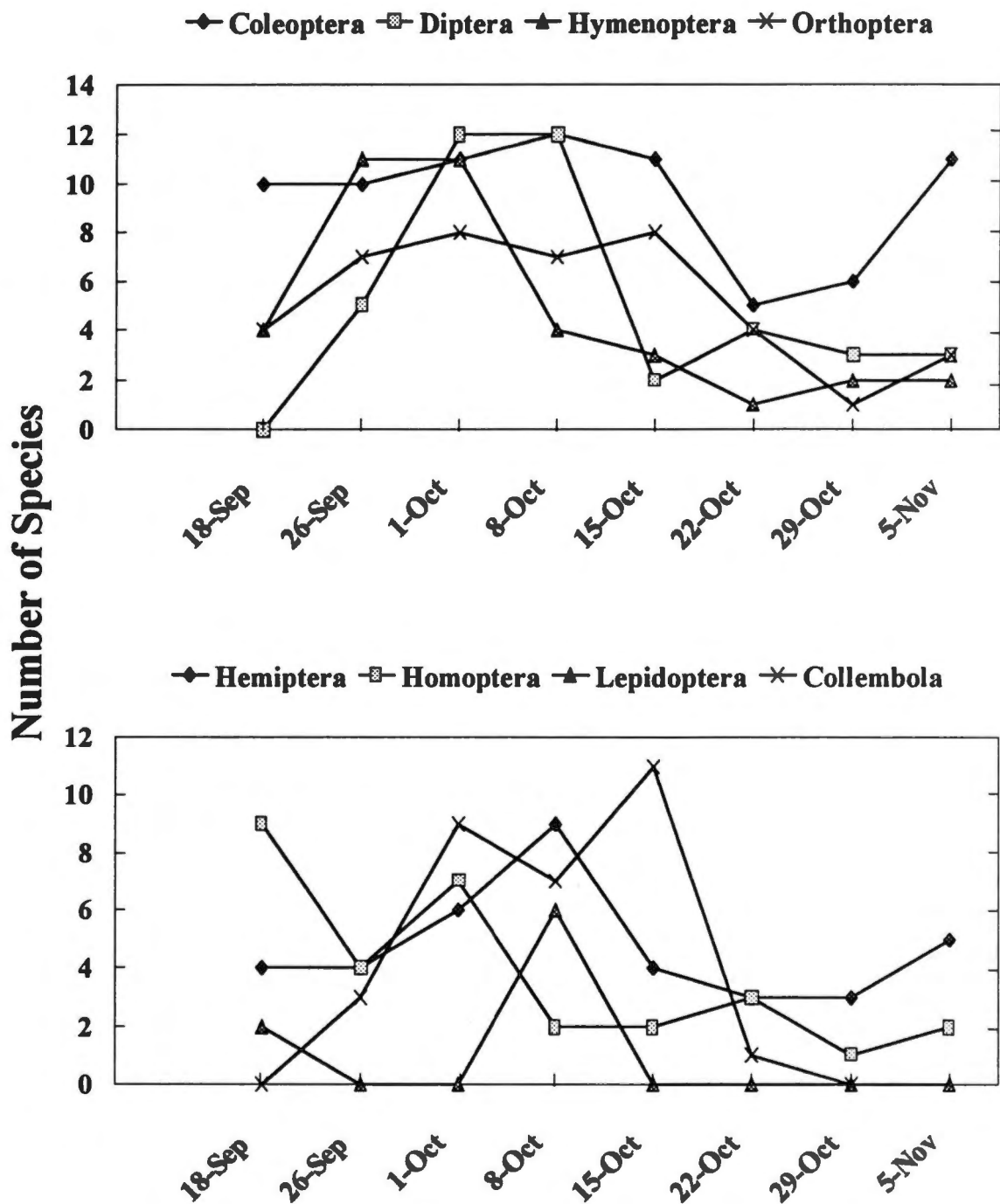


Figure 9. Seasonality of selected orders collected in the burned site at Arnold Air Force Base, Tullahoma, TN, 1997.

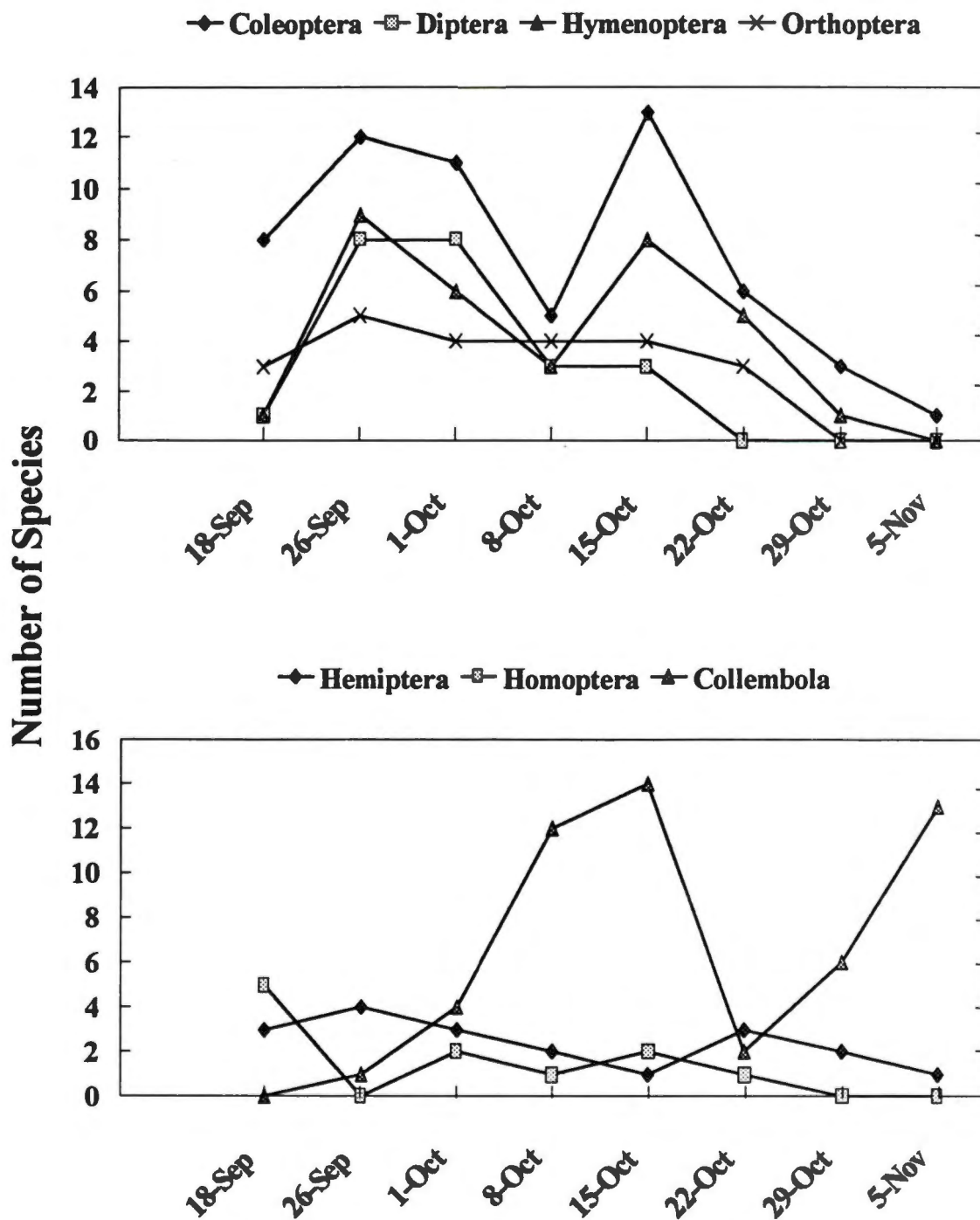


Figure 10. Seasonality of selected orders collected in the non-burned site at Arnold Air Force Base, Tullahoma, TN, 1997.

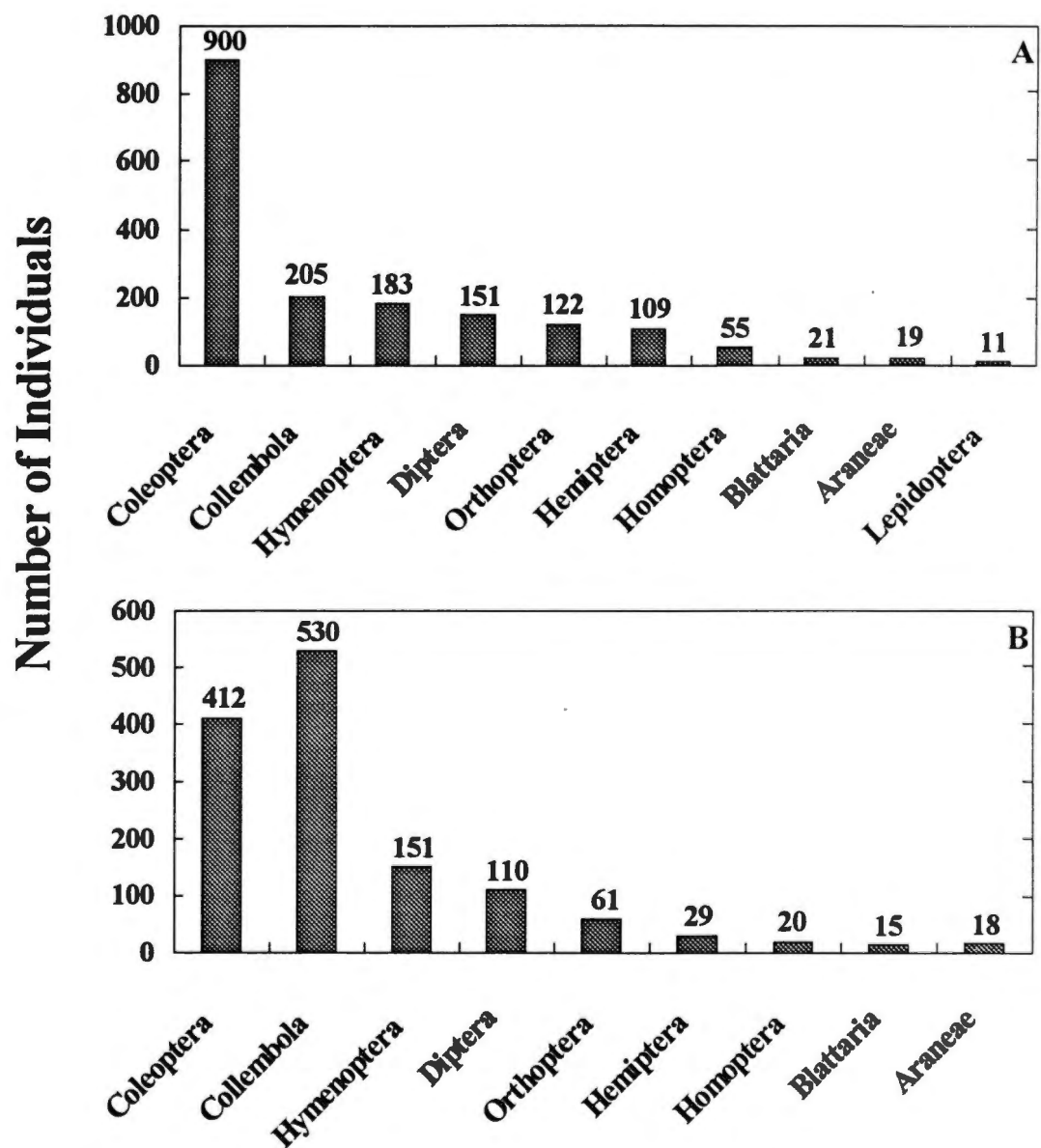


Figure 11. Number of individuals collected in the burned (A) and non-burned (B) sites at Arnold Air Force Base, Tullahoma, TN, 1997.

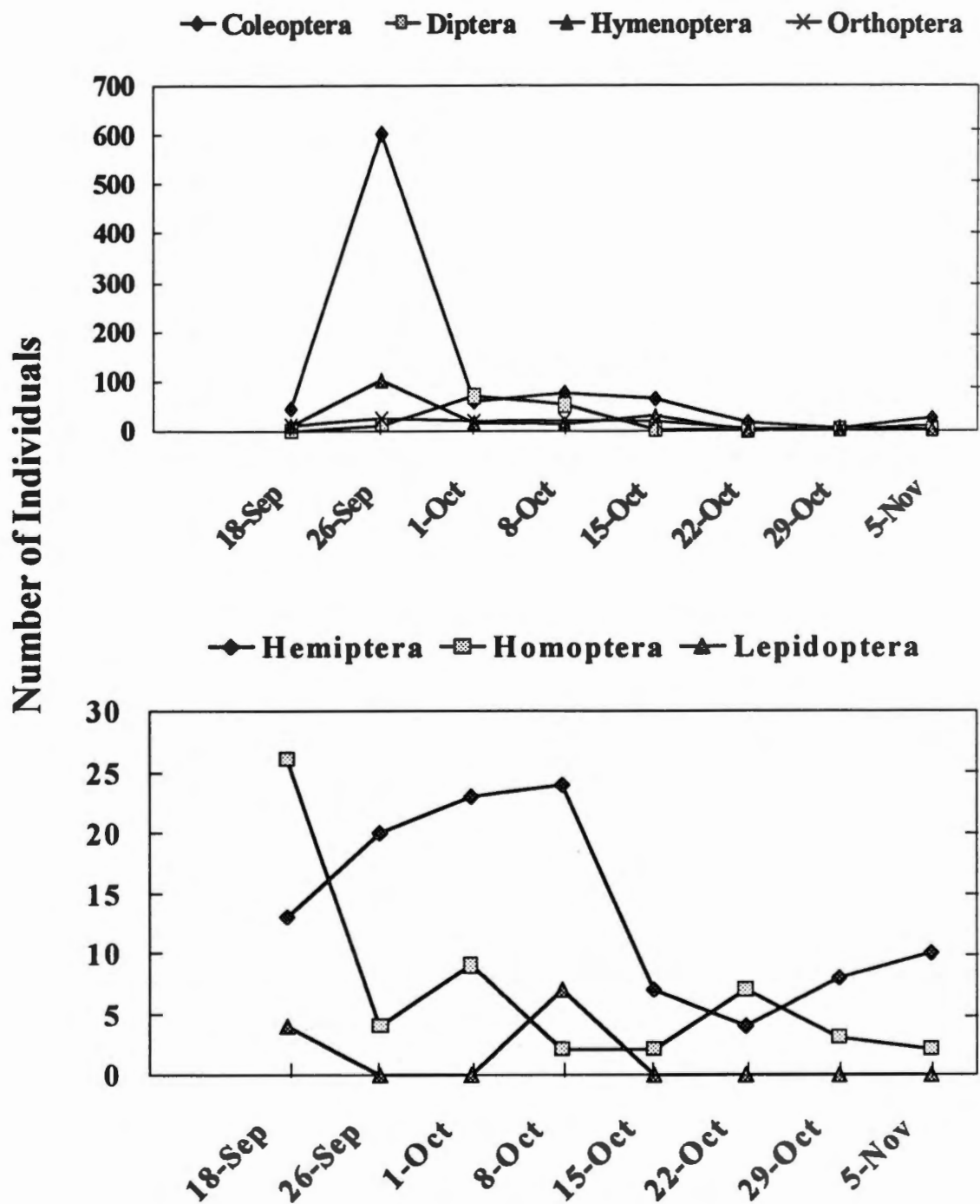


Figure 12. Seasonality of individuals collected in the burned site at Arnold Air Force Base, Tullahoma, TN, 1997.

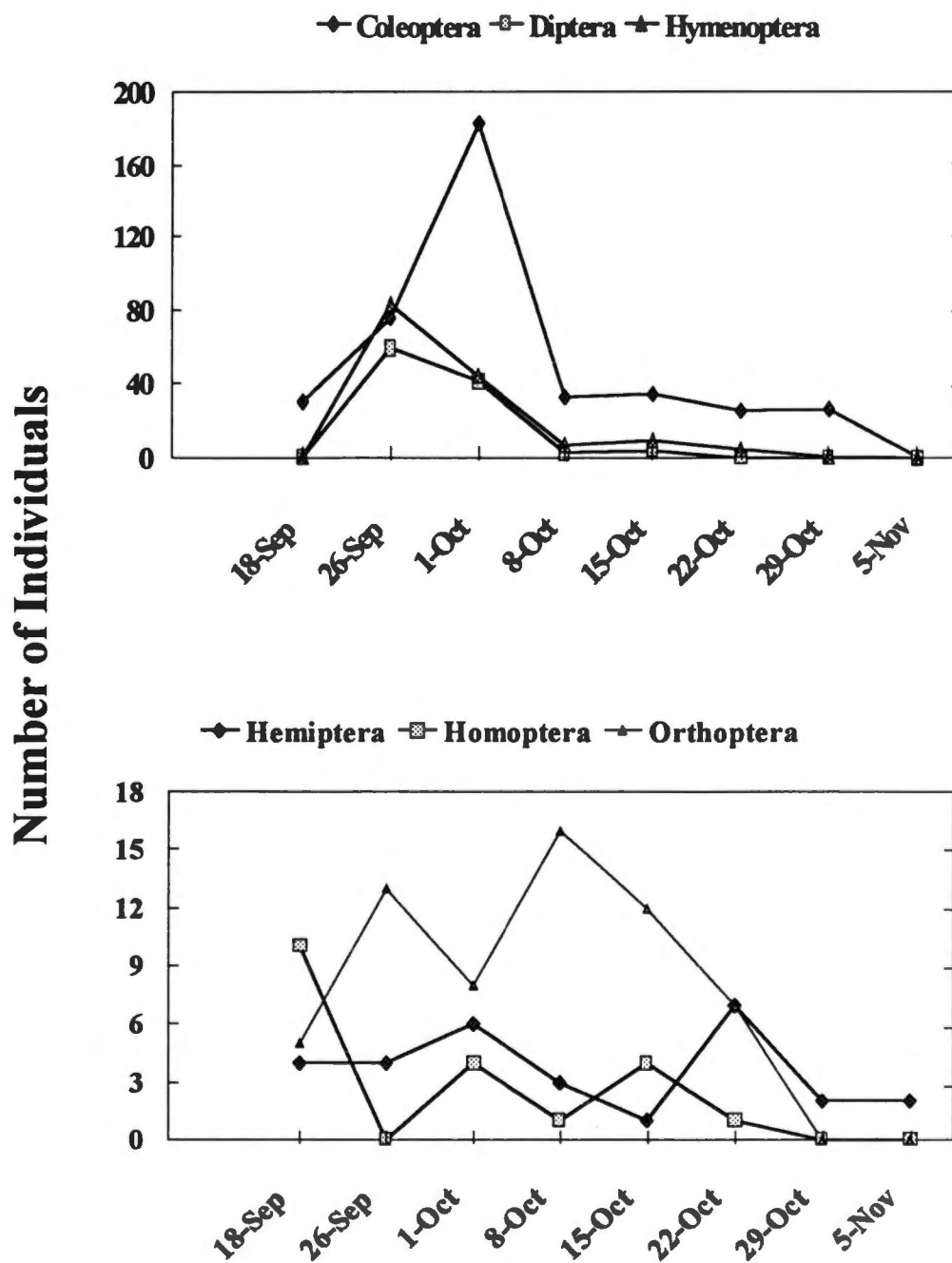


Figure 13. Seasonality of individuals in the non-burned site at Arnold Air Force Base, Tullahoma, TN, 1997.

Effectiveness of Sampling Methods. Pitfall traps and sweep-net sampling yielded the most species. In fact, 35.1% (n = 65) and 30.4% (n = 41) of all species recorded were collected in pitfall traps in the burned (Fig. 14A) and non-burned sites (Fig 14B), respectively, while 27.0% (n = 50) and 31.1% (n = 42) of all species, respectively, were collected in sweep-net samples. The greatest numbers of species recorded from these methods were ground-dwelling arthropods.

About 42.5% of all individuals collected from the burned site were found on sticky traps (Fig. 15A); on the other hand, only 22.5% of those individuals collected from the non-burned site were found on sticky traps (Fig. 15B). The larger populations of goldenrod, a food preference of the soldier beetle (Root and Cappuccino 1992), in the burned site may account for the larger number of beetles, particularly the soldier beetle. Thus, sticky traps were good tools to monitor for incidence of *C. pennsylvanicus*. Leaf-litter samples yielded approximately 27.5% of all individuals in the non-burned site, while yielding only 4.8% of all individuals in the burned site. It is likely that more ground cover was available in the non-burned site, accounting for the large numbers of litter-inhabiting arthropods. About 31.4% and 36.7% of all individuals collected in pitfall traps were found in the burned and non-burned sites, respectively. Most of the individuals recorded were ground-dwelling assemblages (Carabidae) and pollen feeders (Cantharidae).

1998

Species Diversity. More species were collected in the recent burned site than the initial burned and non-burned sites (328, 327, and 318, respectively). In the three sites sampled in 1998, eighteen families showed either a positive or negative response to burning

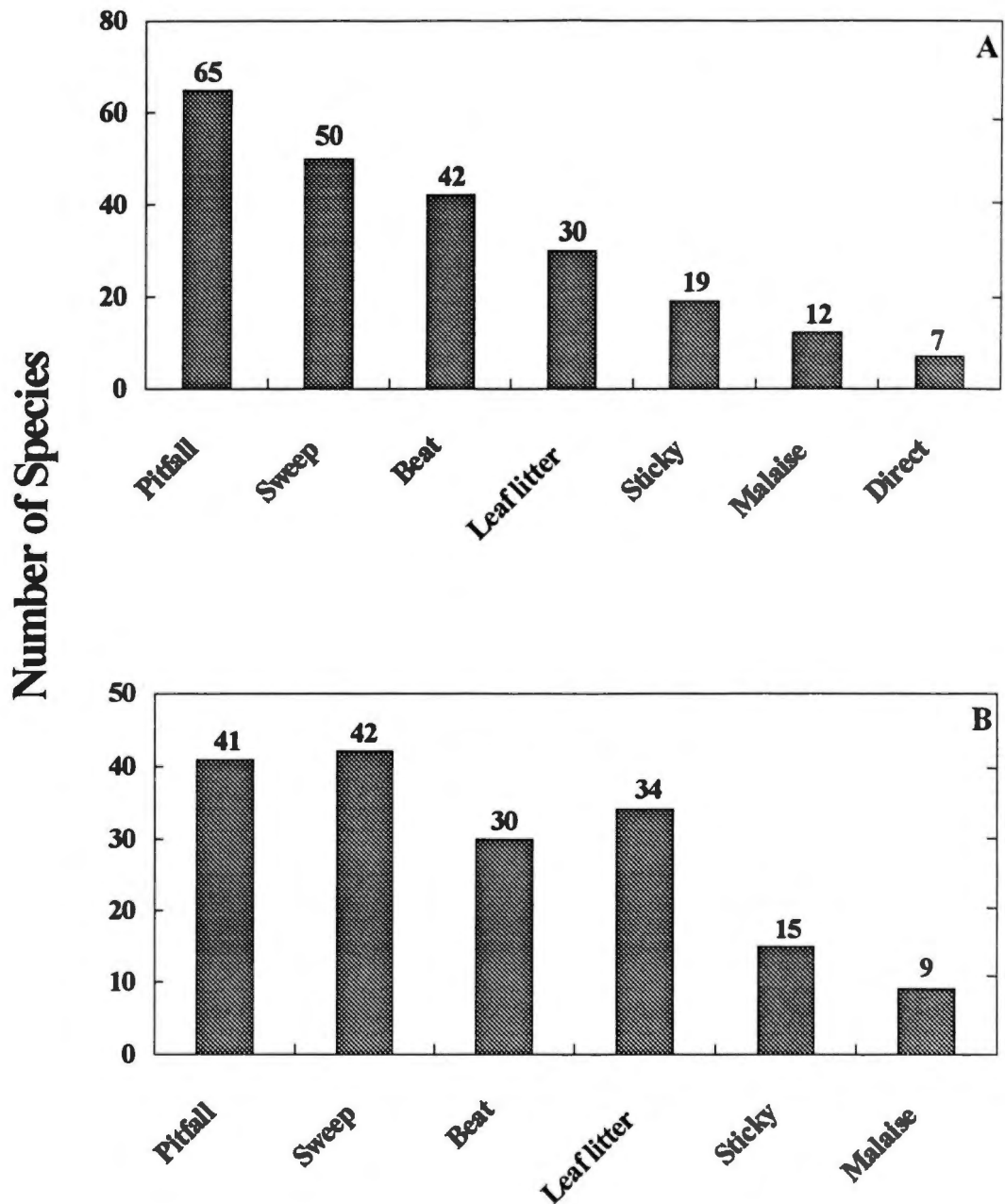


Figure 14. Number of species collected from each sampling method in the burned (A) and non-burned (B) sites in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

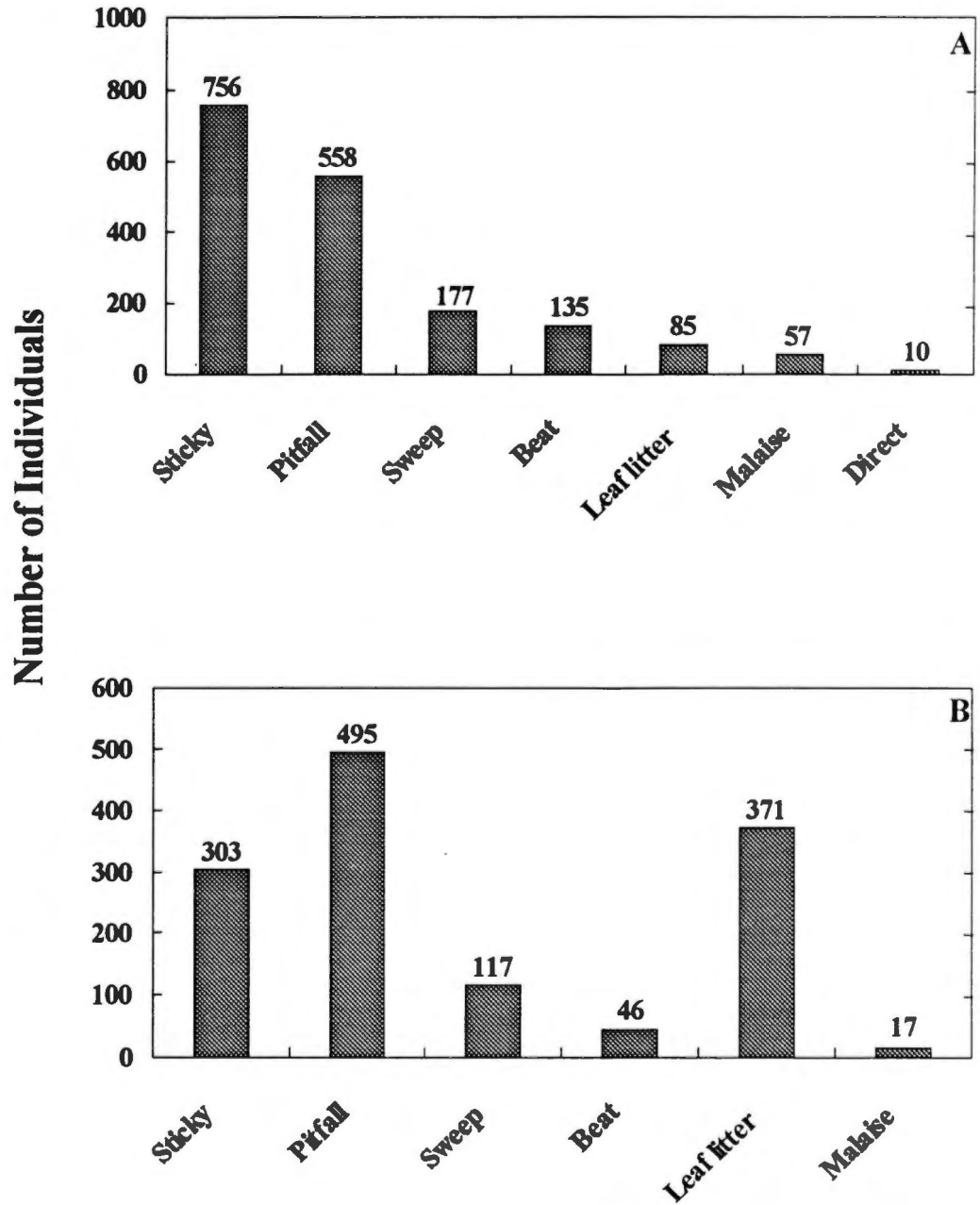


Figure 15. Number of individuals collected from each sampling method in the burned (A) and non-burned (B) sites in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1997.

(Table 7). Variation in the number of insects is apparent. In most cases, the number of insects is greater in the recent burned site than any other site; however, one group (Collembola) was far more abundant in the non-burned site. An in-depth discussion is provided in the following sections.

In the initial burned site, 2,234 specimens, representing 327 species, 101 families, and 14 orders, were identified. Eight orders were represented by 5 or more species (Fig. 16A), and six orders were represented by fewer than 5 species including: Blattaria (3), Mantodea (2), Collembola (1), Mecoptera (1), Neuroptera (1), and Phasmida (1). In the initial burned site, the Coleoptera, Diptera, and Hymenoptera comprised 66.4% of all species.

In the recent burned site, 3,211 specimens, representing 328 species, 101 families, and 15 orders, were identified. Eight orders were represented by 10 species or more (Fig. 16B), and seven orders were represented by fewer than 10 species including: Blattaria (4), Araneae (1), Collembola (1), Isoptera (1), Dermaptera (1), Neuroptera (1), and Phasmida (1). The Coleoptera, Hymenoptera, and Diptera comprised 59.1% of all species collected. The 10 species of Trichoptera were all collected in the light traps.

In the non-burned site, 3,456 specimens, representing 318 species, 105 families, and 14 orders, were identified. Eight orders were represented by 5 or more species (Fig. 16C), and six orders were represented by less than 5 species including: Araneae (2), Neuroptera (2), Odonata (2), Collembola (1), Mantodea (1), and Psocoptera (1). Nearly 64.8% of all species identified in the non-burned site were represented by the Coleoptera,

Table 7. Total number of arthropods collected from each family in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

Order	Family	Initial Burned	Recent Burned	Non-burned
Araneae	Gnaphosidae	0	0	4
	Lycosidae	0	1	2
Blattaria	Blattellidae	8	10	36
Coleoptera	Anthicidae	1	0	0
	Anthribidae	1	0	0
	Bruchidae	7	0	0
	Buprestidae	1	1	2
	Cantharidae	52	107	45
	Carabidae	36	69	28
	Cerambycidae	12	12	4
	Chrysomelidae	103	112	164
	Cicindellidae	2	3	2
	Coccinellidae	8	2	10
	Curculionidae	25	37	39
	Dermestidae	1	0	0
	Dryopidae	0	10	0
	Dytiscidae	1	7	0
	Elateridae	3	4	5
	Eucinetidae	1	0	0
	Halipidae	0	1	0
	Heteroceridae	0	7	0
	Histeridae	40	3	12
	Hydrophilidae	2	64	1
	Languriidae	6	0	6
	Meloidae	28	8	1
	Mordellidae	1	0	2
	Nitidulidae	0	1	0
	Oedomeridae	0	0	1
	Rhipiphoridae	0	4	1
	Scarabaeidae	107	87	160
	Silphidae	2	7	2
	Staphylinidae	2	173	9
Collembola	Tomoceridae	734	325	1747
Dermaptera	Labiidae	0	5	0
Diptera	Agromyzidae	2	0	1
	Anthomyiidae	5	0	4
	Asilidae	22	11	15
	Bibionidae	1	1	21

Table 7 (cont.). Total number of arthropods from each family collected in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

Order	Family	Initial Burned	Recent Burned	Non-burned
Diptera	Bombyliidae	2	1	0
	Calliphoridae	1	0	5
	Ceratopogonidae	0	1	0
	Chironomidae	0	0	22
	Chloropidae	13	35	75
	Dolichopodidae	35	6	24
	Drosophilidae	1	3	10
	Empididae	2	0	14
	Ephydriidae	5	2	3
	Lauxaniidae	0	0	1
	Milichiidae	0	0	1
	Muscidae	2	8	6
	Mycetophilidae	2	1	3
	Mydidae	0	1	0
	Otitidae	3	15	2
	Phoridae	8	8	1
	Pipunculidae	5	0	0
	Platystomatidae	5	0	0
	Sarcophagidae	4	2	2
	Sciaridae	39	645	8
	Sciomyzidae	14	4	20
	Sphaeroceridae	1	0	0
	Stratiomyidae	1	0	3
	Syrphidae	6	5	10
	Tabanidae	21	2	12
	Tachinidae	22	6	14
	Tephritidae	5	1	2
	Tipulidae	0	1	3
Hemiptera	Alydidae	15	3	15
	Coreidae	7	16	6
	Corimelaenidae	15	24	4
	Cydnidae	7	1	0
	Lygaeidae	100	128	43
	Miridae	19	61	92
	Nabidae	0	1	1
	Pentatomidae	29	49	46
	Phymatidae	4	1	2
	Reduviidae	3	3	3

Table 7 (cont.). Total number of arthropods from each family collected in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

Order	Family	Initial Burned	Recent Burned	Non-burned
Hemiptera	Rhopalidae	5	21	7
	Scutelleridae	0	1	0
	Tingidae	0	1	1
Homoptera	Acanaloniidae	0	1	5
	Cercopidae	31	56	31
	Cicadellidae	22	50	32
	Cicadidae	0	0	1
	Dictyopharidae	4	8	4
	Issidae	1	2	1
	Membracidae	19	21	21
Hymenoptera	Andrenidae	0	0	1
	Anthophoridae	5	0	0
	Aphelinidae	1	0	0
	Apidae	3	0	6
	Braconidae	0	6	4
	Ceraphronidae	0	0	1
	Chalcididae	1	0	3
	Chrysididae	1	1	12
	Diapriidae	0	0	3
	Encyrtidae	0	1	0
	Eulophidae	8	0	0
	Eumenidae	2	6	4
	Eupelmidae	0	0	1
	Formicidae	74	438	151
	Halictidae	26	42	45
	Ichneumonidae	3	2	1
	Megachilidae	8	3	2
	Pamphiliidae	0	0	1
	Platygastridae	0	0	1
	Pompilidae	0	0	1
	Pteromalidae	1	0	0
	Scelionidae	0	2	0
	Sphecidae	50	11	11
	Tenthredinidae	0	4	1
	Tiphiidae	0	5	2
	Vespidae	6	1	4
Isoptera	Rhinotermitidae	0	20	0
Lepidoptera	Arctiidae	3	26	5

Table 7 (cont.). Total number of arthropods from each family collected in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

Order	Family	Initial Burned	Recent Burned	Non-burned
Lepidoptera	Geometridae	3	2	1
	Hesperiidae	3	5	1
	Megalopygidae	0	1	2
	Noctuidae	14	5	0
	Notodontidae	0	3	2
	Nymphalidae	24	2	2
	Papilionidae	1	1	0
	Pieridae	1	1	0
	Saturniidae	0	2	1
	Satyridae	1	0	0
	Sphingidae	4	1	4
	Thyrididae	0	0	3
Mantodea	Mantidae	4	0	3
Mecoptera	Panorpidae	1	0	0
Neuroptera	Chrysopidae	3	1	4
Odonata	Gomphidae	1	0	0
	Lestidae	2	0	1
	Libellulidae	3	0	1
Orthoptera	Acrididae	135	213	103
	Gryllacrididae	5	1	0
	Gryllidae	55	53	51
	Gryllotalpidae	0	1	0
	Tetrigidae	2	7	5
	Tettigonidae	87	40	131
Phasmida	Heteronemiidae	1	1	0
Psocoptera	Psocidae	0	0	1
Trichoptera	Hydropsychidae	0	2	0
	Leptoceridae	0	32	0
	Polycentropodidae	0	2	0

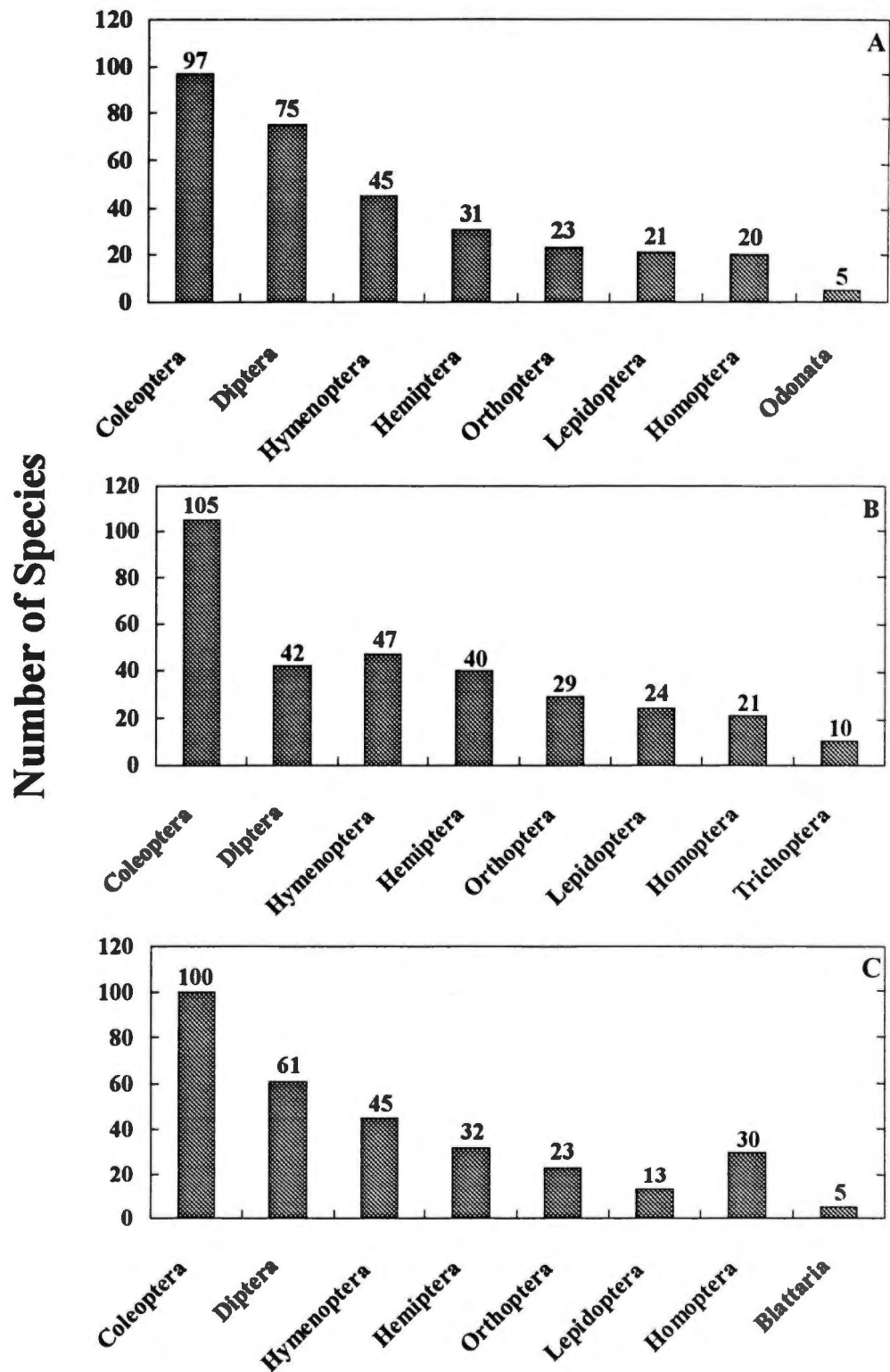


Figure 16. Number of species in initial burned (A), recent burned (B), and non-burned (C) sites at Arnold Air Force Base, Tullahoma, TN, 1998.

Diptera, and Hymenoptera. Perhaps the most obvious difference among these sites is seen in the number of species of Diptera; that is, only 42 species were recorded from the recent burned site as compared to 61 and 75 species in the non-burned and initial burned sites, respectively. These data suggest that the Diptera show a response to immediate burning, but become present in successive years (as seen in the initial burned site).

Abundance and Seasonality of Arthropods. In the initial burned site, the Coleoptera exhibited the greatest species diversity in July, while Diptera reached their greatest diversity in June, before declining rapidly (Fig. 17). Species diversity of Homoptera and Lepidoptera was highest in July before declining as the summer progressed. The number of hemipteran species were highest from May to August, although they resurged slightly from September to October.

In the recent burned site, more than 45 species of Coleoptera were collected in July; before dropping dramatically by August (Fig. 18). This rapid decline is somewhat unexpected because ample food resources, such as goldenrod and tickseed, were available this time of year.

In the non-burned site, species of beetles peaked in June (Fig. 19), one month earlier than in the recent burned site. Furthermore, the greatest numbers of species of Hemiptera and Homoptera occurred during the middle of summer, before tapering off by October. More individuals were collected from the non-burned site than the initial burned and recent burned sites (3,456, 2,234, and 3,211, respectively). The abundance of individuals in all three sites during 1998 is illustrated in Figure 20. The Collembola, which are considered to be an integral component of the soil/litter fauna, and often second

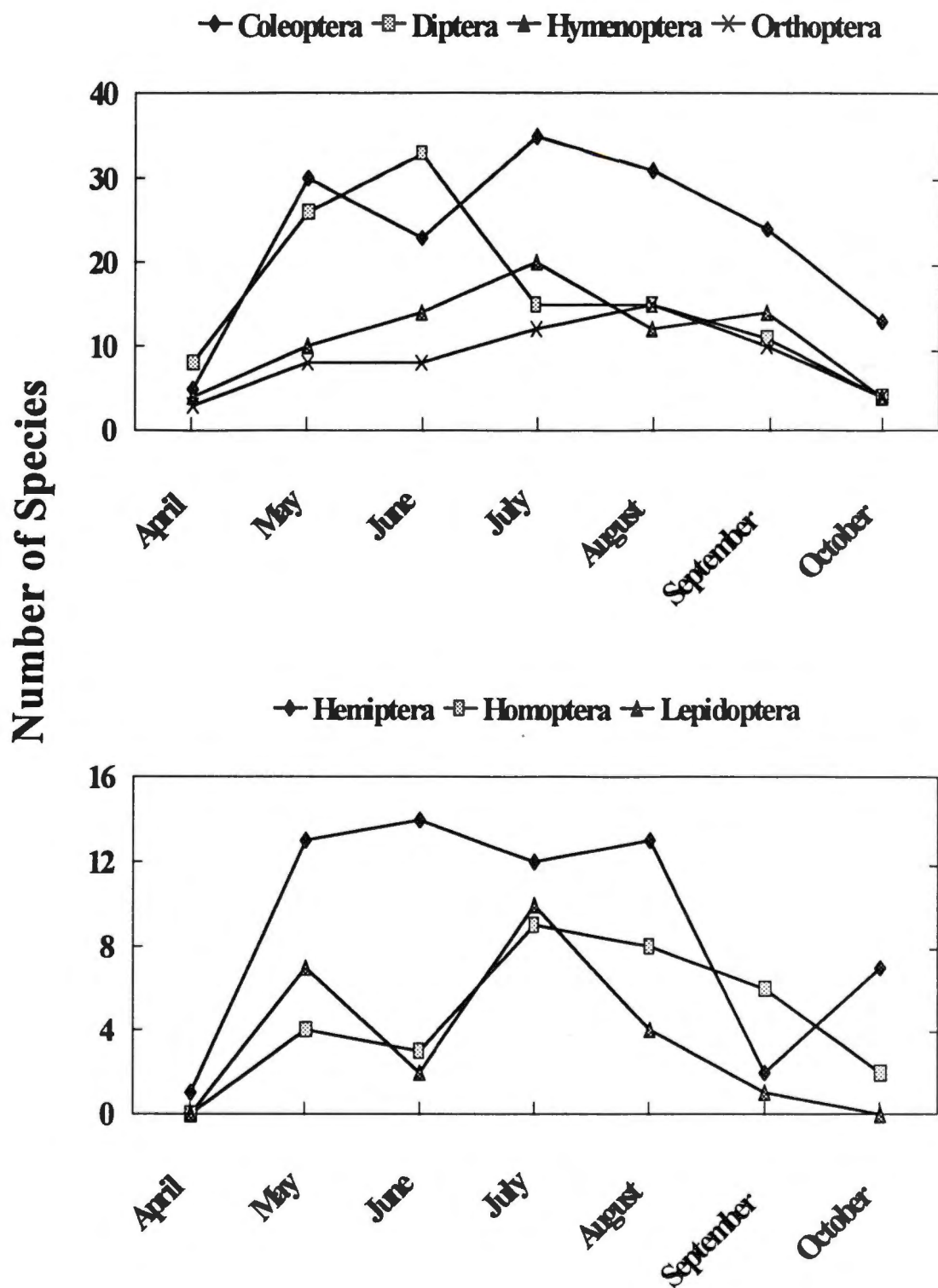


Figure 17. Seasonality of species in the initial burned site at Arnold Air Force Base, Tullahoma, TN, 1998.

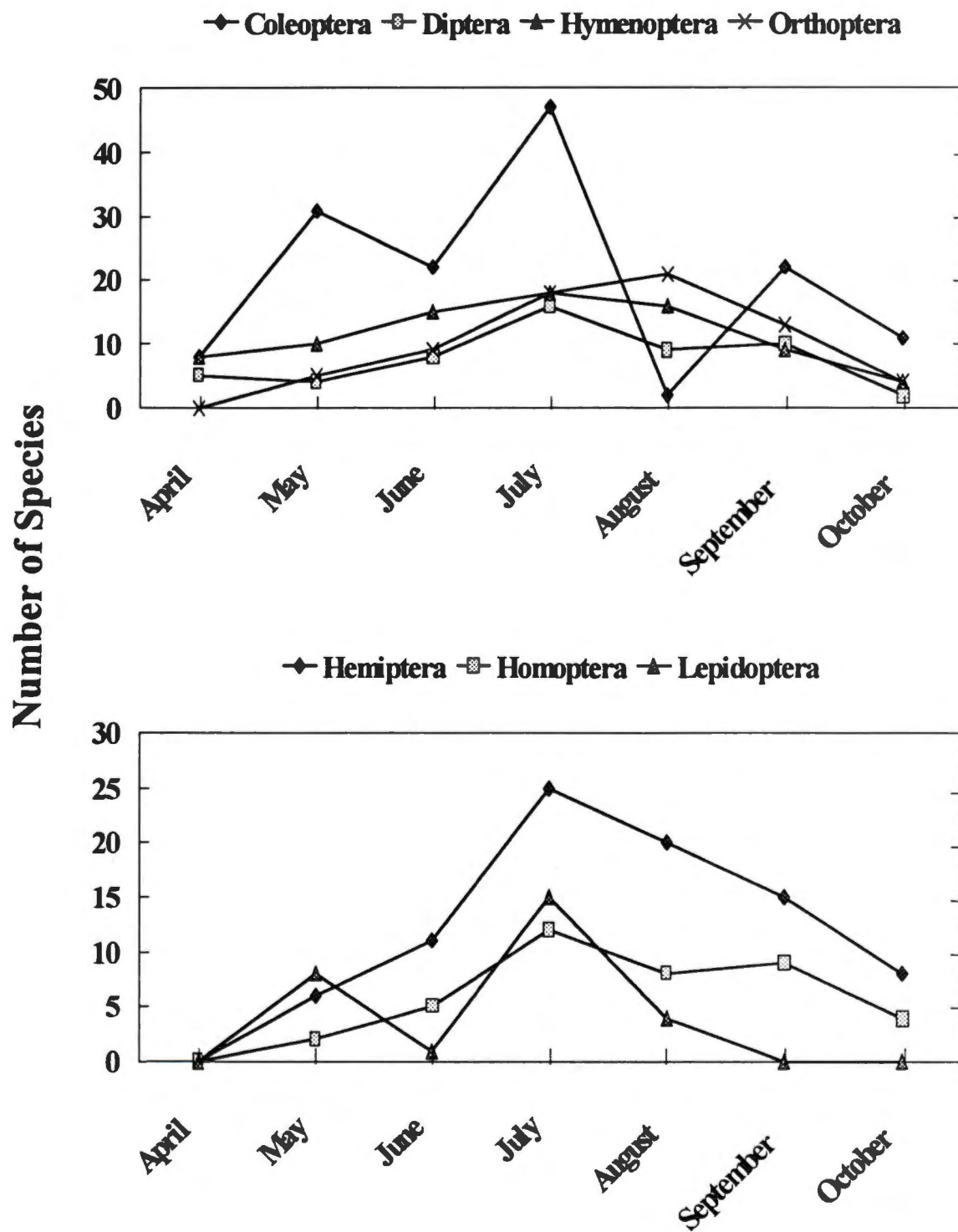


Figure 18. Seasonality of species in the recent burned site at Arnold Air Force Base, Tullahoma, TN, 1998.

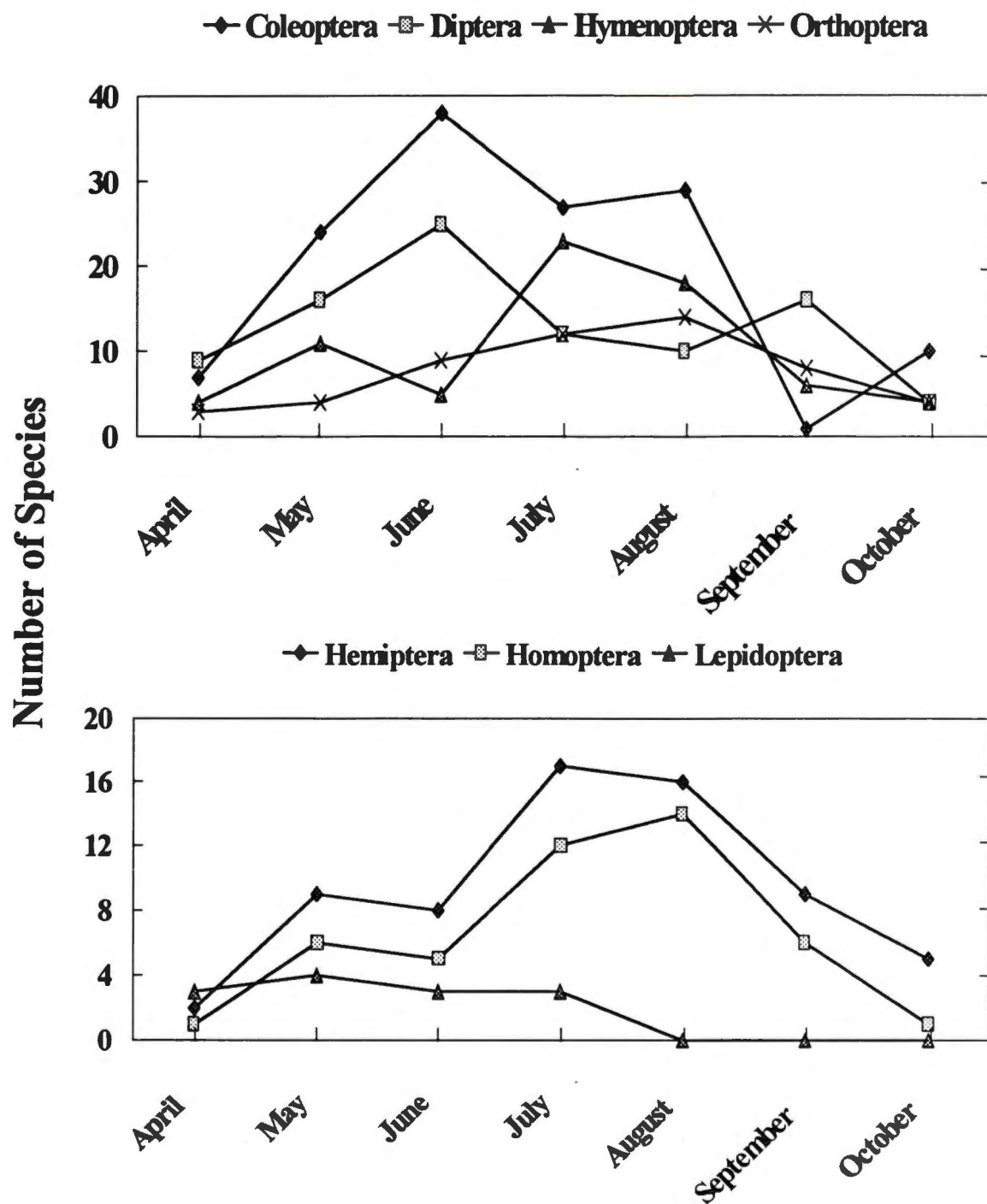


Figure 19. Seasonality of species in the non-burned site at Arnold Air Force, Tullahoma, TN, 1998.

Number of Individuals

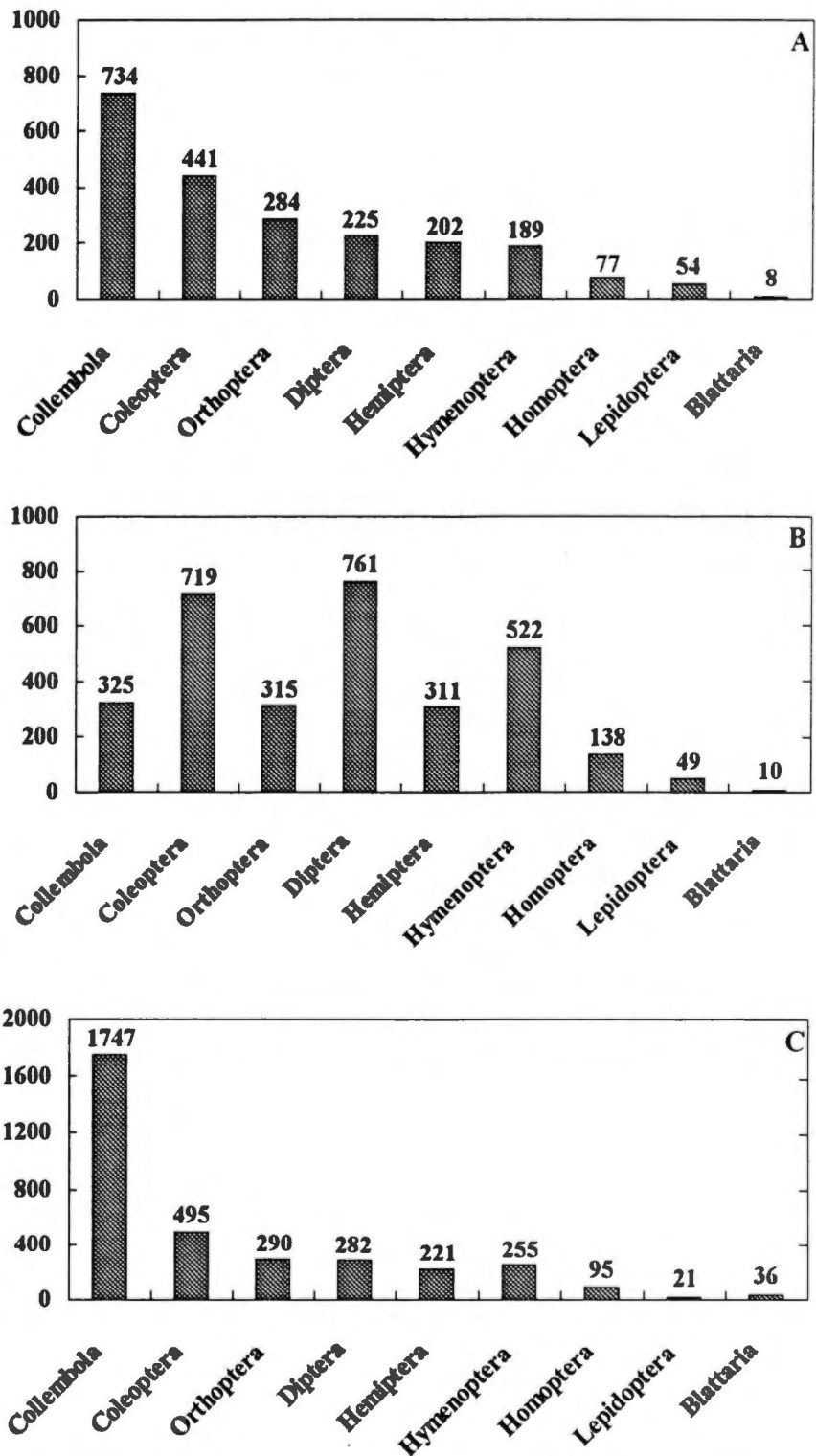


Figure 20. Number of individuals in the initial burned (A), recent burned (B), and non-burned (C) sites at Arnold Air Force Base, Tullahoma, TN, 1998.

in abundance only to mites, seemed to have the most notable response to burning, as populations were greater in the non-burned site than in the burned sites (Table 7). In the non-burned site, 1,747 specimens of collembolans, representing a single species, *T. flavescens*, were collected in both pitfall traps and malaise traps. This abundance was five times greater than that of the recent burned site, and twice as much as the initial burned site. These findings imply that burning does affect litter-inhabiting insects, perhaps by destroying the habitat in which they live. Pomeroy and Rwakaikara (1975) reported that collembolans decreased on areas subjected to two burns per year and theorized that drying of the soil was the cause. Perhaps the decline of collembolans in the burned sites was a result of low moisture. Removal of litter, a darkened surface, and increased insolation can cause an increase in soil temperature, a greater evaporation rate, and reduction in soil moisture in burned sites (Old 1969).

Although the recent burned site had the fewest number of species of Diptera, it had more individuals (761) than any other order. Nearly 75% of these individuals were the dark-winged fungus gnats, *Corynoptera* spp. The Diptera is represented by a large number of families in the grassland fauna. One family, Sciaridae, had larger numbers in the burned sites, particularly the recent burned site. The Sciaridae are fairly common insects and occur in various habitats. Three other dipteran families, Bibionidae, Chironomidae, and the Chloropidae, were more abundant in the non-burned site. The adult bibionids, or lovebugs, are most common in spring and early summer. Their larvae live in decaying organic matter and among plant roots. Increased leaf litter may explain their higher numbers, as well as the chironomids, in the non-burned site. The Chironomidae is a large family, whose larvae

are aquatic, and occur in various habitats, such as decaying matter, soil, under bark, and similar habitats that are wet or rich in organic matter. Chloropidae, or grass flies, are common in meadows and grasses. The larvae feed in grass stems, and some are serious pests of cereals. Some grass flies are considered scavengers, and some even predators, such as the *Hippelates* genus, which breed in decaying vegetation and excrement.

The Coleoptera were more numerous in the recent burned site as well when compared to the initial burned and non-burned sites. Five families within the Coleoptera exhibited a response to burning (Table 7). The families Carabidae and Staphylinidae, generally considered predaceous, and the Cantharidae with herbivorous adults, were biologically more abundant in the burned sites, particularly the recent burned site. Tester and Marshall (1961) suggested that greater populations of Coleoptera are associated with sparse litter but drew no conclusions. The adults of Cantharidae often feed on pollen. The vegetative response of greater flower production in the burned sites may explain the higher numbers of Cantharidae in these sites. Scarabaeidae and Chrysomelidae were more numerous in the non-burned site. No plausible explanation can be given for this account, because Rice (1932) and Nagel (1973) have recorded marked increases of these beetles, especially the chrysomelids, or leaf beetles, in burned areas. They reported these beetles were attracted to disturbed areas, especially those areas subjected to fire. The weevils (Curculionidae) were the only family that showed no differentiation among sites.

Chauliognathus pennsylvanicus and *Diabrotica undecimpunctata howardi*

Barber, the spotted cucumber beetle, were the most abundant species in the recent burned

site. Their abundance is probably the result of more attractive plant species for these insects available in the recent burned site.

In the recent burned site, Hymenoptera was represented by 522 individuals (Fig. 20). The harvester ant, *Pheidole dentata* Mayr, was the most prominent species found in the recent burned site. In fact, Rice (1932) reported ant populations to be more than one-third higher following burning of an Illinois prairie. The ants showed a positive response to fire, whose abundance in the recent burned site far exceeded expectations, especially since this group is predominantly cursorial.

In the Hemiptera, only two families, Lygaeidae and Miridae, seemed to vary among sites. The lygaeids, or seed bugs, were far more abundant in the burned sites. Many of these are common bugs which feed on seeds. The Blissinae, which includes the chinch bug [*Blissus leucopterus* (Say)], feed on the sap of host plants, and the big-eyed bugs (Geocorinae) feed on other insects. The chinch bug is the most injurious bug in this family, attacking wheat, corn, and other cereals, but it also can become a serious pest of turf grasses. Their abundance in the burned sites is hard to accept, since most lygaeids overwinter as adults in grass clumps, litter, and other protected places. Perhaps they were deep enough in the soil, or that the soil was impervious to the fire. Nevertheless, only 43 lygaeids were collected in the non-burned site, as opposed to 128 and 100 in the recent burned and initial burned sites, respectively. The Miridae is the largest family in the order and occur on vegetation in almost all habitats. The mirids, or plant bugs, were more numerous in the non-burned site. Little explanation can be given to these findings since most species are plant feeders, and increased plant production was more apparent in the

burned sites. The most abundant species collected was the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) (Table 3), which is a common bug and often causes serious damage to legumes, vegetables, and flowers. This species occurs throughout the eastern and central states.

The Cercopidae, or spittlebugs, and the Cicadellidae, the planthoppers, were the only two families of Homoptera that showed a response to burning. Larger numbers of these families were collected in the burned sites, especially the recent burned site, than the non-burned site. These families feed on plant juices, and it is likely that the new growth in the burned sites provided better feeding habitat and greater reproduction. Cancelado and Yonke (1970) reported that planthoppers were more numerous on a burned prairie in Missouri and concluded that spring burning had an effect upon populations of several Homoptera and Hemiptera.

Two families of Lepidoptera, Arctiidae and Nymphalidae, responded to burning, as their numbers were greater in the recent burned and initial burned sites, respectively. Adults of the Arctiidae, or tiger moths, are day-fliers and can be nocturnal. The Nymphalidae, or brush-footed butterflies, include many common species. Reasons for their responses are obscure.

In the Orthoptera, two families showed a response to burning. The Acrididae (short-horned grasshoppers) were more numerous in the burned sites, particularly the recent burned site, while the Tettigonidae (long-horned grasshoppers) differed from expectations, being more abundant in the non-burned site. Tester and Marshall (1961) indicated that these grasshoppers were more abundant where there was a moderate cover

of litter. Above or below this optimum the habitat is less desirable. The amount of litter in the non-burned site could have been nearer the optimum, accounting for the higher populations in this site. However, these assumptions may be invalid since most species of tettigonids feed on plants and other soft-bodied insects. Several studies have shown grasshopper populations to increase after fire (Nagel 1973, Rice 1932, and Porter and Redak 1996). Gillon (1971) has stated that grasshopper species differ in response to burning, with some being unaffected, while others greatly decreased.

Insect seasonality in the initial burned, recent burned, and non-burned sites is illustrated in Figures 21, 22, and 23, respectively. The Collembola were more numerous in July in the non-burned and initial burned sites than in the recent burned site. The abundance of Collembola indicates that their food preferences, such as algae and fungal spores, were more readily available in the thicker leaf-litter present in the non-burned and the initial burned sites at this time of the year. Furthermore, the greatest number of dipterans, primarily the dark-winged fungus gnats, were found during August in the recent burned site, as a result of using sticky traps.

Effectiveness of Sampling Methods. Sweep-net sampling, malaise traps, and pitfall traps were the most effective sampling method as they yielded the most species. For instance, sweep-net sampling recorded 41.9%, 39.3%, and 49.4% of all species collected in the initial burned, recent burned, and non-burned sites, respectively (Fig. 24). Pitfall traps also were effective sampling methods, as they collected 22.6%, 28.7%, and 20.4% of all species in these sites, respectively. Although malaise traps were effective sampling methods in the initial burned and non-burned sites (19.9% and 23.3% of all species,

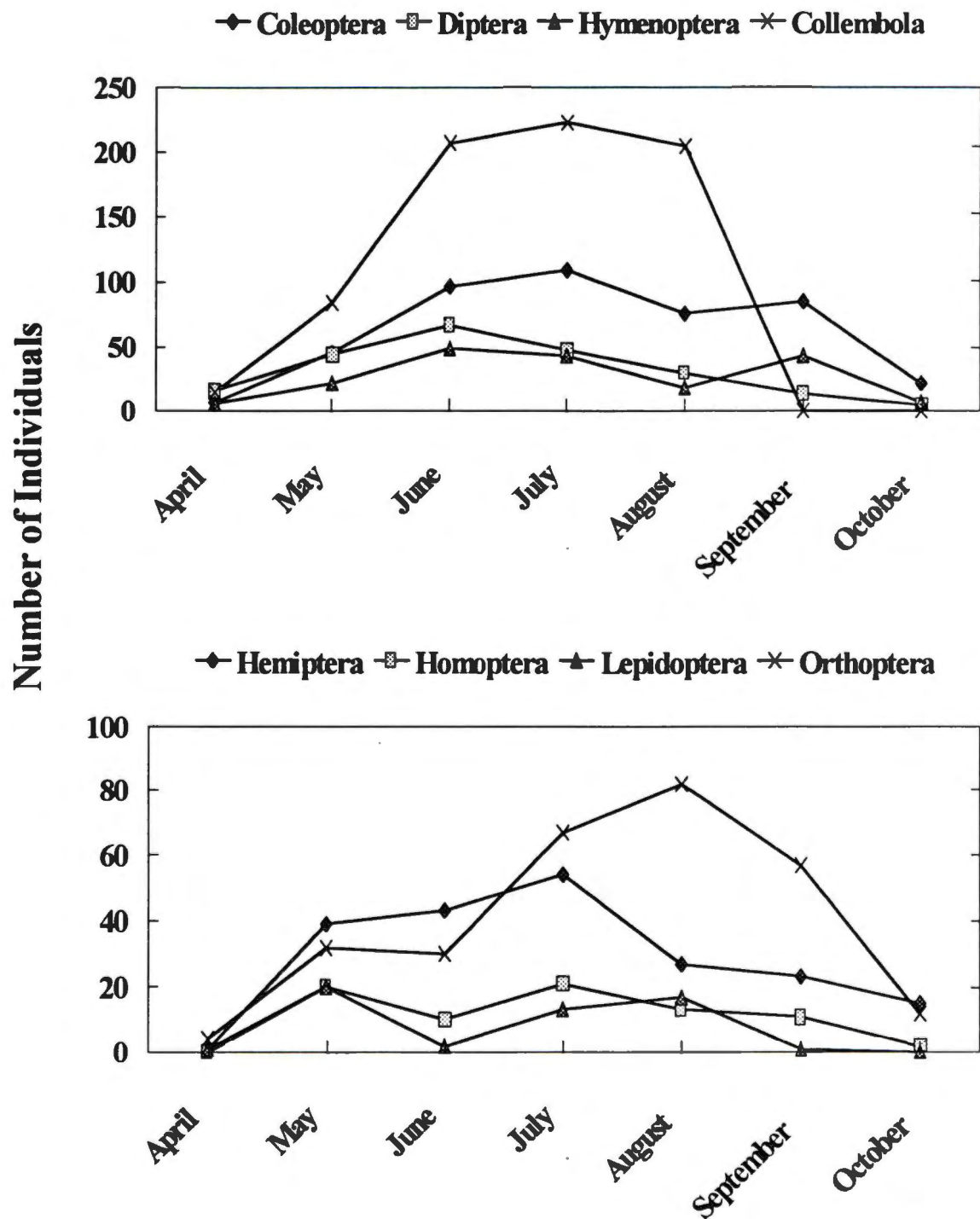


Figure 21. Seasonality of individuals in the initial burned site at Arnold Air Force Base, Tullahoma, TN, 1998.

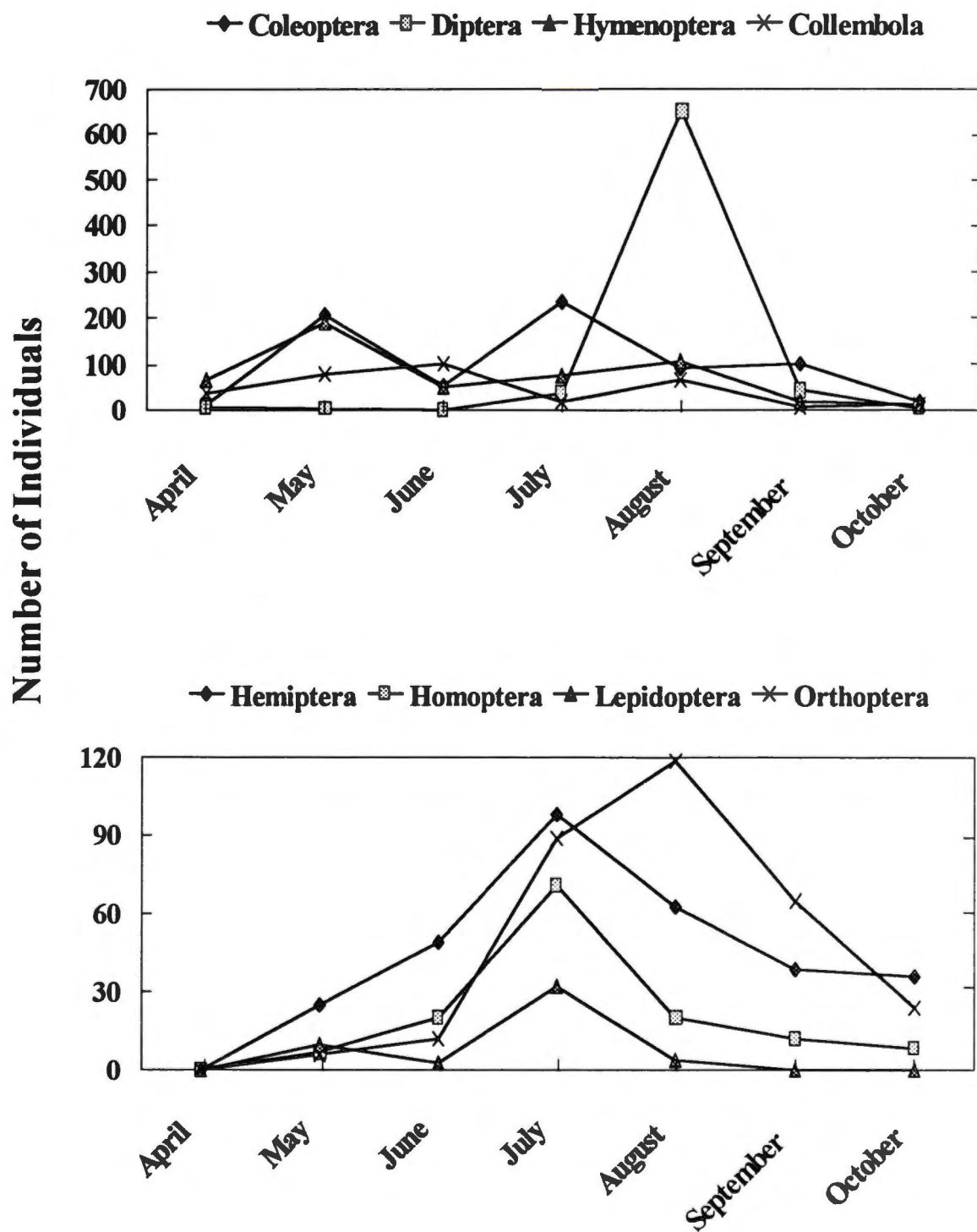


Figure 22. Seasonality of individuals in the recent burned site at Arnold Air Force Base, Tullahoma, TN, 1998.

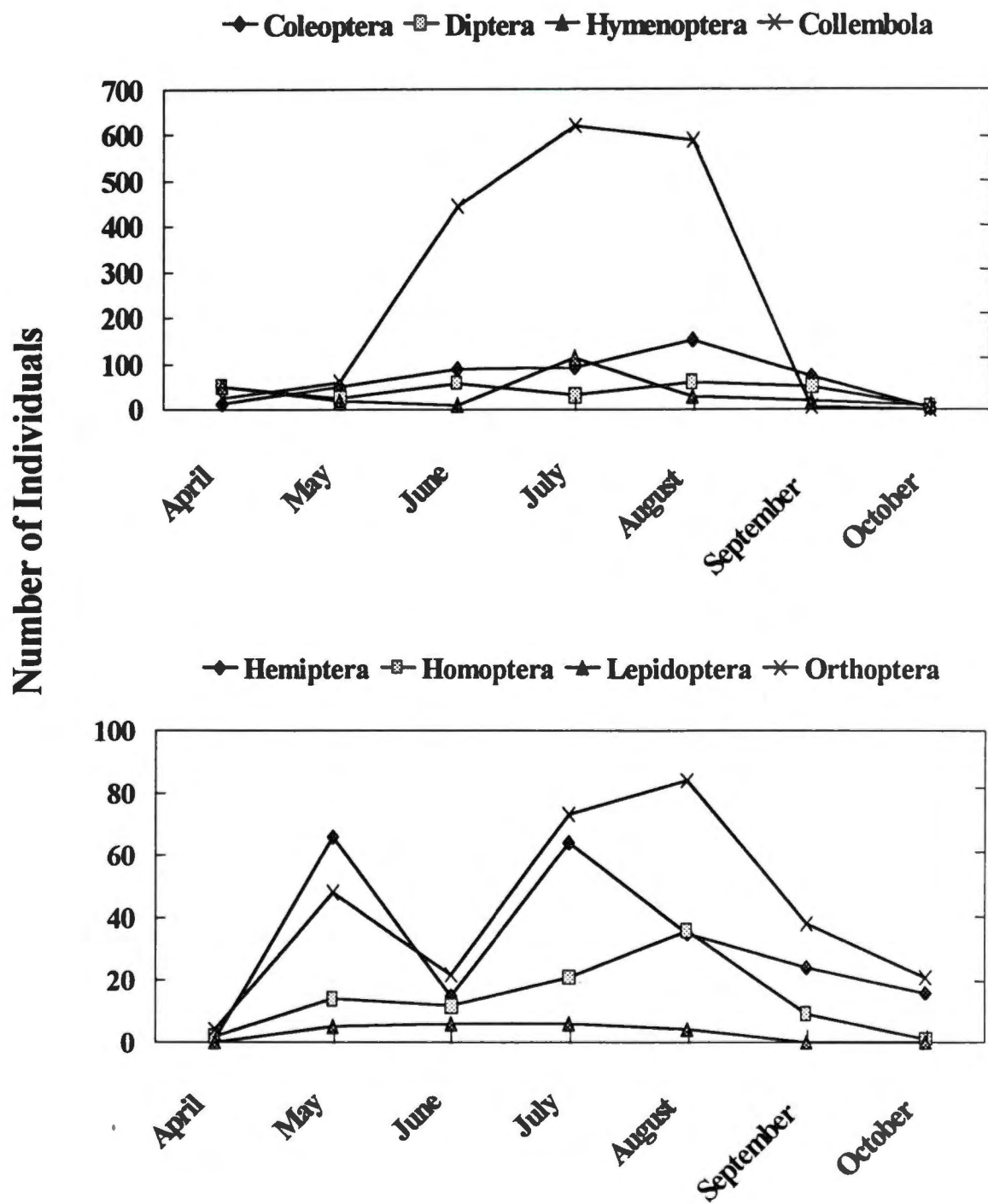


Figure 23. Seasonality of individuals in the non-burned site at Arnold Air Force Base, Tullahoma, TN, 1998.

Number of Species

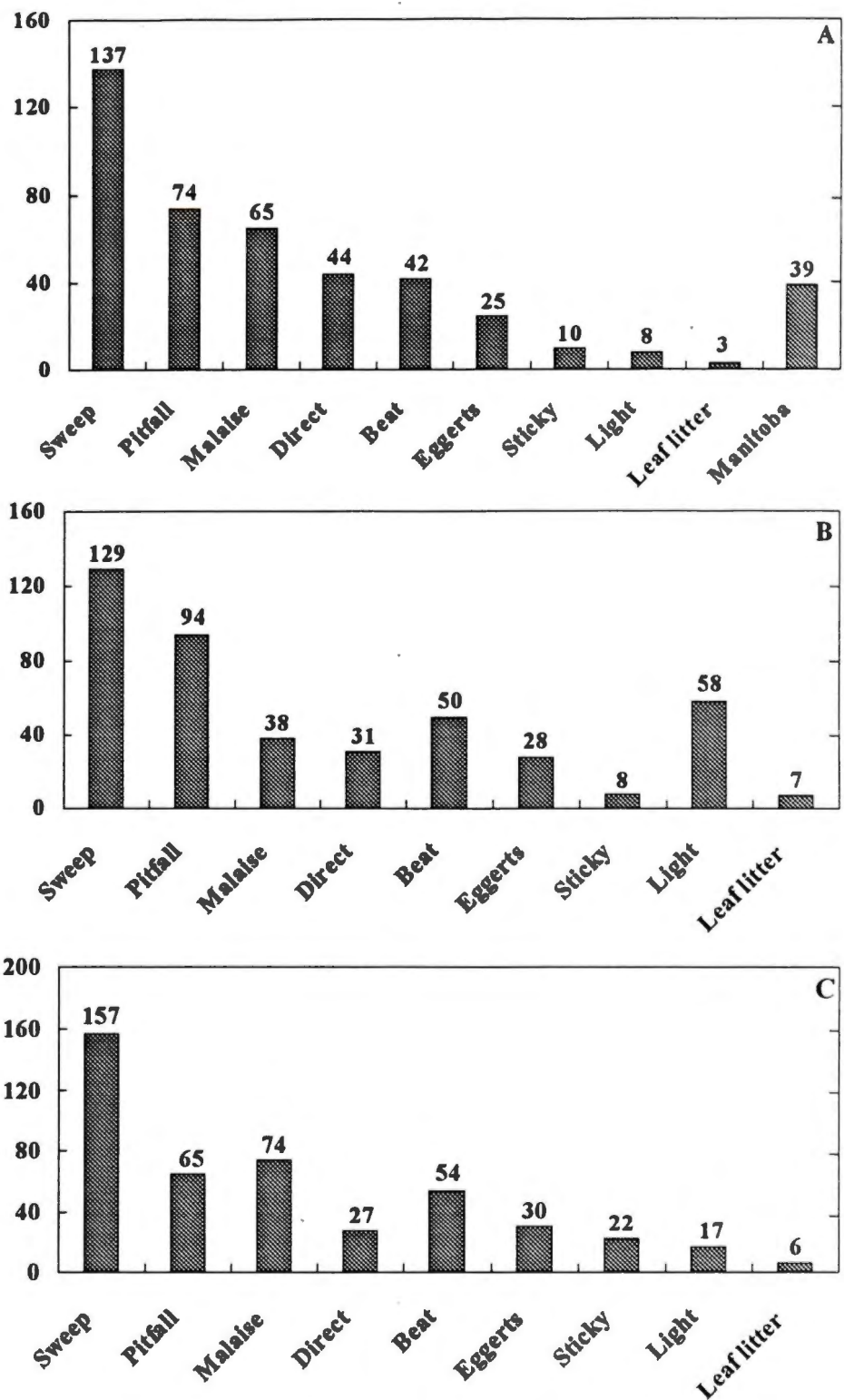


Figure 24. Number of species collected from each sampling method in the initial burned (A), recent burned (B), and non-burned (C) sites at Arnold Air Force Base, Tullahoma, TN, 1998.

respectively), they collected only 11.6% of the species in the recent burned site. About 76.0% and 80.2% of all individuals were collected using pitfall traps and sweep-net sampling from the initial burned (Fig. 25A) and the non-burned sites (Fig. 25C), respectively. Only 50.4% of all individuals from the recent burned site (Fig. 25B) were collected by pitfall traps and sweep-net sampling. On the other hand, light traps yielded approximately 14.4% of all individuals in the recent burned site, while yielding less than 1% of all individuals in both the initial burned and non-burned sites. Perhaps the location and placement of the light trap (in denser vegetation and on the ground) provided higher yields in the recent burned site.

Species Evenness and Richness

Species diversity implies both the number of species and the number of individuals in a community. Species diversity can be described numerically by using various diversity indices. For example, the Shannon-Wiener index, derived from informational theory, describes the degree of uncertainty of predicting the species of a given individual picked at random from the community. As the number of species increases, and the individuals are more equally distributed among the species present, the more the uncertainty increases.

Diversity indices are given in Table 8. The lowest values were obtained in the non-burned site in 1998 and the initial burned site in 1997. When all sites were combined, an average evenness value of 0.655 was obtained, indicating a uniform distribution of species within the barrens. The highest values for species evenness were at the non-burned site in 1997 (0.717) and the recent burned site in 1998 (0.705). Species evenness was lowest in the non-burned site in 1998. As expected, species richness was greater in 1998, due to the

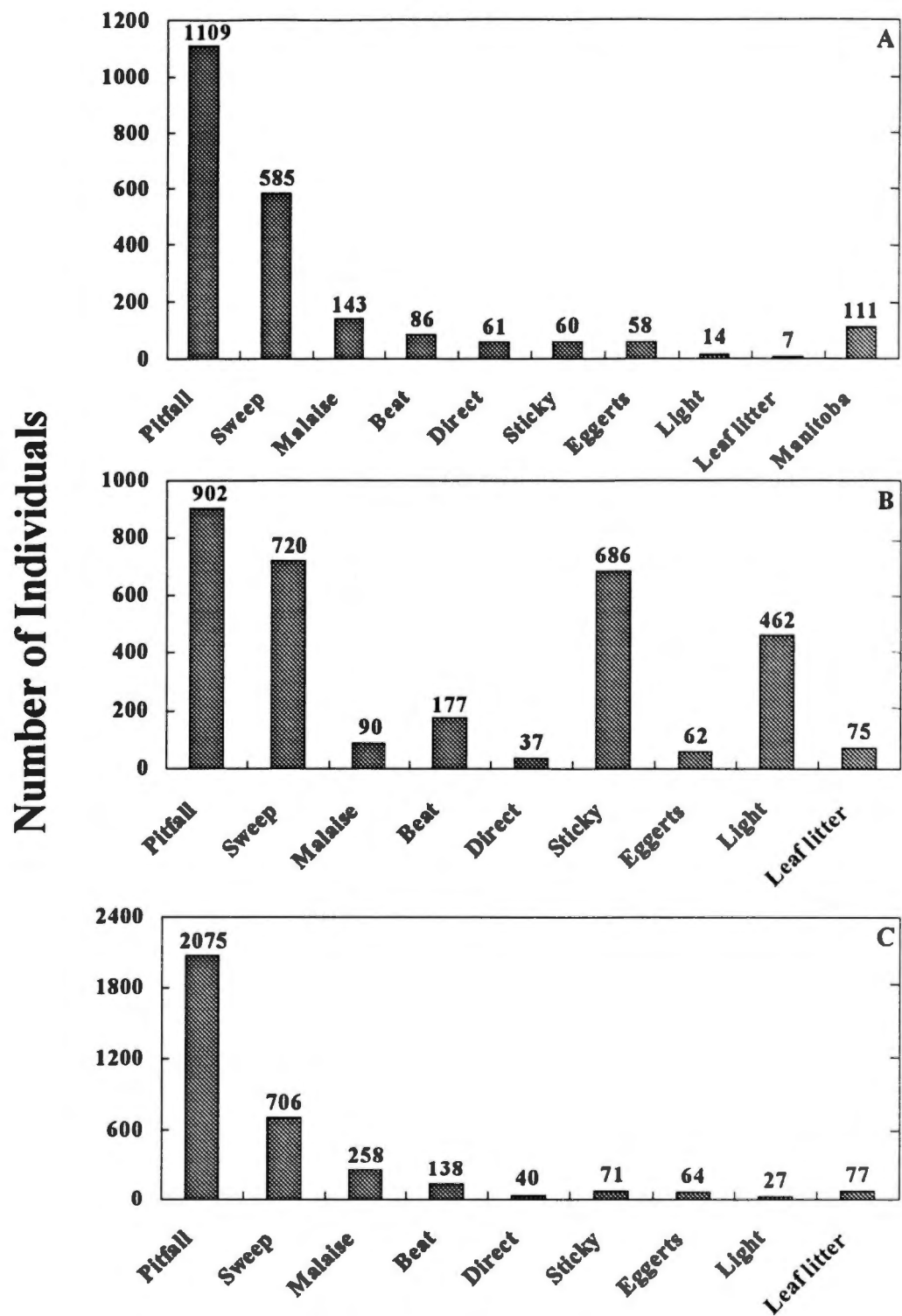


Figure 25. Number of individuals collected from each sampling method in the initial burned (A), recent burned (B), and non-burned (C) sites at Arnold Air Force Base, Tullahoma, TN, 1998.

Table 8. Diversity indices, species evenness, and richness for all arthropod species collected (n = 709) in 1997 and 1998 in each sampling site, Arnold Air Force Base, Tullahoma, TN.

Site	Shannon-Wiener		Species Evenness	Species Richness	Percent Total Species
	H'	H max			
Initial Burn 1997	3.277	5.218	0.628	185	26.10
Non-burn 1997	3.515	4.902	0.717	135	19.04
Initial Burn 1998	3.978	5.791	0.687	327	46.12
Recent Burn 1998	4.082	5.790	0.705	328	46.26
Non-burn 1998	3.101	5.764	0.538	318	44.85

^a Shannon-Wiener formula:

$$H' = -\sum_{i=1}^s (p_i)(\log p_i)$$

Where H' = diversity index

s = species number

p_i = proportion of the ith species in the total sample.

^b Species evenness = H' / H max, therefore, maximum = 1.

much shorter sampling period in 1997. Almost the same number of species (richness) were found in each site in 1998; however, large differences in species richness was found between the initial burned and non-burned sites in 1997.

iv. Summary

Species richness was greatest in the burned site (185) in 1997. It would have been advantageous to have had an entire sampling season in 1997 which would have allowed a better comparison of species richness between the two sites. Species richness values among the sites sampled in 1998, however, were fairly equal. The recent burned site contained the most species with 328, when compared to the initial burned and non-burned sites, 327 and 318 species, respectively.

In 1997, the number of species collected from each order in the burned site and non-burned site were nearly equal. This similarity may be due, in part, to the lateness of the year when sampling began. Perhaps only two months of sampling did not allow for the collection of great arthropod diversity. However, seasonality data show that species of Collembola and Coleoptera were abundant late in the year (15 October) in both sites. Furthermore, coleopterans, especially *C. pennsylvanicus*, were more numerous in late September and early October in both the burned and non-burned sites.

In 1998, the number of species collected from each order in the initial burned, recent burned, and non-burned sites were somewhat different. Even though the number of species of Coleoptera and Hymenoptera were nearly equal in all sites in 1998, there were differences in the number of species of Diptera. Species of Diptera were less diverse in the recent burned site (42 species) when compared to the initial burned and non-burned sites,

(75 and 61 species, respectively). These data suggest that flies are less adapted to areas subjected to burning. In addition, seasonality data show that species of Coleoptera and Hymenoptera were more abundant in July in both the initial burned and recent burned sites, while species of Diptera were more abundant in June in the initial burned and non-burned sites.

Even though the Diptera contained the fewest number of species in the recent burned site (42), they did account for the highest number of individuals in the recent burned site (761). These findings result from numerous individuals of *Corynoptera* spp. collected in August (from sticky traps). Furthermore, more individuals of Collembola (*T. flavescens*) were collected in July in the non-burned site than the other two sites.

The response of arthropod populations to prescribed burning in the grassland barrens of middle Tennessee showed that more insect taxa had larger populations in the burned sites. The variation in arthropod numbers in the burned and non-burned sites may be, in part, due to plant succession and the immigration of arthropods into burned areas after burning. Burned areas usually offer greater floristic diversity, and appear to offer more suitable food resources for the arthropods. Further research needs to be devoted to the ecology and effects of prescribed burning on arthropod communities.

CHAPTER IV

INCIDENCE OF SELECTED ARTHROPODS ON EGGERT'S SUNFLOWER, *HELIANTHUS EGGERTII* SMALL, IN THE BARRENS OF MIDDLE TENNESSEE

i. Introduction

Eggert's sunflower, *Helianthus eggertii* Small, is a perennial member of the aster family (Asteraceae) known only from Kentucky, Tennessee, and Alabama (Fig. 2) (Bullington et al. 1998). This species is commonly associated with the barrens/woodland ecosystem, a complex of xeric to subxeric plant communities maintained by drought and fire with a grassy ground cover and scattered medium to small canopy trees. Although it was originally described in 1897 (Small 1903), most plant collections have been made since 1990, when extensive searches for the species began (Tennessee Natural Heritage Database 1997).

Eggert's sunflower is a tall (up to 2.5 m) plant arising from a short, thick base, anchored by shallow elongate, fleshy rhizomes that can form an extensive network. The plant is glabrous (smooth), except for some slight roughening (scabrous) on the upper leaf surfaces, and possesses a blue-waxy coloration. The lower leaves are conspicuously whitened. The plant's opposite (rarely whorled) leaves are mostly lanceolate to narrowly ovate, the largest being 10 to 20 cm long. Leaf edges are smooth or minutely toothed, and

the tip is usually pointed. Large yellow flowers (8 cm) are borne on the upper one-third of the stem (Fig. 26). Cypselas (seeds) are blackish or grayish and mottled, 5 to 6 mm long, faintly striated, and with a few scattered trichomes. Flowering begins in early August and continues through mid-September, and achenes mature from early September to early October (Jones 1991). Fruit sets at between 5 and 25 seeds per flowerhead (Jones 1991). Seed germination rates are generally low (rarely exceeding 25%) and most require exposure to cold to break dormancy (Heiser et al. 1969). Other sunflowers that may be confused with *H. eggertii* are *H. strumosus* L., which has petiolate leaves, and *H. laevigatus* T. & G., an Appalachian species. *Helianthus eggertii* often occurs with *H. microcephalus* T. & G., which has small flowerheads and petioled leaves, and *H. mollis* Lam. and *H. hirsutus* Raf., which have pubescence on the stem and leaves (Cronquist 1980).

Eggert's sunflower develops an extensive rhizome system, and these rhizomes can live for many years. Thus, the plant does not have to produce seeds every year to ensure its survival. If environmental conditions change (e.g., increased competition, shading, etc.), it can survive for several years by vegetative means (Jones 1991). Most nonflowering colonies are located under substantial forest cover, so it is likely that a certain light level is critical to induce flowering. Also, populations in full sun nearly always produce flowers, some notably more prolific than in heavily forested settings (McKinney 1997).

The natural condition of the barrens/woodland ecosystem where Eggert's sunflower occurs is a mosaic of grassy openings and mixed oak woodlands. A

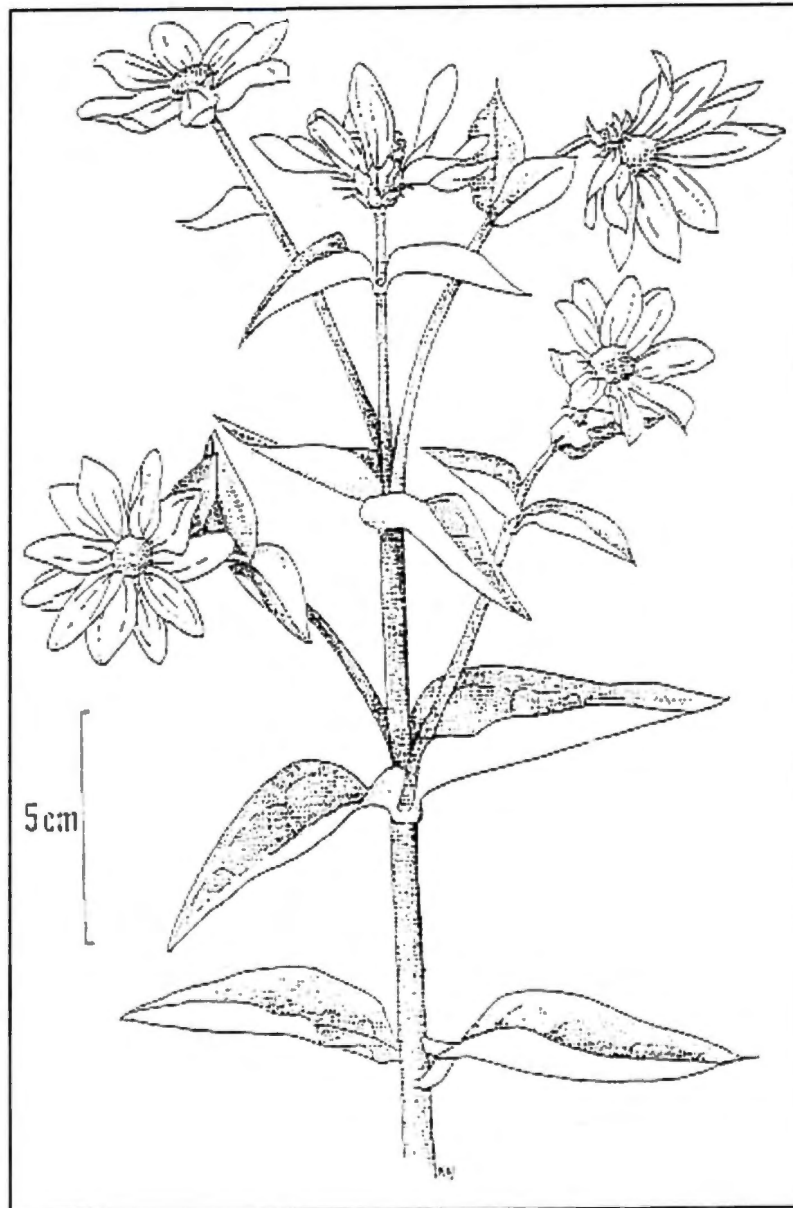


Figure 26. Illustration of *Helianthus eggertii* Small (Small 1903).

combination of drought, periodic fire, edaphic factors and grazing maintained these habitats. Common trees in this ecosystem include post oak (*Quercus stellata* Wang.), southern red oak (*Quercus falcata* Michx.), red cedar (*Juniperus virginiana* L.), mockernut hickory [*Carya tomentosa* (Poir.)], winged elm (*Ulmus alata* Michx.), and blackgum (*Nyssa sylvatica* Marsh.). Grasses with affinities to prairies often dominate the openings in these community complexes, some of which include big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* Nash), switchgrass (*Panicum virgatum* L.), and Indian grass (*Sorghastrum nutans* L.). Numerous forbs and other grasses that are typical of the barrens/woodland ecosystem also are common in this grassy cover (DeSelm 1989).

Barrens are inherently vulnerable to development because they have a sparse tree cover that allows for easier land clearing and because they are not valued as timberland. The extent and quality of barrens are influenced by periodic fire, and with the disruption of normal fire cycles throughout this region, these communities have declined, especially with efforts to reduce wildfires. Few good examples of these community types remain and most are considered globally rare (Tennessee Natural Heritage Database 1997). Although the topography for these communities is typically low and rolling, *H. eggertii* has been found in hillside barrens of Davidson County, TN, on steep rocky slopes.

The predominant habitat for *H. eggertii* is the ecotone between the woodland and barrens interface. Although not as evident at the present, with changes in the barrens habitat, this species probably occurred in association with stands of trees scattered throughout the barrens. These stands were open, with little woody understory due to

periodic fire (Bullington et al. 1998). When fire is suppressed, succession proceeds with an increase in woody understory and other growth that eventually excludes *H. eggertii*.

Although open to semi-open barrens and woodlands appear optimal for this species, it also tolerates considerable disturbance and a range of light conditions (Kral 1983). It persists in and may even move into roadsides, power line rights-of-way, or fields that have suitable open habitat. Numerous populations of this species persist at Arnold AFB, perhaps because the habitat upon which it depends is maintained by prescribed burning, mowing, and other such practices. Nearly 15% of the total occurrences of Eggert's sunflower at Arnold AFB is located within the barrens (Bullington et al. 1998).

Although the lack of periodic fire and conversion of habitat may be the primary reasons for the rare occurrences of Eggert's sunflower, other reasons, such as herbivorous insects, also may be responsible for its decline. Numerous insects have been discovered on Eggert's sunflower, but the insect/plant interactions are not fully understood. Long-term monitoring of insects associated with Eggert's sunflower is essential to determine if they impact the plant or cause premature mortality.

Because no researchers have fully investigated the relationship between herbivorous insects and *H. eggertii*, a study in the barrens at Arnold AFB was initiated to obtain information on the influence of burning on the: 1) species composition of herbivorous insects on Eggert's sunflower; 2) incidence of collapsed peduncles (dropped flowerheads) and the possible role of associated insects; 3) infestation level and seasonality of spittlebugs on *H. eggertii*; and 4) presence of insect larvae within the plant (stems and rhizomes). This information is especially important because this plant was listed as

threatened by the U.S. Fish and Wildlife Service on 22 May 1997, under the Endangered Species Act of 1973, as amended (Bullington et al. 1998).

ii. Materials and Methods

During 1998, arthropod incidence on Eggert's sunflower was monitored at three sites within the grassland barrens on Arnold AFB: 1) initial burned, 2) recent burned, and 3) non-burned sites (Fig. 3). These sites, also sampled for arthropod diversity and abundance, were described in Chapter III.

Permission was granted by the U.S. Fish and Wildlife Service under Section 10 (a) (1) (B) of the Endangered Species Act of 1973 to sample and remove *H. eggertii* from the three sites during 1998. This section of the Endangered Species Act is an incidental take permit that allows the taking of a species which is otherwise prohibited, when such taking is incidental to, and not the purpose of an otherwise lawful activity, and covered by a habitat conservation plan.

One fiberglass screen cage (145 cm height, 50 cm diameter; 73 meshes/6.45 cm²) was positioned over two plants in the initial burned site, one plant in the recent burned site, and two plants in the non-burned site. These plants were caged from late July through mid-September and monitored weekly for insects that may have emerged from plant parts, such as flowerheads, stems, and seeds. Insects, if present, were removed and taken to the laboratory, where they were processed and identified.

Peduncle collapse (dropped flowerheads) is a symptom indicating that the plant has possibly been damaged by insects. This problem may be a result of the feeding pattern of insects, which feed (girdle) around the stem in a concentric manner, until the stem is

weakened, resulting in collapsed peduncles. In the initial burned site (Site 1) on 23 September 1998, eight flowerheads, along with a portion of the girdled stem, were removed from their respective plants, taken to the laboratory, and held for insect emergence. The rhizomes and the majority of the stems were not removed. However, two complete plants, including rhizomes, stems, and flowerheads, were removed on 18 November 1998, placed in a canvas bag, and taken to the laboratory, where each specimen was carefully examined. This examination involved dissecting the stems and rhizomes for presence of insect eggs and larvae. Insects obtained from these plant parts were either placed in vials or reared to adulthood on a moist substrate, including topsoil and a moistened paper towel. A label, including plant number, plant part collected, date, and site, was affixed to vial specimens. An identification label also was placed in each vial; however, due to inadequate keys, larvae were identified only to order.

In the recent burned site (Site 2), four flowerheads and a portion of the girdled stem and leaves were taken from their respective plants on 23 September 1998. Rhizomes and stems remained intact for these plants. One complete plant, including the rhizomes, stem, and flowerheads, was extricated on 18 November 1998 and taken to the laboratory as described above.

In the non-burned site (Site 3), eight dropped flowerheads were removed on 23 September 1998. Two complete plants, including the rhizomes, stems, and flowerheads, were removed on 18 November 1998 and maintained as described earlier.

Densities and seasonalities of selected arthropods were monitored weekly on populations of *H. eggertii* at the initial burned, recent burned, and non-burned sites. In

each site, 10 plants were flagged, numbered, and observed for insect activity and damage. On each sampling date selected insects were collected from these plants and taken to the laboratory for identification. The location of insects on these plants, i.e. stems, leaves, or flowerheads, also was recorded. In addition, collapsed peduncles were measured on the main flowering stem, the first lateral flowering stem, and the second lateral flowering stem. Measurements were recorded from the top surface of the flowerhead to the site of the clipped stem (L_1) and from the base of the flowerhead to the site of the clipped stem (L_2). From these data, flower length (L_1-L_2) was determined. Furthermore, the number of spittlebug masses per plant also was recorded each week for each site. Incidence of insects and peduncle collapse, as well as the infestation levels and seasonality of spittlebugs, were determined.

Data Analysis

All specimens collected from Eggert's sunflower were taken to the laboratory, identified, and entered into the database. Least Significant Differences were determined through mean separation analysis (SAS Institute 1997) to compare the length of clipped stems among all plants affected by peduncle collapse for each site. This analysis included differences among the main flowering stem, the first lateral flowering stem, and second lateral flowering stem of each plant affected by peduncle collapse, as well as the influence of burning on incidence of clipped stems. Spittlebug masses were compared among sites and graphically represented over time.

iii. Results and Discussion

During August and September 1998, 67 species representing 58 genera, 32 families, and 8 orders were collected from Eggert's sunflower in the grassland barrens at Arnold AFB (Table 9). The greatest number of species occurred in the orders Coleoptera (28), Hymenoptera (11), Orthoptera (9), Hemiptera (7) and Lepidoptera (6). The most commonly encountered families were: the Chrysomelidae (leaf beetles), 11 species representing about 16.4% of all species collected; Curculionidae (weevils), 8 species representing about 11.9% of all species collected; and Acrididae (short-horned grasshoppers), 7 species representing about 10.4% of all species collected. All of these groups of insects are phytophagous, except a few which feed on dead organic matter and a few leaf beetles which live with ants or termites and are probably scavengers.

The most commonly collected insect species were the cantharid *C. pennsylvanicus* (the soldier beetle), the chrysomelid *Luperaltica nigripalpis* (LeConte), and the weevil *Odontocorynus* spp., representing 15.8%, 12.5%, and 10.3% of all species, respectively. The soldier beetle feeds primarily on goldenrod, and *L. nigripalpis* feeds on a variety of perennials including *Ambrosia* spp. (ragweed) and *Rudbeckia* spp. (coneflower). *Odontocorynus* spp. feed on members of the composite family, including daisies and sunflowers. Also, a common economic pest, the twelve-spotted cucumber beetle, *D. undecimpunctata howardi*, was collected from Eggert's sunflower at each site. Adults of this pest feed upon the blossoms and foliage of many species, including cucumbers, melons, beans, and numerous other cultivated plants.

Table 9. Species collected from Eggert's sunflower, *Helianthis eggertii* Small, in the grassland barrens of Arnold Air Force Base, Tullahoma, TN, 1998.

Order	Family	Genus	species subspecies	Site No. ^a		
				1	2	3
Coleoptera	Cantharidae	<i>Chauliognathus</i>	<i>pennsylvanicus</i>	10 ^b	15	4
	Carabidae	<i>Anisodactylus</i>	<i>species 1</i>	0	0	1
	Cerambycidae	<i>Plectrodera</i>	<i>scalator</i>	1	0	0
	Chrysomelidae	<i>Anomoea</i>	<i>flavokansiensis</i>	0	1	0
	Chrysomelidae	<i>Calligrapha</i>	<i>multipunctata</i>	0	0	1
	Chrysomelidae	<i>Cryptocephalus</i>	<i>venustus</i>	0	1	0
	Chrysomelidae	<i>Diabrotica</i>	<i>cristata</i>	2	1	5
	Chrysomelidae	<i>Diabrotica</i>	<i>undecimpunctata howardi</i>	1	1	2
	Chrysomelidae	<i>Disonycha</i>	<i>species 1</i>	0	0	1
	Chrysomelidae	<i>Luperaltica</i>	<i>nigripalpis</i>	4	7	12
	Chrysomelidae	<i>Odontota</i>	<i>dorsalis</i>	0	0	1
	Chrysomelidae	<i>Ophraella</i>	<i>notata</i>	1	0	0
	Chrysomelidae	<i>Pachybrachis</i>	<i>trinotatus</i>	0	0	1
	Chrysomelidae	<i>Sumitrosis</i>	<i>ancoroides</i>	1	0	0
	Curculionidae	<i>Anthonomus</i>	<i>disjunctus</i>	1	0	0
	Curculionidae	<i>Haploryhynchites</i>	<i>aeneus</i>	0	1	0
	Curculionidae	<i>Listronotus</i>	<i>species 1</i>	0	0	1
	Curculionidae	<i>Myrmex</i>	<i>chevrolati</i>	0	1	0
	Curculionidae	<i>Odontocorynus</i>	<i>spp.</i>	7	5	7
	Curculionidae	<i>Pantomorus</i>	<i>tessellatus</i>	1	0	0
	Curculionidae	<i>Smicronyx</i>	<i>sordidus</i>	1	0	0
	Curculionidae	<i>Sphenophorus</i>	<i>parvulus</i>	0	1	0
	Meloidae	<i>Epicauta</i>	<i>pensylvanica</i>	4	0	0
	Meloidae	<i>Epicauta</i>	<i>pestifera</i>	0	1	0
	Meloidae	<i>Zonitis</i>	<i>bilineata</i>	1	0	0
	Mordellidae	<i>Mordellistena</i>	<i>divisa</i>	0	0	2
	Mordellidae	<i>Mordellistena</i>	<i>trifasciata</i>	1	0	0
	Scarabaeidae	<i>Popillia</i>	<i>japonica</i>	1	1	0
Diptera	Tabanidae	<i>Tabanus</i>	<i>mularis</i>	0	1	0
Hemiptera	Alydidae	<i>Alydus</i>	<i>eurinus</i>	0	0	1
	Coreidae	<i>Euthochtha</i>	<i>galeator</i>	0	0	1
	Coreidae	<i>Mercoris</i>	<i>typhaeus</i>	3	0	0
	Pentatomidae	<i>Euschistus</i>	<i>servus</i>	0	1	4
	Pentatomidae	<i>Harmostes</i>	<i>reflexulus</i>	0	1	0
	Pentatomidae	<i>Mormidea</i>	<i>lugens</i>	1	0	0
	Pentatomidae	<i>Oebalus</i>	<i>pugnax</i>	0	1	0

Table 9 (Cont). Species collected from Eggert's sunflower, *Helianthis eggertii* Small, in the grassland barrens of Arnold Air Force Base, Tullahoma, TN, 1998.

Order	Family	Genus	species subspecies	Site No. ^a		
				1	2	3
Homoptera	Acanaloniidae	<i>Acanalonia</i>	<i>bivittata</i>	0	1	0
	Cercopidae	<i>Lepyronia</i>	<i>quadrangularis</i>	0	0	2
	Cicadellidae	<i>Agallia</i>	<i>constricta</i>	0	0	1
	Cicadidae	<i>Tibicen</i>	<i>canicularis</i>	0	0	1
Hymenoptera	Aphelinidae	<i>Aphelinus</i>	<i>mali</i>	1	0	0
	Apidae	<i>Bombus</i>	<i>pennsylvanicus</i>	0	0	1
	Braconidae	<i>Meteorus</i>	species 1	0	0	1
	Ceraphronidae	Genus	species 1	0	0	1
	Diapriidae	Genus	species 1	0	0	1
	Encyrtidae	<i>Ooencyrtus</i>	species 1	0	1	0
	Formicidae	<i>Camponotus</i>	<i>ferrugineus</i>	1	0	0
	Formicidae	<i>Formica</i>	<i>schaufussi schaufussi</i>	3	7	3
	Halictidae	<i>Dialictus</i>	species 1	0	1	0
	Pteromalidae*	Genus	species 1	1	0	0
	Scelionidae	<i>Trissolcus</i>	<i>euschisti</i>	0	1	0
Lepidoptera	Arctiidae	Genus	species 1	2	1	2
	Geometridae	Genus	species 1	0	1	0
	Geometridae	Genus	species 2	0	1	1
	Nymphalidae	Genus	species 1	0	0	1
	Nymphalidae	Genus	species 2	1	0	0
	Nymphalidae	Genus	species 3	0	1	0
Neuroptera	Chrysopidae	<i>Chrysopa</i>	<i>carnea</i>	1	0	0
Orthoptera	Acrididae	<i>Chortophaga</i>	<i>viridifasciata</i>	0	2	0
	Acrididae	<i>Hippiscus</i>	<i>ocelote</i>	0	2	0
	Acrididae	<i>Melanoplus</i>	species 1	0	0	1
	Acrididae	<i>Melanoplus</i>	<i>differentialis</i>	2	0	0
	Acrididae	<i>Melanoplus</i>	<i>femurrubrum</i>	1	2	0
	Acrididae	<i>Melanoplus</i>	<i>femurrubrum propinquus</i>	0	1	0
	Acrididae	<i>Schistocerca</i>	<i>americana</i>	1	0	0
	Tettigonidae	<i>Orchelium</i>	<i>vulgare</i>	3	0	3
	Tettigonidae	<i>Scudderia</i>	<i>furcata</i>	0	0	1
				58	62	64

* collected inside a gall on 18 November 1998 (Eggert #1)

^a Site 1 = Initial burned , Site 2 = Recent burned, and Site 3 = Non-burned.

^b Number of individuals collected from Eggert's sunflower at each site.

The Curculionidae are found in a wide variety of habitats, and more than 2,600 species occur in North America. They show considerable variation in size, shape, and the form of the snout. The snout is well developed in most species. All snout weevils (except a few occurring in ant nests) are plant feeders, and many are serious pests. Every part of a plant may be attacked, from the roots upward. The larvae usually feed inside the tissues of the plant, and the adults drill holes in fruits, nuts, and other plant parts (Casey 1920).

Myrmex chevrolati Horn, ranging from Georgia, North Carolina, and Virginia, is a weevil rarely collected, whose host plants include oak, elm, grape, and hazelnut. Only one specimen was collected from *H. eggertii* on 13 August 1998 in the recent burned site.

The bluegrass billbug, *Sphenophorus parvulus* Gyllenhal, whose hosts include Kentucky bluegrass and pea pratense, often develops on many plant species including corn, wheat, rye, timothy, bent, and other sedges. It ranges from Ontario south to Texas. One specimen was collected on *H. eggertii* on 13 August 1998 in the recent burned site.

The total number of specimens collected was consistent among sites (58, 62, and 64 for initial burned, recent burned, and non-burned sites, respectively) (Table 9). Numbers of collected *C. pennsylvanicus* were lower from the non-burned site (4) than from the initial burned (10) and recent burned sites (15). On the other hand, numbers of collected *L. nigripalpis* were much higher in the non-burned site (12) than in the two burned sites (4 and 7, respectively). Numbers of *Odontocorynus* spp. were almost equally distributed among the sites. Among the Lepidoptera, caterpillars of arctiid moths were observed feeding on the flowers of sunflowers.

The majority of Hymenoptera recorded from Eggert's sunflower, with the exception of ants, are parasitic, generally parasitizing eggs, immatures, and even adults of other insects. For example, the Encyrtidae are a large and widespread group with 345 described North American species. Most encyrtids are parasitoids of Homoptera, such as aphids, scale insects, mealybugs, and whiteflies. *Ooencyrtus* species are parasitoids of the eggs of some Lepidoptera and Neuroptera. One specimen (*Ooencyrtus* species 1) was collected while parasitizing lacewing eggs on *H. eggertii* on 13 August 1998 in the recent burned site (Table 9).

The Pteromalidae is a large group of parasitic wasps with approximately 340 described North American species. Most attack a wide variety of hosts but many are valuable in the control of crop pests. Species are known to attack eggs, larvae, nymphs, and pupae. Both solitary and gregarious parasitoids occur. Hosts include Lepidoptera, Hymenoptera, Diptera, and Coleoptera; a few are gall formers. One specimen (Pteromalidae species 1) was collected from within the stem of *H. eggertii* on 18 November 1998 in the burned site (Table 9).

The Diapriidae are small to minute insects that are parasitoids of immature Diptera and ants. The diapriids only occur in wooded areas and along ecotone breaks. More than 300 North American species have been described. They maintain a wide range including North America, South America, southern Africa, and Australia. One specimen Diapriidae species 1) was collected from *H. eggertii* on 20 August 1998 in the non-burned site (Table 9).

Insects may damage Eggert's sunflower by feeding on various parts of the plant. For example, piercing-sucking insects may cause injury by extracting sap from the leaves or other plant part, resulting in spotting, browning, or wilting. Insect groups that may cause this type of damage include spittlebugs, planthoppers, and leafhoppers. About 16.4% of all insects collected from Eggert's sunflower had piercing-sucking mouthparts. Other insects, such as weevils and other beetles, have chewing mouthparts and may damage the plant by leaf feeding, stem or root boring, or girdling. Approximately 52.2% of all species collected were primarily leaf feeders or girdlers. Stem girdling, causing stem and peduncle collapse, can be devastating to plant reproduction and survivability. Stem girdling was commonly observed throughout this study.

By 9 September 1998, 100 and 90% of the main stems in the initial burned and recent burned sites, respectively, were clipped (Fig. 27). Conversely, only about 20% of the main stems were clipped in the non-burned site. Also, 100 and 90% of the first lateral stems in the recent burned and initial burned sites were clipped by 16 September 1998. The first lateral stems in the non-burned site sustained minimal damage ($\leq 20\%$) throughout the monitoring of this plant. Second lateral stems did not sustain as much damage as the other two stem types. Approximately 70% of the second lateral stems were clipped by 2 September 1998 in the recent burned site, while only about 50% were clipped in the initial burned site by 16 September 1998. The second lateral stems in the non-burned site were not greatly affected, as only about 20% were clipped on any one sampling date.

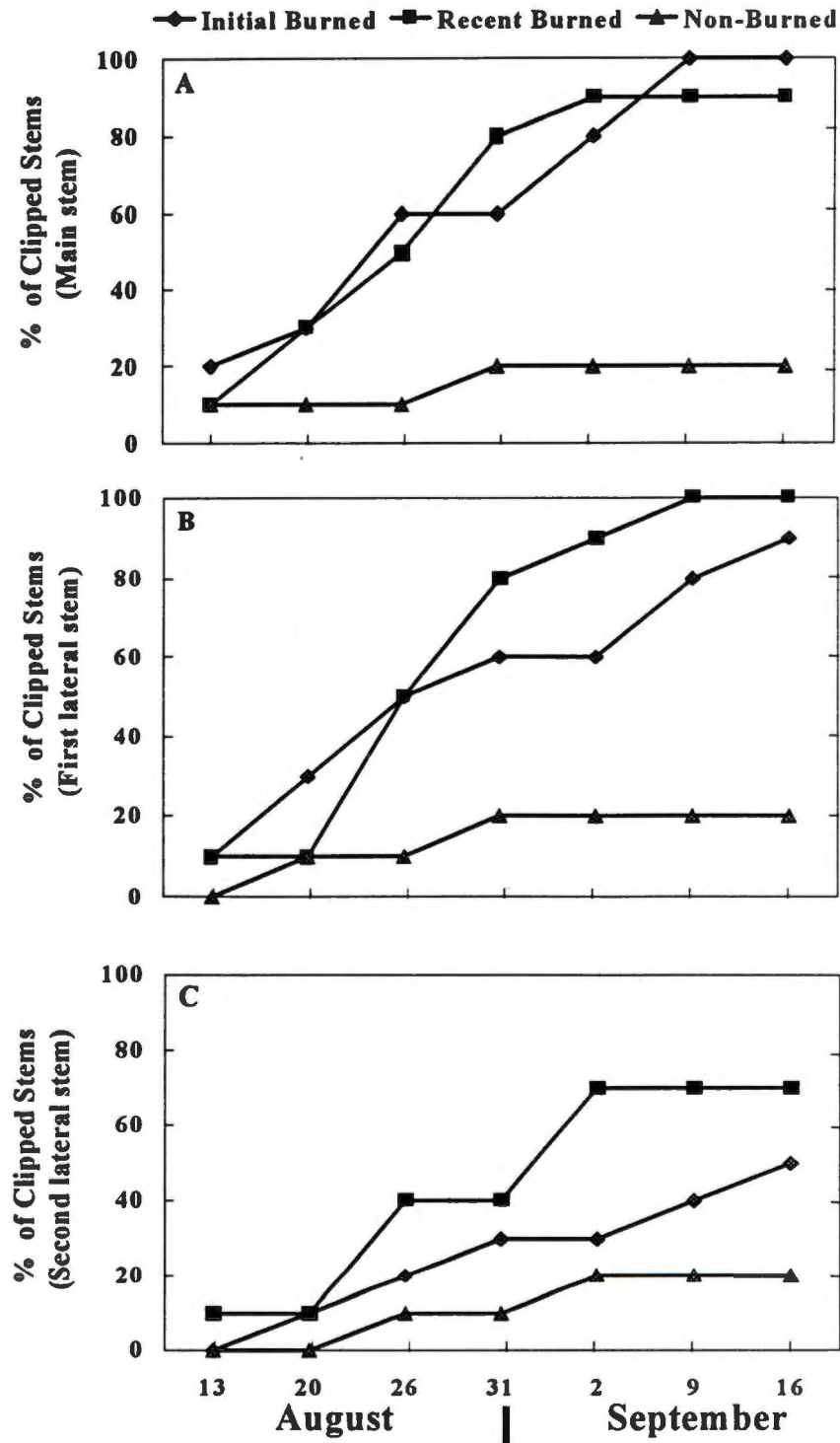


Figure 27. Percent of clipped stems [main stem (A), first lateral (B), and second lateral stem (C)] of *Helianthus eggertii* Small in the initial burned, recent burned, and non-burned sites in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

In addition to the number of clipped stems discussed previously, the length of clipped stems also was examined. For the main stem, the length of the clipped stem was significantly greater in the recent burned site than in the initial burned site (Table 10). The lengths of clipped stems on the first lateral flowering stem were significantly different among all sites, with the longest length in the non-burned site and the shortest length in the initial burned site. Also, lengths of clipped stems on the second lateral flowering stem were significantly greater in the recent burned site than in the initial burned site.

The lengths of the flowers on the main stem were significantly longer in the recent burned site than the initial burned and non-burned sites (Table 11). No significant differences in flower lengths of the first lateral flowering stems were found among plots. Significant differences among sites were detected on flower lengths of the second lateral flowering stem, where the shortest length was recorded in the non-burned site. In general, these results indicate that the length of clipped stems, as well as flower lengths, increases with burning. Reasons are obscure and no plausible explanation can be derived.

Eleven insect larvae were found inside the stems; however, only two orders (Coleoptera and Hymenoptera) were identified (Table 12). Unfortunately, attempts to rear the three hymenopteran larvae to adulthood were unsuccessful. However, 2 of the 8 coleopteran larvae collected from the stems were successfully reared to adulthood and identified as *Odontocorymus* spp. (weevils). Incidentally, these weevils were collected from the recent burned site on 18 November 1998 (plant # 6), but did not emerge as adults until 6 and 10 June 1999. These *Odontocorymus* spp. may have been responsible for the peduncle collapse often discerned on populations of *H. eggertii*. It is probable that these

Table 10. Influence of burning on the length of clipped stems (in cm) on the main, first lateral, and second lateral flowering stems in the grassland barrens of Arnold Air Force Base, Tullahoma, TN, 1998.

Stem	Site	Mean $\pm$ SD ^a
Main	Initial Burn	2.286 $\pm$ 0.207 B
	Recent Burn	2.421 $\pm$ 0.276 A
	Non-burn	2.316 $\pm$ 0.151 AB
First Lateral	Initial Burn	2.213 $\pm$ 0.182 C
	Recent Burn	2.385 $\pm$ 0.475 B
	Non-burn	2.849 $\pm$ 0.325 A
Second Lateral	Initial Burn	2.192 $\pm$ 0.129 B
	Recent Burn	2.486 $\pm$ 0.303 A
	Non-burn	2.294 $\pm$ 0.160 AB

^a LS Mean $\pm$ standard deviation; means within a stem type followed by a different letter are significantly different ($p \leq 0.05$) (Least Significant Difference Test).

Table 11. Influence of burning on flower length of clipped stems (in cm) on the main, first lateral, and second lateral flowering stems in the grassland barrens of Arnold Air Force Base, Tullahoma, TN, 1998.

Stem	Site	Mean $\pm$ SD ^a
Main	Initial Burn	1.163 $\pm$ 0.179 B
	Recent Burn	1.432 $\pm$ 0.294 A
	Non-burn	1.015 $\pm$ 0.005 B
First Lateral	Initial Burn	1.301 $\pm$ 0.242 A
	Recent Burn	1.293 $\pm$ 0.429 A
	Non-burn	1.471 $\pm$ 0.207 A
Second Lateral	Initial Burn	1.292 $\pm$ 0.183 A
	Recent Burn	1.342 $\pm$ 0.251 A
	Non-burn	0.986 $\pm$ 0.031 B

^a LS Mean $\pm$ standard deviation; means within a stem type followed by a different letter are significantly different ($p \leq 0.05$) (Least Significant Difference Test).

Table 12. Larval insects found in the stems of *Helianthus eggertii* in the grassland barrens of Arnold Air Force Base, Tullahoma, TN, 1998.

Site	Date	Plant #	Order	# larvae/stem
Burn	23 Sep 1998	Eggert 7	Hymenoptera	2
Recent burn	23 Sep 1998	Eggert 4	Hymenoptera	1
Burn	18 Nov 1998	Eggert 2*	Coleoptera	1
Burn	18 Nov 1998	Eggert 8	Coleoptera	1
Recent burn	18 Nov 1998	Eggert 6*	Coleoptera	4
Non-burn	18 Nov 1998	Eggert 1	Coleoptera	1
Non-burn	18 Nov 1998	Eggert 10	Coleoptera	1

* sampled from entire plant

weevils girdled the stems, and after collapse, deposited eggs into the stem where they matured into larvae, thus accounting for the presence of larvae.

Spittlebugs, also known as froghoppers, are similar to leafhoppers. These piercing-sucking homopterans feed on herbaceous plants, trees, and shrubs. Immatures produce a spittle-like mass, which they use to cover their bodies for protection from dessication and predation. Each mass may contain one or more immature spittlebugs. Spittlebug masses were commonly found on Eggert's sunflower at all three sites, with infestation levels peaking at 20, 30, and 40% in the non-burned, initial burned, and recent burned sites, respectively (Fig. 28). Infestation levels were lowest on plants in the non-burned site. The highest percentage of spittlebug masses occurred during the period from 31 August to 2 September in the recent burned site, and from 31 August to 9 September in the initial burned site. In the non-burned site, the highest percentage of spittlebug masses occurred from 2 September to 9 September. Even though adults of the sunflower spittlebug, *Clastoptera xanthocephala* Germar, were not collected from Eggert's sunflower in 1998, this homopteran is considered to be a pest specific to *Helianthus* species (Arnett 1993), and was collected quite often in sweeps at all three sites. It is possible that immatures of this insect are responsible for the frothy masses on *H. eggertii*. Burning seems to influence the infestation level of spittlebugs in grassland ecosystems, as infestation levels were greater in both the recent burned and initial burned sites than the non-burned site. Perhaps the plants in the burned treatments were more suitable to the spittlebugs than the non-burned site because of the increased/renewed plant growth.

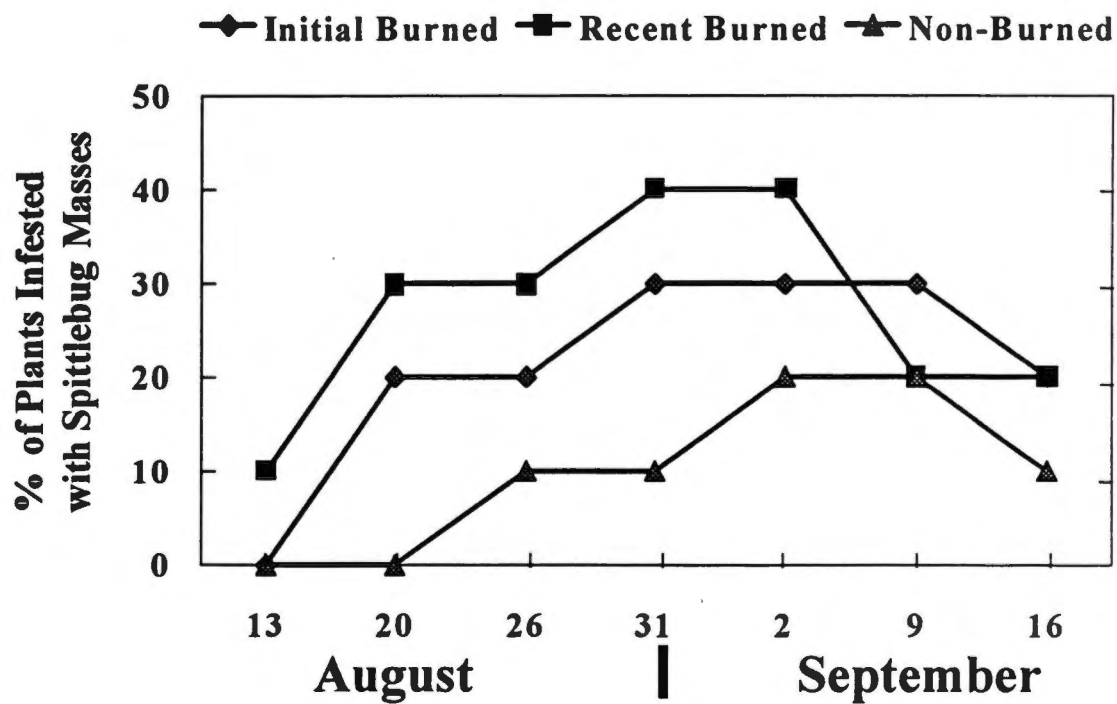


Figure 28. Percent infestation of spittlebug masses on *Helianthus eggertii* Small in the grassland barrens at Arnold Air Force Base, Tullahoma, TN, 1998.

iv. Summary

During August and September 1998, 67 insect species were collected from Eggert's sunflower in the grassland barrens of Arnold AFB in middle Tennessee. The Coleoptera, representing 41.8% of the total species collected, were an important constituent of the insect fauna occurring on *H. eggertii*, with the Chrysomelidae and Curculionidae representing the most species collected (11 and 8 species, respectively). The Hymenoptera represented 16.4% of all species found on Eggert's sunflower.

The most commonly collected species were *C. pennsylvanicus*, *L. nigripalpis*, and *Odontocorymus* spp. (29, 23, and 19, respectively). The total number of insects collected was nearly equal among sites. The two most notable differences were observed in regard to *C. pennsylvanicus* and *L. nigripalpis*. Numbers of *C. pennsylvanicus* were 3.8X greater in the recent burned site than in the non-burned site. Conversely, numbers of *L. nigripalpis* were 1.7X higher in the non-burned site than in the recent burned site. It is probable that the greater vegetative reproduction in the recent burned site accounts for the higher numbers of the pollen-feeding soldier beetles. However, reasons for the higher numbers of leaf beetles (*L. nigripalpis*) in the non-burned site are not as apparent.

Stem girdling was commonly observed throughout this study. By the second week in September, the initial burned and recent burned sites contained the highest incidence of clipped stems, particularly on the main flowering stems. Damage levels on the first lateral flowering stems were high as well in these same two sites. The second lateral flowering stems did not sustain as much damage in the initial and recent burned sites when compared to the other two stem types. The incidence of clipped stems in the non-burned site was

remarkably low. It is evident that burning increases the incidence of clipped stems, particularly on the main flowering stem and the first lateral flowering stem as seen in the recent burned and initial burned sites.

Furthermore, the length of clipped stems was usually greater in the initial burned and recent burned sites than in the non-burned site. The flower lengths were longer as well in the burned sites, especially the recent burned site, when compared to the non-burned site. Again, burning seems to influence stem length as well as flower length.

In addition to the clipped stems, several coleopteran larvae were found inside the stems of Eggert's sunflower. Two of the larvae found within the stems of this plant were reared to adulthood. It is likely that the adults of these larvae, *Odontocorymus* spp., are responsible for the clipped stems often observed on Eggert's sunflower.

Spittlebug masses were commonly encountered throughout the monitoring of Eggert's sunflower. Infestation levels were highest in the recent burned site and lowest in the non-burned site, implying that these homopterans are more suited to the new plant vigor of *H. eggertii* in the recent burned site than in the non-burned site. *Clastoptera xanthocephala* is the probable spittlebug present in these masses, especially since so many adults were collected through sweep-net sampling in the barrens. This insect is considered to be a pest of sunflowers.

Of all groups collected from Eggert's sunflower in 1998, perhaps no insects affected the plant as much as the beetles. Even though leaf-feeding beetles were found on Eggert's sunflower, the weevils seemed to have the most action on the plant. Larvae of *Odontocorymus* spp. were found inside the stem of most plants, and it is plausible that

adult weevils were responsible for the clipped stems often observed in each site within the barrens. Also, burning affected the incidence of clipped stems in each site. Efforts to conserve populations of Eggert's sunflower should be continued, and the impact of burning on viability and survivability of Eggert's sunflower, as well as impact of phytophagous insects should be fully investigated.

CHAPTER V

CONCLUSIONS

During 1997 and 1998, abundance, seasonality, and species composition of insects associated with the grassland barrens in middle Tennessee, along with the effectiveness of various sampling methods in assessing insect communities in the barrens, were examined. The impact of burning on arthropod communities and incidence of selected arthropods occurring on Eggert's sunflower, *H. eggertii*, also were evaluated.

A total of 12,028 specimens was collected in the grassland barrens at Arnold AFB in 1997 and 1998. From these specimens, 709 arthropod species, representing 21 orders and 165 families, were identified. Incidentally, more arthropods were identified in 1998 than in 1997 due to the shorter sampling period in 1997. The collembolan *T. flavescens* was the most abundant species collected (3,114 individuals). Pitfall traps and sweep-net sampling were the most effective sampling methods and accounted for more of the total species collected and individuals collected in 1997 and 1998. Furthermore, diversity indices were lowest for collections from the sticky traps and Manitoba traps and highest for collections from direct sampling, malaise traps, and sweep-net sampling.

Coleoptera was the most species-rich order, with 208 species representing 30 families. Diptera (127 species in 33 families) and Hymenoptera (94 species in 27 families) also were well represented. These three orders constituted 61.9% of all species collected

in 1997 and 1998. However, the Collembola contained the most number of individuals collected.

Despite the short sampling period in 1997, more species were prevalent during the week of 1 October than at any other time. Also, the number of individuals collected in 1997 were most abundant during the week of 26 September. Seasonality data in 1998 indicate that the greatest species diversity in all orders occurred during the middle of summer (July). Also, most of the insects were collected in July and August in each of the sites.

Species richness in the burned sites was slightly higher than in the non-burned sites in both 1997 and 1998. The variation in species numbers in the burned and non-burned sites may be a result of plant species succession and the influx of many insect species into the burned sites after burning. Burned areas may be considered semi-natural because secondary plant succession, due to periodic burning, is attractive to a wide species (insect) range. Plant successions may attract a multi-faceted species complex to include species from bordering forested areas. Habitats with greater floral diversity appear to offer better and richer food resources for the insect species present, particularly in grasslands.

In 1997, the number of species collected from each order in the burned site and non-burned site were fairly equal. This similarity may be due, in part, to the lateness of the year when sampling began. Perhaps only two months of sampling did not allow for the collection of great arthropod diversity. However, seasonality data show that species of Collembola and Coleoptera were abundant late in the year (15 October) in both sites.

Furthermore, coleopterans, especially *C. pennsylvanicus*, were more numerous in late September and early October in both the burned and non-burned sites.

In 1998, the number of species collected from each order in the initial burned, recent burned, and non-burned sites were somewhat different. Even though the number of species of Coleoptera and Hymenoptera were nearly equal in all sites in 1998, there were differences in the number of species of Diptera. Species of Diptera were less diverse in the recent burned site (42 species) when compared to the initial burned and non-burned sites (75 and 61 species, respectively). These data suggest that flies are less adapted to areas subjected to burning. In addition, seasonality data show that species of Coleoptera and Hymenoptera were more abundant in July in both the initial burned and recent burned sites, while species of Diptera were more abundant in June in the initial burned and non-burned sites. Even though the Diptera contained the fewest number of species in the recent burned site (42), they did account for the highest number of individuals in the recent burned site (761), which resulted from numerous individuals of *Corynoptera* spp. collected in August (from sticky traps). Furthermore, more individuals of Collembola (*T. flavescens*) were collected in July in the non-burned site than the other two sites.

During August and September 1998, 67 insect species were collected from Eggert's sunflower. The Coleoptera, representing 41.8% of the total species collected, were an important constituent of the insect fauna occurring on *H. eggertii*, with the Chrysomelidae and Curculionidae representing the most species collected (11 and 8 species, respectively). The Hymenoptera represented 16.4% of all species found on Eggert's sunflower.

Peduncle collapse was commonly observed on Eggert's sunflower throughout this study. By the second week in September, the initial burned and recent burned sites contained the highest incidence of peduncle collapse (clipped stems) on the main flowering stem and the first lateral flowering stem. Second lateral flowering stems did not sustain as much damage in the initial and recent burned sites when compared to the other two stem types. The incidence of clipped stems in the non-burned site was remarkably low. It is evident that burning increases the incidence of clipped stems, particularly on the main flowering stem and the first lateral flowering stem as seen in the recent burned and initial burned sites. Furthermore, the length of clipped stems was usually greater in the initial burned and recent burned sites than in the non-burned site. The flower lengths were longer as well in the burned sites, especially the recent burned site, when compared to the non-burned site. Again, burning seems to influence flower length, as well as the length of clipped stems.

Spittlebug masses were commonly encountered throughout the monitoring of Eggert's sunflower. Infestation levels were highest in the recent burned site and lowest in the non-burned site, implying that these homopterans are more suited to the new plant vigor of *H. eggertii* in the recent burned site than in the non-burned site. It is likely that the sunflower spittlebug (*C. xanthocephala*) is responsible for the infestation, especially since so many were collected through sweep-net sampling in the barrens.

Of all groups collected from Eggert's sunflower in 1998, perhaps no insects affected the plant as much as the beetles. Even though leaf-feeding beetles were found on Eggert's sunflower, the weevils seemed to have the most effect on the plant. Larvae of

Odontocorynus spp. were found inside the stem of plants, and it is plausible that adult weevils were responsible for the clipped stems often observed in each site within the barrens. Efforts to conserve populations of Eggert's sunflower should be continued, and the impact of burning on viability and survivability of Eggert's sunflower, as well as impact of plant-feeding weevils, should be fully investigated.

Results of this study suggest that burning has a major influence on the presence and persistence of arthropod species in the grassland barrens of middle Tennessee. The variation in arthropod numbers in the burned and non-burned sites may be, in part, due to plant succession and the immigration of arthropods into burned areas after burning. Burned areas usually offer greater floristic diversity, and appear to offer more suitable food resources for the arthropods. However, the effects of burning on some plants, such as Eggert's sunflower, presents a paradox. That is, even though burning perpetuates and maintains populations of this plant, it also causes a higher incidence of damage by insects in burned areas.

Furthermore, to predict the effects of burning on the insect community of grasslands, researchers must determine the species initially present on the site, and whether they are reproducing on the site or colonizing the site from adjacent areas. Also, depending upon what species are present in the surrounding areas and on their mobility, as well as their attraction to various postburn successional stages, different insect species will invade and colonize the site, both immediately after the burn and during various stages of vegetative regrowth. Interactions of surviving species with invading species, also may

affect insect species composition. Finally, other changes will occur in the habitat, such as the succession of plant communities, with or without future burning.

After burning, as regrowth of the vegetation begins, burn-tolerant species may persist, and species attracted by fire or by the immediate postburn habitat may invade. Widespread, mobile species also may invade. If an area or site is not burned again, burn-sensitive arthropod species that are dependent on postburn successional plant species colonize the site if they are present nearby or if they have survived in unburned areas, which may be the time of highest insect species richness. If no further burning occurs, burn-sensitive plants and arthropods colonize the site and the burn-tolerant species decline. If the site remains unburned, over the course of a few years (and if no drought occurs), woody plants invade, grassland plant species decline, burn-sensitive arthropod and plant species invade, and arthropod species that are dependent on the postburn habitat decline as grasslands become forest. The highest arthropod species richness may occur in landscapes (the barrens in this case) containing sites at different successional stages and sites varying in burn frequency.

The grassland barrens in middle Tennessee provide habitat for a diverse arthropod fauna. Little information, however, is available on the impact of management strategies on insect species composition in grassland ecosystems. Furthermore, biological features must be considered in connection with the goals and scale of grassland management. The goal of arthropod management in grassland barrens may be to protect individual species, to maintain a typical grassland insect community, to maximize biological diversity, or some combination of these. No site can be managed for all species simultaneously. The scale of

management may be small (a single site) or large (entire barrens region). Much more research is needed to describe grassland insect communities and the factors that influence them, and to devise management strategies, such as burning and mowing on a rotational basis, that can be applied to the grassland ecosystems that are now being maintained and restored.

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APPENDICES

Appendix A. Literature Used to Identify Taxa Collected for the Arthropod Survey at Arnold Air Force Base, Tullahoma, TN.

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Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Araneae	Araneidae	<i>Acanthepeira</i>	<i>stellata</i> (Walckenaer)	N97	SW	1
	Araneidae	<i>Araneus</i>	<i>pratensis</i> (Emerton)	N97	SW	1
	Araneidae	<i>Araneus</i>	sp.	I97	BT	2
	Araneidae	<i>Argiope</i>	<i>aurantia</i> Lucas	I97	PF	1
	Araneidae	<i>Eustala</i>	sp.	N97	BT,SW	2
	Araneidae	<i>Neoscona</i>	<i>arabesca</i> (Walckenaer)	I97	SW	1
	Araneidae	<i>Neoscona</i>	sp.	N97	SW	1
	Araneidae	<i>Nuctenea</i>	sp.	N97	SW	1
	Araneidae	<i>Singa</i>	sp.	I97	LI	1
	Dictynidae	<i>Dictyna</i>	sp.	I97	LI	1
	Gnaphosidae	<i>Callilepus</i>	<i>pluto</i> Banks	N98	PF	4
	Gnaphosidae	<i>Micaria</i>	<i>longipes</i> Emerton	N97	PF	1
	Linyphiidae	<i>Meioneta</i>	sp.	I97	LI	1
	Liocranidae	<i>Phrurotimpus</i>	sp.	N97	LI	1
	Lycosidae	<i>Allocosa</i>	sp.	I97	LI	1
	Lycosidae	<i>Hogna</i>	<i>frondicola</i> (Emerton)	N98	PF	1
	Lycosidae	<i>Lycosa</i>	<i>punctulata</i> Hentz	I97	PF	1
	Lycosidae	<i>Pardosa</i>	<i>saxatilis</i> (Hentz)	N98,R98	PF	2
	Lycosidae	<i>Pardosa</i>	sp.	N97	LI	1
	Lycosidae	<i>Pirata</i>	sp.	N97	LI	1
	Philodromidae	<i>Thanatus</i>	<i>formicinus</i> (Clerck)	I97	PF	1
	Salticidae	<i>Ballus</i>	sp.	N97	LI	1
	Salticidae	<i>Maevia</i>	sp.	I97	LI	1
	Salticidae	<i>Pelegrina</i>	<i>proterva</i> (Walckenaer)	I97,N97	BT,SW	2
	Salticidae	<i>Phiddipus</i>	<i>cardinalis</i> (Hentz)	N97	BT	1
	Salticidae	<i>Phiddipus</i>	sp.	I97	BT	1
	Salticidae	<i>Thiodina</i>	<i>peurpera</i> (Hentz)	I97	BT,SW	2

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Araneae	Theridiidae	<i>Euryopsis</i>	<i>tavara</i> Levi	N97	LI	1
	Theridiidae	<i>Steotoda</i>	<i>americana</i> (Emerton)	I97	LI	1
	Thomisidae	<i>Misumenops</i>	<i>formosipes</i> (Walckenaer)	I97	BT	1
	Thomisidae	<i>Misumenops</i>	sp.	N97	SW	3
	Thomisidae	<i>Xysticus</i>	<i>funestis</i> Keyserling	I97	BT	1
	Thomisidae	<i>Xysticus</i>	sp.	I97,N97	LI,SW	2
Blattaria	Blattellidae	<i>Ischnoptera</i>	<i>deropeltiformes</i> (Brunner)	I97,I98,N97,N98,R98	ML,PF	49
	Blattellidae	<i>Parcoblatta</i>	<i>bolliana</i> Saussure & Zehntner	N98,R98	LT	2
	Blattellidae	<i>Parcoblatta</i>	<i>fulvescens</i> Saussure & Zehntner	I98,N98,R98	PF	19
	Blattellidae	<i>Parcoblatta</i>	<i>virginica</i> Brunner	I97,I98,N97,N98,R98	PF,ST	18
	Blattellidae	<i>Parcoblatta</i>	<i>zebra</i> Hebard	N98	LT	2
Coleoptera	Anthicidae	<i>Tomoderus</i>	<i>constrictus</i> (Say)	I98	PF	1
	Anthribidae	<i>Ormiscus</i>	<i>quadrimaculatus</i> (Pierce)	I98	BT	1
	Bruchidae	<i>Acanthoscelides</i>	<i>longistilus</i> (Horn)	I98	BT,SW	7
	Buprestidae	<i>Acmaeodera</i>	<i>tubulus</i> (Fabricius)	R98	SW	1
	Buprestidae	<i>Brachys</i>	<i>ovatus</i> (Weber)	N98	SW	2
	Buprestidae	<i>Chrysobothris</i>	<i>femorata</i> (Olivier)	I98	ML	1
	Cantharidae	<i>Cantharis</i>	<i>bilineatus</i> Say	N98,R98	ML,PF,SW	8
	Cantharidae	<i>Chauliognathus</i>	<i>marginatus</i> (Fabricius)	I98,N98,R98	BT,DI,ML,SW	49
	Cantharidae	<i>Chauliognathus</i>	<i>pennsylvanicus</i> (DeGeer)	I97,I98,N97,N98,R98	BT,EG,ML,PF,ST,SW	988
	Cantharidae	<i>Podabrus</i>	<i>frater</i> LeConte	I98	LT	1
	Cantharidae	<i>Podabrus</i>	<i>rugosulus</i> LeConte	R98	SW	1
	Cantharidae	<i>Silis</i>	<i>bidentatus</i> (Say)	I97,I98,N98	BT,SW	10
	Carabidae	<i>Abacidus</i>	<i>atratus</i> Newman	I97,I98,N97,N98,R98	BT,PF	221
	Carabidae	<i>Amara</i>	species 2	I97	PF	1
	Carabidae	<i>Anisodactylus</i>	species 1	I98,N98	EG,PF	5
	Carabidae	<i>Calathus</i>	<i>gregarius</i> (Say)	I97,I98,N97,R98	PF	9

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Carabidae	<i>Calosoma</i>	<i>externum</i> Say	I98,N98,R98	PF	6
	Carabidae	<i>Calosoma</i>	<i>sayi</i> Dejean	I98	PF	1
	Carabidae	<i>Carabus</i>	<i>sylvosus</i> Say	I97	PF	1
	Carabidae	<i>Chlaenius</i>	<i>emarginatus</i> Say	N98	PF	1
	Carabidae	<i>Cyclotrachelus</i>	<i>convivus</i> LeConte	I98,N97,N98,R98	PF	21
	Carabidae	<i>Dicaelus</i>	<i>ambiguus</i> LaFerte-Senectere	I98	PF	2
	Carabidae	<i>Dicaelus</i>	<i>elongatus</i> Bonelli	I98	PF	2
	Carabidae	<i>Dicaelus</i>	<i>purpuratus</i> Bonelli	I97,I98	PF	4
	Carabidae	<i>Harpalus</i>	<i>caliginosus</i> Fabricius	I97	PF	1
	Carabidae	<i>Harpalus</i>	sp.	I97,N97,R98	LT,PF	13
	Carabidae	<i>Lebia</i>	<i>grandis</i> Hentz	R98	LT	1
	Carabidae	<i>Lebia</i>	<i>pectita</i> Horn	N98,R98	SW	2
	Carabidae	<i>Lebia</i>	<i>pulchella</i> Dejean	I98,N97	PF	5
	Carabidae	<i>Myas</i>	<i>coracinus</i> (Say)	I97,N97,N98,R98	PF	23
	Carabidae	<i>Myas</i>	<i>cyanescens</i> Dejean	N97	PF	1
	Carabidae	<i>Notiophilus</i>	<i>novemstriatus</i> LeConte	I98	PF	1
	Carabidae	<i>Pasimachus</i>	<i>depressus</i> Fabricius	I98	PF	1
	Carabidae	<i>Pasimachus</i>	<i>marginatus</i> Fabricius	I97,I98,N97,N98,R98	DI,PF	19
	Carabidae	<i>Pterostichus</i>	<i>chalcites</i> (Say)	R98	LT	1
	Carabidae	<i>Scarites</i>	<i>subterraneus</i> Fabricius	R98	PF	1
	Carabidae	<i>Stenolophus</i>	<i>comma</i> Fabricius	R98	LT	1
	Carabidae	<i>Stenolophus</i>	<i>lecontei</i> Chaudoir	R98	LT	4
	Carabidae	<i>Stenolophus</i>	<i>ochropezus</i> (Say)	I98,N98,R98	LT	27
	Cerambycidae	<i>Batyle</i>	<i>suturalis</i> (Say)	I98	DI	3
	Cerambycidae	<i>Dorcaschema</i>	<i>nigrum</i> (Say)	R98	SW	1
	Cerambycidae	<i>Ecyrus</i>	<i>dasycerus</i> (Say)	N98	LT	1
	Cerambycidae	<i>Eutrichillus</i>	<i>biguttatus</i> (LeConte)	N98	DI	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Cerambycidae	<i>Oberea</i>	<i>perspicillata</i> Haldeman	N98,R98	SW	5
	Cerambycidae	<i>Orthosoma</i>	<i>brunneum</i> (Forster)	I98	DI	1
	Cerambycidae	<i>Plectrodera</i>	<i>scalator</i> (Fabricius)	I98,R98	DI,EG	4
	Cerambycidae	<i>Typocerus</i>	<i>lunulatus</i> (Swederus)	N98	SW	1
	Cerambycidae	<i>Typocerus</i>	<i>octonotatus</i> (Haldeman)	I98,R98	BT,DI,SW	11
	Chrysomelidae	<i>Agroiconota</i>	<i>bivittata</i> (Say)	I98	SW	1
	Chrysomelidae	<i>Anisostena</i>	<i>ariadne</i> Newman	R98	BT	1
	Chrysomelidae	<i>Anomoea</i>	<i>flavokansiensis</i> Moldenke	I98,R98	BT,EG	2
	Chrysomelidae	<i>Babia</i>	<i>quadriguttata</i> (Olivier)	I98	SW	4
	Chrysomelidae	<i>Bassareus</i>	<i>lituratus lativittis</i> (Germar)	I98	SW	3
	Chrysomelidae	<i>Calligrapha</i>	<i>bidenticola</i> Brown	I97	SW	1
	Chrysomelidae	<i>Calligrapha</i>	<i>multipunctata</i> (Say)	I98,N98,R98	EG,SW	26
	Chrysomelidae	<i>Capraita</i>	<i>thymoides</i> (Crotch)	I98,N98,R98	BT,PF,SW	7
	Chrysomelidae	<i>Ceratoma</i>	<i>trifurcata</i> (Forster)	N98,R98	SW	2
	Chrysomelidae	<i>Chaetocnema</i>	<i>denticulata</i> (Illiger)	I97,N98	SW	2
	Chrysomelidae	<i>Chaetocnema</i>	<i>pulicaria</i> Melsheimer	I98,N98	BT,SW	4
	Chrysomelidae	<i>Charidotella</i>	<i>bicolor</i> (Fabricius)	N98,R98	SW	3
	Chrysomelidae	<i>Charidotella</i>	<i>purpurata</i> (Boheman)	I98	SW	1
	Chrysomelidae	<i>Chelymorpha</i>	<i>cassidea</i> Linnaeus	I98,R98	SW	3
	Chrysomelidae	<i>Chrysolina</i>	<i>inornata</i> (Rogers)	N97,R98	BT,SW	3
	Chrysomelidae	<i>Colaspis</i>	<i>brunnea</i> (Fabricius)	I97,I98,N98,R98	BT,LT,ML,PF,SW	31
	Chrysomelidae	<i>Colaspis</i>	<i>favosa</i> Say	R98	SW	2
	Chrysomelidae	<i>Coscinoptera</i>	<i>dominicana</i> (Fabricius)	I98,N98	SW	3
	Chrysomelidae	<i>Cryptocephalus</i>	<i>venustus</i> Fabricius	I98,N98,R98	BT,EG,SW	9
	Chrysomelidae	<i>Diabrotica</i>	<i>cristata</i> Harris	I98,N98,R98	BT,EG,LT,SW	23
	Chrysomelidae	<i>Diabrotica</i>	<i>undecimpunctata howardi</i> Barber	I97,I98,N97,N98,R98	BT,EG,ML,SW	139
	Chrysomelidae	<i>Disomycha</i>	<i>admirabilis</i> Blatchley	I98,N98,R98	BT,SW	10

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Chrysomelidae	<i>Disonycha</i>	species 1	I98,N98	BT,EG,SW	14
	Chrysomelidae	<i>Graphops</i>	<i>marcassita</i> (Crotch)	I98,R98	LI,PF	3
	Chrysomelidae	<i>Griburius</i>	<i>scutellaris</i> (Fabricius)	I98,N98	SW	5
	Chrysomelidae	<i>Kuschelina</i>	<i>fallax</i> (Melsheimer)	I98,N98,R98	BT,ML,SW	8
	Chrysomelidae	<i>Kuschelina</i>	<i>fimbriata</i> (Forster)	N98,R98	BT,SW	3
	Chrysomelidae	<i>Kuschelina</i>	<i>gibbitarsa</i> (Say)	N98	DI	1
	Chrysomelidae	<i>Kuschelina</i>	<i>vians</i> (Illiger)	N98	ML	1
	Chrysomelidae	<i>Luperaltica</i>	<i>nigripalpis</i> (LeConte)	I97,I98,N97,N98,R98	BT,EG,ML,SW	72
	Chrysomelidae	<i>Microrhopala</i>	<i>vittata</i> (Fabricius)	N98	SW	3
	Chrysomelidae	<i>Nodonota</i>	<i>clypealis</i> Horn	I98,N98	BT,SW	5
	Chrysomelidae	<i>Nodonota</i>	<i>tristis</i> (Olivier)	I98,N98	BT,SW	5
	Chrysomelidae	<i>Odontota</i>	<i>dorsalis</i> (Thunberg)	N98	EG	1
	Chrysomelidae	<i>Opacinota</i>	<i>bisignata</i> (Boheman)	I98,R98	ML,PF,SW	4
	Chrysomelidae	<i>Ophraella</i>	<i>cribrata</i> (LeConte)	I97,I98,N98,R98	BT,SW	15
	Chrysomelidae	<i>Ophraella</i>	<i>notata</i> (Fabricius)	I97,I98,N97,N98,R98	BT,EG,SW	20
	Chrysomelidae	<i>Pachybrachis</i>	<i>luridus</i> (Fabricius)	N98,R98	SW	7
	Chrysomelidae	<i>Pachybrachis</i>	<i>nigricornis carbonarius</i> Haldeman	N98	SW	2
	Chrysomelidae	<i>Pachybrachis</i>	<i>trinotatus</i> (Melsheimer)	N98	EG	1
	Chrysomelidae	<i>Paria</i>	<i>scutellaris</i> Notman	I98	SW	4
	Chrysomelidae	<i>Paria</i>	<i>sellata</i> (Horn)	I97,I98,N97,N98	LI,SW	8
	Chrysomelidae	<i>Saxinus</i>	<i>omogera</i> Lacordaire	I98,N98,R98	BT,SW	9
	Chrysomelidae	<i>Sumitrosis</i>	<i>ancoroides</i> (Schaeffer)	I98	EG	1
	Chrysomelidae	<i>Systema</i>	<i>elongata</i> (Fabricius)	N98	SW	1
	Chrysomelidae	<i>Systema</i>	<i>hudsonias</i> (Forster)	N98,R98	ML,SW	9
	Chrysomelidae	<i>Tymnes</i>	<i>metasternalis</i> Crotch	N98	BT	1
	Chrysomelidae	<i>Typophorus</i>	<i>nigritus viridicyaneus</i> Crotch	I98	SW	2
	Chrysomelidae	<i>Zygogramma</i>	<i>suturalis</i> (Fabricius)	R98	DI,PF,SW	3

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Cicindelidae	<i>Cicindela</i>	<i>unipunctata</i> Fabricius	R98	PF	1
	Cicindelidae	<i>Megacephala</i>	<i>virginica</i> Linnaeus	I98,N98,R98	PF	6
	Coccinellidae	<i>Brachyacantha</i>	<i>ursina</i> (Fabricius)	N98	ML	1
	Coccinellidae	<i>Coccinella</i>	<i>septempunctata</i> Linnaeus	I97,I98,N97,N98	BT,DI,SW	11
	Coccinellidae	<i>Coleomegilla</i>	<i>maculata lengi</i> Timberlake	I98,N98,R98	ML,SW	6
	Coccinellidae	<i>Cycloneda</i>	<i>munda</i> (Say)	I97,I98,N97,N98,R98	BT,ML,SW	9
	Coccinellidae	<i>Epilachna</i>	<i>varivestis</i> Mulsant	N97	BT	1
	Coccinellidae	<i>Harmonia</i>	<i>axyridis</i> (Pallas)	I98	SW	1
	Coccinellidae	<i>Myzia</i>	<i>pullata</i> (Say)	I97	BT	2
	Curculionidae	<i>Anthonomus</i>	<i>disjunctus</i> LeConte	R98	SW	1
	Curculionidae	<i>Anthonomus</i>	<i>elongatus</i> LeConte	R98	SW	1
	Curculionidae	<i>Anthonomus</i>	<i>molochinus</i> Dietz	I97,N97,R98	SW	4
	Curculionidae	<i>Apion</i>	<i>segnipes</i> Say	N98	SW	2
	Curculionidae	<i>Apion</i>	<i>species 1</i>	I98	SW	1
	Curculionidae	<i>Apion</i>	<i>species 3</i>	I97	BT	1
	Curculionidae	<i>Auleutes</i>	<i>tenuipes</i> (LeConte)	R98	SW	1
	Curculionidae	<i>Baris</i>	<i>aerea</i> (Boheman)	I98,N98	PF,SW	3
	Curculionidae	<i>Chalcodermus</i>	<i>collaris</i> Horn	R98	SW	1
	Curculionidae	<i>Cyrtopistomis</i>	<i>castaneus</i> (Roelofs)	N98	ML	1
	Curculionidae	<i>Epicaerus</i>	<i>imbricatus</i> (Say)	N98,R98	BT,PF,SW	5
	Curculionidae	<i>Geraeus</i>	<i>perscillus</i> (Gyllenhal)	R98	ML	1
	Curculionidae	<i>Geraeus</i>	<i>picumnus</i> (Herbst)	I97,I98,R98	BT,SW	3
	Curculionidae	<i>Graphognathus</i>	<i>leucoloma</i> (Boheman)	N98	SW	2
	Curculionidae	<i>Gymnetron</i>	<i>pascuorum</i> (Gyllenhal)	N98	SW	5
	Curculionidae	<i>Haplorhynchites</i>	<i>aeneus</i> (Boheman)	I98,R98	DI,EG,SW	5
	Curculionidae	<i>Listronotus</i>	<i>species 1</i>	N98	EG	1
	Curculionidae	<i>Myrmex</i>	<i>chevrolati</i> (Horn)	R98	EG	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Curculionidae	<i>Odontocorymus</i>	<i>boonei</i> Casey	I98,N98,R98	BT,SW	12
	Curculionidae	<i>Odontocorymus</i>	<i>illini</i> Casey	N97	SW	2
	Curculionidae	<i>Odontocorymus</i>	<i>iowensis</i> Casey	N97	SW	1
	Curculionidae	<i>Odontocorymus</i>	<i>salebrosus</i> (Casey)	I98,R98	DI,SW	6
	Curculionidae	<i>Odontocorymus</i>	sp.	I98,N98,R98	EG	15
	Curculionidae	<i>Pantomorus</i>	<i>tessellatus</i> (Say)	I97,I98,N97,N98,R98	BT,SW	60
	Curculionidae	<i>Rhyssomatus</i>	<i>palmacollis</i> (Say)	I97	BT	1
	Curculionidae	<i>Smicronyx</i>	<i>sordidus</i> LeConte	N98	SW	2
	Curculionidae	<i>Smicronyx</i>	<i>squalidus</i> Casey	R98	SW	1
	Curculionidae	<i>Sphenophorus</i>	<i>parvulus</i> Gyllenhal	R98	EG	1
	Curculionidae	<i>Tachyerges</i>	<i>niger</i> (Horn)	I97,N97,R98	BT,SW	3
	Curculionidae	<i>Tachyerges</i>	<i>salicis</i> (Linnaeus)	I98	SW	1
	Curculionidae	<i>Thecestermus</i>	<i>affinis</i> (LeConte)	N98	SW	1
	Curculionidae	<i>Tyloderma</i>	<i>fragariae</i> (Riley)	I97,I98,N98,R98	BT,PF	5
	Dermestidae	<i>Cryptorhopalum</i>	<i>triste</i> LeConte	I98	SW	1
	Dryopidae	<i>Helichus</i>	<i>lithophilus</i> (Germar)	R98	LT	10
	Dytiscidae	<i>Copelatus</i>	<i>glyphicus</i> (Say)	R98	LT	1
	Dytiscidae	<i>Coptotomus</i>	<i>lenticus</i> Hilsenhoff	R98	LT	6
	Dytiscidae	<i>Thermonectus</i>	<i>basillaris</i> (Harris)	I98	LT	1
	Elateridae	<i>Aeolus</i>	<i>mellillus</i> (Say)	N98,R98	PF	6
	Elateridae	<i>Dicrepidius</i>	<i>palmatius</i> Candeze	N98	LT	1
	Elateridae	<i>Limoniis</i>	<i>griseus</i> Beauvois	I98	SW	3
	Elateridae	<i>Orthostethus</i>	<i>infuscatus</i> (Germar)	N98	LT	2
	Eucinetidae	<i>Eucinetus</i>	<i>terminalis</i> LeConte	I98	SW	1
	Halipidae	<i>Halipus</i>	<i>triopsis</i> Say	R98	LT	1
	Heteroceridae	<i>Heterocerus</i>	species 1	R98	LT	5
	Heteroceridae	<i>Tropicus</i>	<i>pusillus</i> (Say)	R98	LT	2

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Histeridae	<i>Hister</i>	<i>carinifrons</i> Schaeffer	I97,N98	PF	2
	Histeridae	<i>Hister</i>	<i>fungicola</i> Schaeffer	I97,I98,N98,R98	ML,PF	56
	Histeridae	<i>Hister</i>	<i>servus</i> Erichson	I97	PF	1
	Hydrophilidae	<i>Berosus</i>	<i>infuscatus</i> LeConte	I98,R98	LT	65
	Hydrophilidae	<i>Berosus</i>	<i>striatus</i> Say	I98	LT	1
	Hydrophilidae	<i>Hydrochara</i>	<i>soror</i> Smetana	N98	LT	1
	Languriidae	<i>Languria</i>	<i>angustata</i> (Beauvois)	I98	SW	1
	Languriidae	<i>Languria</i>	<i>mozardi</i> Latreille	I98,N98	PF,SW	11
	Leptodiridae	<i>Catops</i>	<i>simplex</i> Say	I97	BT	1
	Leptodiridae	<i>Ptomophagus</i>	<i>consobrinus</i> (LeConte)	I97	PF	1
	Meloidae	<i>Epicauta</i>	<i>atrata</i> (Fabricius)	I98	DI,ML,SW	12
	Meloidae	<i>Epicauta</i>	<i>pensylvanica</i> (DeGeer)	I97,I98,N98,R98	EG,LT,ML,PF,SW	20
	Meloidae	<i>Epicauta</i>	<i>pestifera</i> Werner	R98	EG,SW	2
	Meloidae	<i>Epicauta</i>	<i>vittata</i> (Fabricius)	I98,R98	DI,LT,PF	3
	Meloidae	<i>Meloe</i>	<i>americanus</i> Leach	I97	PF	1
	Meloidae	<i>Zonitis</i>	<i>bilineata</i> Say	I98	EG	1
	Mordellidae	<i>Mordellistena</i>	<i>divisa</i> LeConte	N98	EG	2
	Mordellidae	<i>Mordellistena</i>	<i>trifasciata</i> (Say)	I98	EG	1
	Nitidulidae	<i>Carpophilus</i>	<i>hemipterus</i> (Linnaeus)	R98	LT	1
	Oedomeridae	<i>Oxycopsis</i>	<i>thoracica</i> (Fabricius)	N98	SW	1
	Rhipiphoridae	<i>Macrosiagon</i>	<i>dimidiatum</i> (Fabricius)	N98,R98	BT,DI,SW	5
	Scarabaeidae	<i>Anomala</i>	<i>innuba</i> (Fabricius)	N98	SW	1
	Scarabaeidae	<i>Anomala</i>	<i>marginata</i> (Fabricius)	I98,N98,R98	LT,ML,SW	10
	Scarabaeidae	<i>Bolbocerosoma</i>	<i>bruneri</i> Dawson & McColloch	I98,N98,R98	PF	133
	Scarabaeidae	<i>Bolbocerosoma</i>	<i>farctum</i> (Fabricius)	I98,N98,R98	PF	80
	Scarabaeidae	<i>Canthon</i>	<i>chalcites</i> (Haldeman)	N98	PF	7
	Scarabaeidae	<i>Copris</i>	<i>minutus</i> (Drury)	I98,N97,N98	BT,PF,SW	8

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Scarabaeidae	<i>Copris</i>	<i>tullius</i> (Olivier)	I97,N97,R98	PF	4
	Scarabaeidae	<i>Dyscinetus</i>	<i>morator</i> (Fabricius)	R98	LT	1
	Scarabaeidae	<i>Euphoria</i>	<i>sepulchralis</i> (Fabricius)	I97,I98,N98,R98	PF	12
	Scarabaeidae	<i>Geotrupes</i>	<i>egeriei</i> Germar	N98	PF	1
	Scarabaeidae	<i>Hoplia</i>	<i>modesta</i> Haldeman	I98,N98,R98	DI,PF,SW	7
	Scarabaeidae	<i>Onthophagus</i>	<i>hecate</i> Panzer	I97,I98,N97,N98,R98	PF,SW	8
	Scarabaeidae	<i>Onthophagus</i>	<i>orpheus</i> Panzer	I98,N98	PF	3
	Scarabaeidae	<i>Onthophagus</i>	<i>tuberculifrons</i> Harold	I97,N97	PF	4
	Scarabaeidae	<i>Phanaeus</i>	<i>vindex</i> MacLeay	N98	PF	1
	Scarabaeidae	<i>Pleurophorus</i>	<i>atlanticus</i> Cartwright	I97,N97,R98	LI	28
	Scarabaeidae	<i>Popillia</i>	<i>japonica</i> Newman	I98,N98,R98	BT,DI,EG,ML,SW	81
	Scarabaeidae	<i>Serica</i>	species 1	R98	PF	1
	Scarabaeidae	<i>Trichiotinus</i>	<i>bibens</i> (Fabricius)	R98	DI	1
	Scarabaeidae	<i>Trichiotinus</i>	<i>piger</i> (Fabricius)	R98	DI	1
	Silphidae	<i>Necrodes</i>	<i>surinamensis</i> (Fabricius)	N98,R98	LT	6
	Silphidae	<i>Nicrophorus</i>	<i>marginatus</i> Fabricius	I98,R98	PF	5
	Staphylinidae	<i>Homaeotarsus</i>	<i>capito</i> (Casey)	R98	PF	1
	Staphylinidae	<i>Homaeotarsus</i>	<i>pimerianus</i> (LeConte)	R98	LT	15
	Staphylinidae	<i>Osorius</i>	<i>planifrons</i> LeConte	I98	PF	1
	Staphylinidae	Genus B	species 2	R98	LT	1
	Staphylinidae	Genus C	species 3	N98	PF	1
	Staphylinidae	Genus D	species 4	R98	LT	3
	Staphylinidae	Genus F	species 21	N98	LT	1
	Staphylinidae	Genus H	species 8	N98	ML	1
	Staphylinidae	Genus L	species 12	N97	SW	1
	Staphylinidae	Genus Q	species 26	N98,R98	LT	150
	Staphylinidae	Genus Q	species 27	N98	LT	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Coleoptera	Staphylinidae	<i>Staphylinus</i>	<i>fossator</i> Gravenhorst	N97,R98	PF	6
	Staphylinidae	<i>Staphylinus</i>	<i>maculosus</i> Gravenhorst	I98,N98	PF	3
	Staphylinidae	<i>Sunius</i>	<i>confluentus</i> (Say)	R98	LT	1
Collembola	Brachystomellidae	<i>Brachystomella</i>	sp.	I97	PF	1
	Entomobryidae	<i>Entomobrya</i>	sp.	I97	PF	1
	Entomobryidae	<i>Homidia</i>	<i>socia</i> Denis	N97	LI	1
	Entomobryidae	<i>Lepidocyrtus</i>	<i>cinereus</i> Folsom	I97,N97	LI,PF	25
	Entomobryidae	<i>Lepidocyrtus</i>	species 2	I97,N97	LI,PF	17
	Entomobryidae	<i>Orchesella</i>	sp.	I97,N97	LI,PF	6
	Entomobryidae	<i>Pseudosinella</i>	<i>violenta</i> (Folsom)	I97,N97	LI	2
	Hypogastruridae	<i>Hypogastrura</i>	species 1	I97,N97	LI,PF	91
	Isotomidae	<i>Folsomia</i>	<i>duodecimoculata</i> Ford	N97	LI	66
	Isotomidae	<i>Folsomia</i>	<i>stella</i> Christiansen & Tucker	N97	LI	1
	Isotomidae	<i>Folsomides</i>	<i>parvulus</i> Stach	I97	LI	1
	Isotomidae	<i>Folsomina</i>	<i>onychiurina</i> Denis	N97	LI	1
	Isotomidae	<i>Isotoma</i>	species 1	N97	LI	7
	Isotomidae	<i>Isotoma</i>	<i>viridis</i> Bourlet	I97,N97	LI,PF	43
	Isotomidae	<i>Isotomurus</i>	<i>bimus</i> Christiansen & Belli	I97	LI	2
	Isotomidae	<i>Isotomurus</i>	sp.	N97	LI	4
	Neanuridae	<i>Anurida</i>	<i>harti</i> Christiansen & Belli	I97	LI	1
	Neanuridae	<i>Pseudachorutes</i>	sp.	I97,N97	LI,PF	26
	Neanuridae	<i>Sensillamura</i>	sp.	N97	LI	1
	Onychiuridae	<i>Onychiurus</i>	<i>encarpatus</i> Denis	N97	LI	4
	Onychiuridae	<i>Onychiurus</i>	sp.	N97	LI	9
	Onychiuridae	<i>Tullbergia</i>	<i>silvicola</i> Folsom	N97	LI	3
	Onychiuridae	<i>Tullbergia</i>	<i>yosiii</i> Rusek	N97	LI	3
	Sminthuridae	<i>Neosminthurus</i>	sp.	I97,N97	LI	12

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Collembola	Sminthuridae	<i>Sminthurides</i>	<i>malmgreni</i> (Tullberg)	I97,N97	LI	50
	Sminthuridae	<i>Sminthurinus</i>	<i>henshawi</i> (Folsom)	I97,N97	LI	7
	Sminthuridae	<i>Sminthurus</i>	<i>butcheri</i> Snider	I97	PF	5
	Sminthuridae	<i>Sminthurus</i>	species 2	I97,N97	LI	4
	Sminthuridae	<i>Sphaeridia</i>	<i>pumilis</i> (Krausbauer)	I97	LI	2
	Tomoceridae	<i>Tomocerus</i>	<i>flavescens</i> Tullberg	I97,I98,N97,N98,R98	LI,ML,PF	3114
	Tomoceridae	<i>Tomocerus</i>	sp.	I97,N97	PF	31
Dermaptera	Labiidae	<i>Labia</i>	species 1	R98	LT	5
Diplura	Japygidae	<i>Parajapyx</i>	<i>isabellae</i> (Grassi)	N97	LI	1
Diptera	Agromyzidae	<i>Melanagromyza</i>	species 1	I98,N98	ML,ST	3
	Anthomyiidae	<i>Adia</i>	species 1	I97	PF	1
	Anthomyiidae	<i>Botanophila</i>	species 1	I97	ML	3
	Anthomyiidae	<i>Fucellia</i>	species 1	I97	PF	1
	Anthomyiidae	<i>Hylema</i>	<i>alcathoe</i> (Walker)	I98,N98	ML,PF,SW	5
	Anthomyiidae	<i>Lasiomma</i>	species 1	I98	PF	1
	Anthomyiidae	<i>Pegohylemyia</i>	species 1	N97,N98	ML,ST	4
	Anthomyiidae	<i>Pegomya</i>	species 1	I98,N98	PF	2
	Asilidae	<i>Asilus</i>	species 1	R98	SW	1
	Asilidae	<i>Atomosia</i>	species 1	I97,I98,N97,N98,R98	BT,ML,MN,ST,SW	32
	Asilidae	<i>Diogmites</i>	species 1	R98	DI	1
	Asilidae	<i>Efferia</i>	<i>estuans</i> (Linnaeus)	I98,N98,R98	ML,SW	7
	Asilidae	<i>Efferia</i>	species 1	I98,N98,R98	DI,ML,MN,SW	7
	Asilidae	<i>Ommatius</i>	<i>gemma</i> Brimley	I98,N98	SW	2
	Bibionidae	<i>Bibio</i>	species 1	N97,N98,R98	ML,PF,ST	30
	Bibionidae	<i>Dilophus</i>	species 1	I98	SW	1
	Bombyliidae	<i>Anthrax</i>	species 1	R98	DI	1
	Bombyliidae	<i>Bombylius</i>	species 1	I98	DI	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Diptera	Bombyliidae	<i>Sparnopolius</i>	<i>lherminieri</i> (Macquart)	N97	ML	1
	Bombyliidae	<i>Villa</i>	species 1	I98	ML	1
	Calliphoridae	<i>Calliphora</i>	species 1	I98,N98	ST,SW	3
	Calliphoridae	<i>Phaenicia</i>	species 1	N97,N98	PF,ST	5
	Ceratopogonidae	<i>Dasyhelea</i>	species 1	R98	ML	1
	Chironomidae	<i>Orthocladius</i>	species 1	N97,N98	ML,ST	33
	Chloropidae	<i>Apallates</i>	sp.	I97,I98,N97,N98,R98	BT,ML,PF,ST,SW	89
	Chloropidae	<i>Chlorops</i>	species 1	I98,N97,N98,R98	ML,PF,ST	12
	Chloropidae	<i>Conioscinella</i>	species 1	I97,I98,N98	ML,ST	10
	Chloropidae	<i>Ectecephala</i>	species 1	I98	SW	3
	Chloropidae	<i>Elachiptera</i>	species 1	I97	BT	1
	Chloropidae	<i>Incertella</i>	species 1	I97,N97,R98	ML,ST	44
	Chloropidae	<i>Liohippelates</i>	species 1	I98,N97	ML,ST	21
	Chloropidae	<i>Olcella</i>	<i>cinerea</i> (Loew)	N98	ST	17
	Chloropidae	<i>Parectecephala</i>	species 1	N98	BT	2
	Chloropidae	<i>Thaumatomyia</i>	species 1	I97,I98,R98	ML,PF	3
	Culicidae	<i>Culex</i>	species 1	I97	ST	4
	Dolichopodidae	<i>Campsicnemus</i>	species 1	I98	ML	1
	Dolichopodidae	<i>Chrysotus</i>	sp.	I97,I98,N98,R98	BT,ML,MN,ST,SW	18
	Dolichopodidae	<i>Condyllostylus</i>	species 1	I97,I98,N98,R98	ML,ST,SW	19
	Dolichopodidae	<i>Dolichopus</i>	sp.	I97,I98,N98,R98	ML,MN,ST	10
	Dolichopodidae	<i>Gymnopternus</i>	species 1	I97,I98,N98	ML,SW	5
	Dolichopodidae	<i>Medetera</i>	species 1	I98	ST	11
	Dolichopodidae	<i>Sympycnus</i>	<i>lineatus</i> Loew	I98	ML	4
	Dolichopodidae	<i>Tachytrechus</i>	species 1	N98,R98	ML,ST	5
	Drosophilidae	<i>Drosophila</i>	species 1	N98	ML,ST	3
	Drosophilidae	<i>Scaptomyza</i>	species 1	I97,I98,N98,R98	ML,PF,ST	13

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Diptera	Empididae	<i>Empis</i>	species 1	I97,I98,N98	ML,ST	15
	Empididae	<i>Euthyneura</i>	<i>bucinator</i> Melander	N98	ML	2
	Empididae	<i>Rhamphomyia</i>	species 1	I98,N97,N98	ML,ST,SW	13
	Ephydriidae	<i>Allotrichoma</i>	<i>atrilabre</i> Cresson	I98	MN	1
	Ephydriidae	<i>Callinapaea</i>	species 1	N97	ML	1
	Ephydriidae	<i>Paralimna</i>	<i>punctipennis</i> (Weidemann)	I98,N98,R98	PF,SW	9
	Lauxaniidae	<i>Poecilominettia</i>	<i>ordinaria</i> (Melander)	N98	BT	1
	Milichiidae	<i>Phleomyia</i>	species 1	N98	SW	1
	Muscidae	<i>Caricea</i>	species 1	I97,N98	ML,ST	3
	Muscidae	<i>Coenosia</i>	species 1	I97,I98,N97,N98	ML,SW	10
	Muscidae	<i>Hydrotaea</i>	species 1	N98,R98	ML,PF,ST	7
	Muscidae	<i>Musca</i>	<i>autumnalis</i> DeGeer	I97,I98,R98	BT,ST	6
	Muscidae	<i>Stomoxys</i>	<i>calcitrans</i> (Linnaeus)	N98	ML	1
	Mycetophilidae	<i>Exechia</i>	species 1	I98	PF	1
	Mycetophilidae	<i>Mycetophila</i>	species 1	I97,I98,N97,N98,R98	ML,PF,ST	37
	Mycetophilidae	<i>Rymosia</i>	species 1	I97	PF	1
	Mydidae	<i>Mydas</i>	species 1	R98	BT	1
	Otitidae	<i>Chaetopsis</i>	sp.nr. <i>apicalis</i> Johnson	I97,I98,N98	ST,SW	6
	Otitidae	<i>Euxesta</i>	species 1	R98	ST	15
	Otitidae	<i>Tritoxa</i>	<i>flexa</i> (Wiedemann)	N98	SW	1
	Phoridae	<i>Dohrniphora</i>	species 1	I98,N98,R98	ML,PF,ST	14
	Phoridae	<i>Triphleba</i>	<i>lugubris</i> (Meigen)	I97,I98	ML,ST	48
	Pipunculidae	<i>Pipunculus</i>	species 1	I98	ML	2
	Pipunculidae	<i>Tomosvaryella</i>	species 1	I98	ML,ST	3
	Platystomatidae	<i>Rivellia</i>	species 1	I98	ML	5
	Sarcophagidae	<i>Anolisimyia</i>	<i>blackeae</i> Dodge	R98	SW	1
	Sarcophagidae	<i>Bellieria</i>	<i>melanura</i> (Meigen)	I98	SW	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies	Author	Sites ^a	Sampling Method ^b	No. ^c
Diptera	Sarcophagidae	<i>Bercaeopsis</i>	species 1		I98	ML,MN	2
	Sarcophagidae	<i>Boettcheria</i>	species 1		I97	PF	1
	Sarcophagidae	<i>Metopasarcophaga</i>	species 1		N98,R98	DI,SW	2
	Sarcophagidae	<i>Microcerella</i>	sp.nr. <i>hypopygia</i>	(Townsend)	N98	SW	1
	Sarcophagidae	<i>Ravinia</i>	species 1		I97	SW	1
	Sarcophagidae	<i>Titanogrypa</i>	<i>alata</i>	(Aldrich)	I98	SW	1
	Sciaridae	<i>Bradysia</i>	species 1		R98	PF	1
	Sciaridae	<i>Chaetosciara</i>	<i>joffrei</i>		I97	ML	1
	Sciaridae	<i>Corynoptera</i>	sp.		I98,N97,R98	ML,PF,ST	684
	Sciaridae	<i>Pseudosciara</i>	<i>forceps</i>		I97	PF	1
	Sciaridae	<i>Sciara</i>	species 1		I98,N98,R98	LT,ML	12
	Sciomyzidae	<i>Euthycera</i>	<i>arcuata</i>	(Loew)	I97,I98,N98,R98	BT,DI,PF,SW	36
	Sciomyzidae	<i>Limnia</i>	sp.nr. <i>boscii</i>	(Robineau-Desvoidy)	I98,N97,N98	ML,ST,SW	13
	Sphaeroceridae	<i>Leptocera</i>	<i>frontalis</i>	(Fallen)	I98	ML	1
	Stratiomyidae	<i>Hedriodiscus</i>	species 1		N98	SW	3
	Stratiomyidae	<i>Labostigmina</i>	species 1		I98	DI	1
	Syrphidae	<i>Epistrophella</i>	species 1		N98	SW	3
	Syrphidae	<i>Melangya</i>	species 1		I98,N98	ML	2
	Syrphidae	<i>Microdon</i>	species 1		I98	ML	2
	Syrphidae	<i>Milesia</i>	species 1		N98	DI	1
	Syrphidae	<i>Psilota</i>	<i>buccata</i>	(Macquart)	I98	SW	1
	Syrphidae	<i>Syrphus</i>	species 1		I97,I98,N98,R98	ML,ST,SW	10
	Syrphidae	<i>Toxomerus</i>	sp.nr. <i>jussiaeae</i>	Vige	I98,R98	ML	3
	Tabanidae	<i>Hybomitra</i>	<i>lasiophthalma</i>	(Macquart)	I98,N98	ML,MN	10
	Tabanidae	<i>Stonemyia</i>	<i>isabellina</i>	(Wiedemann)	I98	DI	1
	Tabanidae	<i>Tabanus</i>	<i>calens</i>	Linnaeus	I98,R98	DI	2
	Tabanidae	<i>Tabanus</i>	<i>fuscicostatus</i>	Hine	I98	MN	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Diptera	Tabanidae	<i>Tabanus</i>	<i>lineola</i> Fabricius	I98,N97	MN,ST	2
	Tabanidae	<i>Tabanus</i>	<i>molestus molestus</i> Say	I98,N98	ML,MN	2
	Tabanidae	<i>Tabanus</i>	<i>mularis</i> Stone	I98,N98,R98	EG,ML,SW	10
	Tabanidae	<i>Tabanus</i>	<i>quinquemaculatus</i>	N98	ML	1
	Tabanidae	<i>Tabanus</i>	<i>quinquevittatus</i> Wiedemann	I98,N98	ML	5
	Tabanidae	<i>Tabanus</i>	<i>subsimilis</i> Macquart	I98,N98	ML	2
	Tachinidae	<i>Belvosia</i>	species 1	I98	MN	2
	Tachinidae	<i>Campylochaeta</i>	species 1	N97	ML	1
	Tachinidae	<i>Catharosia</i>	<i>nebulosa</i> (Coquillett)	I98,N98	ML,ST	20
	Tachinidae	<i>Chaetogaedia</i>	sp.nr. <i>townsendi</i> Sabrosky & Arnaud	I98	MN	1
	Tachinidae	<i>Copecrypta</i>	<i>ruficauda</i> (Wulp)	R98	DI	1
	Tachinidae	<i>Cylindromyia</i>	species 1	R98	SW	1
	Tachinidae	<i>Eumasicera</i>	species 1	I98	ML	1
	Tachinidae	<i>Gnadochaeta</i>	species 1	I98	MN	1
	Tachinidae	<i>Gymnosoma</i>	species 1	N98,R98	ML,ST,SW	7
	Tachinidae	<i>Lespesia</i>	species 1	N98	SW	1
	Tachinidae	<i>Ochrocera</i>	<i>vaginalis</i> Townsend	I98	MN	1
	Tachinidae	<i>Paradidyma</i>	species 1	N98,R98	SW	2
	Tachinidae	<i>Siphona</i>	species 1	I98	ML	1
	Tachinidae	<i>Tachina</i>	species 1	R98	DI	1
	Tachinidae	<i>Thelaira</i>	<i>americana</i> Brooks	I98	SW	1
	Tachinidae	<i>Xanthophyto</i>	<i>antennalis</i> (Townsend)	N98	ML	1
	Tephritidae	<i>Euaresta</i>	species 1	I98,N98	BT,SW	3
	Tephritidae	<i>Procecidochares</i>	species 1	I98	SW	1
	Tephritidae	<i>Stenopa</i>	<i>vulnerata</i> (Loew)	N98	SW	1
	Tephritidae	<i>Tomoplagia</i>	<i>obliqua</i> (Say)	I98	ML	1
	Tephritidae	<i>Trupanea</i>	species 1	I98,R98	SW	2

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Diptera	Tipulidae	<i>Erioptera</i>	species 1	I97,N97,N98,R98	ML,ST,SW	11
Hemiptera	Alydidae	<i>Alydus</i>	<i>eurinus</i> (Say)	I97,I98,N97,N98,R98	BT,EG,ML,PF,SW	50
	Alydidae	<i>Alydus</i>	<i>pilosulus</i> (Herrich-Schaeffer)	I97,I98,N97,N98,R98	BT,ML,PF,SW	21
	Coreidae	<i>Archimerus</i>	<i>calcarator</i> (Fabricius)	N98	BT	1
	Coreidae	<i>Euthochtha</i>	<i>galeator</i> (Fabricius)	I98,N98,R98	DI,EG,PF,SW	8
	Coreidae	<i>Leptoglossus</i>	<i>phyllopus</i> (Linnaeus)	R98	SW	2
	Coreidae	<i>Mercoris</i>	<i>typhaeus</i> (Fabricius)	I98,N98,R98	BT,EG,SW	18
	Corimelaenidae	<i>Corimelaena</i>	<i>lateralis</i> (Fabricius)	I98,N98,R98	BT,DI,SW	19
	Corimelaenidae	<i>Corimelaena</i>	<i>marginella</i> Dallas	R98	BT,SW	3
	Corimelaenidae	<i>Corimelaena</i>	<i>pulicaria</i> (Germar)	I98,N98,R98	BT,SW	21
	Cydnidae	<i>Microporus</i>	<i>obliquus</i> Uhler	N97	SW	1
	Cydnidae	<i>Pangaeus</i>	<i>bilineatus</i> (Say)	I97,I98,N97	BT,PF	20
	Cydnidae	<i>Sehirus</i>	<i>cinctus</i> (Palisot de Beauvois)	I98,R98	BT,SW	3
	Lygaeidae	<i>Ischnodemus</i>	species 1	I97,N97	BT,PF	5
	Lygaeidae	<i>Ischnorrhynchus</i>	<i>resedae</i> (Panzer)	R98	SW	7
	Lygaeidae	<i>Ligyrocoris</i>	<i>diffusus</i> (Uhler)	I97,I98,N97,N98,R98	BT,ML,PF,SW	38
	Lygaeidae	<i>Lygaeus</i>	<i>bicrucis</i> Say	I97,N98,R98	BT,LT,SW	8
	Lygaeidae	<i>Malezonotus</i>	<i>sodalicius</i> (Uhler)	I98,R98	PF,SW	52
	Lygaeidae	<i>Myodoca</i>	<i>annulicornis</i> Blatchley	R98	PF	8
	Lygaeidae	<i>Myodoca</i>	<i>serripes</i> Olivier	I98,N98,R98	ML,PF	16
	Lygaeidae	<i>Oedancala</i>	<i>dorsilinea</i> Amyot & Serville	I98,N98,R98	BT,SW	16
	Lygaeidae	<i>Orthaea</i>	<i>basalis</i> (Dallas)	I98,N98,R98	PF	58
	Lygaeidae	<i>Ortholomus</i>	<i>scolopax</i> (Say)	I97,I98,N98,R98	BT,ML,SW	27
	Lygaeidae	<i>Paromius</i>	<i>longulus</i> (Dallas)	N98,R98	BT,PF,SW	35
	Lygaeidae	<i>Perigenes</i>	<i>constrictus</i> (Say)	I97	PF	2
	Lygaeidae	<i>Phlegyas</i>	<i>abbreviatus</i> (Uhler)	I98,N98	SW	13
	Lygaeidae	<i>Sphragisticus</i>	species 1	I97,R98	LI,PF	2

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Hemiptera	Lygaeidae	<i>Zeridoneus</i>	<i>costalis</i> (Van Duzee)	I98	PF	2
	Miridae	<i>Lygus</i>	<i>lineolaris</i> (Palisot de Beauvois)	I97,I98,N97,N98,R98	BT,LT,SW	204
	Miridae	<i>Stenodema</i>	<i>trispinosum</i> Reuter	R98	LT	1
	Miridae	<i>Stenotus</i>	<i>binotatus</i> (Fabricius)	N98,R98	SW	10
	Nabidae	<i>Nabis</i>	<i>subcoleoptratus</i> (Kirby)	N98,R98	PF	2
	Pentatomidae	<i>Acrosternum</i>	<i>hilare</i> (Say)	I97,I98	BT,LT	2
	Pentatomidae	<i>Coenus</i>	<i>delius</i> (Say)	I98,N98	BT,SW	4
	Pentatomidae	<i>Euschistus</i>	<i>servus</i> (Say)	I97,I98,N98,R98	BT,EG,ML,SW	41
	Pentatomidae	<i>Mormidea</i>	<i>lugens</i> (Fabricius)	I98,N98,R98	EG,PF,SW	13
	Pentatomidae	<i>Nezara</i>	<i>viridula</i> (Linnaeus)	I98,R98	SW	2
	Pentatomidae	<i>Oebalus</i>	<i>pugnax pugnax</i> (Fabricius)	I97,I98,N98,R98	BT,DI,EG,SW	38
	Pentatomidae	<i>Stiretrus</i>	<i>anchorago</i> (Fabricius)	R98	DI	1
	Pentatomidae	<i>Thyanta</i>	<i>accerra</i> McAtee	I97,R98	LT,SW	5
	Pentatomidae	<i>Thyanta</i>	<i>calceata</i> (Say)	I98,N98,R98	BT,SW	16
	Pentatomidae	<i>Trichopepla</i>	<i>semivittata</i> (Say)	N98,R98	BT,SW	8
	Phymatidae	<i>Macrocephalus</i>	<i>cimicoides</i> Swederus	I98,N97	DI,SW	4
	Phymatidae	<i>Macrocephalus</i>	<i>prehensilis</i> (Fabricius)	N98	SW	1
	Phymatidae	<i>Phymata</i>	<i>fasciata</i> (Gray)	I98,N98,R98	BT,DI,SW	3
	Phymatidae	<i>Phymata</i>	<i>wolffii</i> Stal	I98	SW	1
	Reduviidae	<i>Sinea</i>	<i>diadema</i> (Fabricius)	I98,R98	SW	3
	Reduviidae	<i>Sinea</i>	<i>spinipes</i> (Herrich-Schaeffer)	N98	SW	1
	Reduviidae	<i>Zelus</i>	<i>cervicalis</i> Stal	I98,N98,R98	BT,SW	6
	Rhopalidae	<i>Harmostes</i>	<i>fraterculus</i> (Say)	N97,R98	BT,SW	2
	Rhopalidae	<i>Harmostes</i>	<i>reflexulus</i> (Say)	I97,I98,N97,N98,R98	BT,EG,PF,SW	41
	Rhopalidae	<i>Liorhyssus</i>	<i>hyalinus</i> (Fabricius)	I98,R98	SW	2
	Scutelleridae	<i>Homaemus</i>	<i>parvulus</i> (Germar)	N97,R98	SW	3
	Tingidae	<i>Atheas</i>	<i>austroriparius</i> Heidemann	N98,R98	BT,SW	2

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Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Homoptera	Acanaloniidae	<i>Acanalonia</i>	<i>bivittata</i> (Say)	I97,N97,N98,R98	BT,EG,SW	10
	Cercopidae	<i>Aphrophora</i>	<i>parallela</i> Say	R98	SW	1
	Cercopidae	<i>Clastoptera</i>	<i>xanthocephala</i> Germar	I98,N98,R98	SW	20
	Cercopidae	<i>Lepyronia</i>	<i>quadrangularis</i> Say	I97,I98,N98	BT,EG,SW	5
	Cercopidae	<i>Philaemus</i>	<i>leucophthalmus</i> Linnaeus	I97,I98,N98,R98	BT,SW	74
	Cercopidae	<i>Prosapia</i>	<i>bicincta</i> Say	N98,R98	LT,ML,PF,SW	24
	Cicadellidae	<i>Actinopterus</i>	<i>acuminatus</i> Van Duzee	R98	SW	1
	Cicadellidae	<i>Agallia</i>	<i>constricta</i> Van Duzee	N98,R98	EG,PF,SW	4
	Cicadellidae	<i>Aphrodes</i>	<i>albifrons</i> (Linnaeus)	I98	PF	1
	Cicadellidae	<i>Aphrodes</i>	<i>serratae</i> (Fabricius)	I98	PF	1
	Cicadellidae	<i>Aulacizes</i>	<i>irrorata</i> (Fabricius)	I97	SW	2
	Cicadellidae	<i>Chlorotettix</i>	<i>spatulatus</i> Osborn & Ball	I98,N98,R98	SW	5
	Cicadellidae	<i>Cicadula</i>	<i>longiseta</i> (Van Duzee)	I97,N98	SW	2
	Cicadellidae	<i>Ciminius</i>	<i>hartii</i> (Ball)	N98	BT	1
	Cicadellidae	<i>Cloanthus</i>	<i>species 1</i>	I97,I98,N97,N98	BT,SW	6
	Cicadellidae	<i>Cuerna</i>	<i>lateralis</i> (Fabricius)	I98,N98,R98	BT,ML,SW	30
	Cicadellidae	<i>Draeculacephala</i>	<i>antica</i> (Walker)	I97,I98,N98,R98	LT,ML,PF,SW	24
	Cicadellidae	<i>Driotura</i>	<i>grammaroides</i> (Van Duzee)	I98,R98	BT,SW	2
	Cicadellidae	<i>Eutettix</i>	<i>pictus</i> Van Duzee	N98	SW	2
	Cicadellidae	<i>Extrusamus</i>	<i>ovatus</i> (Sanders & DeLong)	N98	SW	2
	Cicadellidae	<i>Graphocephala</i>	<i>versuta</i> (Say)	I97,I98,N97,R98	BT,SW	7
	Cicadellidae	<i>Gyponana</i>	<i>species 1</i>	I97,I98,N97,N98,R98	BT,ML,SW	28
	Cicadellidae	<i>Jassus</i>	<i>olitorius</i> Say	N98	ML	2
	Cicadellidae	<i>Mesamia</i>	<i>straminea</i> (Osborn)	I97,I98,N98	BT,SW	6
	Cicadellidae	<i>Ophiola</i>	<i>anthracina</i> (Van Duzee)	I98,N98	SW	5
	Cicadellidae	<i>Ponana</i>	<i>species 2</i>	N98	SW	1
	Cicadellidae	<i>Remadosus</i>	<i>magnus</i> (Osborn & Ball)	I97	SW	1

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Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Homoptera	Cicadellidae	<i>Xerophloea</i>	species 1	I97,N98	PF,SW	3
	Cicadidae	<i>Tibicen</i>	<i>canicularis</i> (Harris)	N98	EG	1
	Dictyopharidae	<i>Phylloscelis</i>	<i>atra</i> Germar	I98,N98,R98	BT,SW	4
	Dictyopharidae	<i>Scolops</i>	<i>angustatus</i> (Uhler)	N98,R98	BT	2
	Dictyopharidae	<i>Scolops</i>	species 1	N98	SW	1
	Dictyopharidae	<i>Scolops</i>	<i>sulcipes</i> Say	I98,N98,R98	BT,SW	9
	Issidae	<i>Bruchomorpha</i>	<i>dorsata</i> Fitch	R98	PF	1
	Issidae	<i>Bruchomorpha</i>	species 1	I97,I98,N97	SW	4
	Issidae	<i>Bruchomorpha</i>	species 2	N98,R98	ML,SW	2
	Membracidae	<i>Acutalis</i>	<i>tartarea</i> (Say)	I97	BT	1
	Membracidae	<i>Archasia</i>	<i>auriculata</i> (Fitch)	N98	ST	5
	Membracidae	<i>Campylenchia</i>	<i>latipes</i> (Say)	N98,R98	BT,SW	3
	Membracidae	<i>Platycotis</i>	<i>vittata</i> (Fabricius)	I97,I98,N97	BT,ST,SW	5
	Membracidae	<i>Spissistilus</i>	<i>festinus</i> (Say)	I97,I98,N97,N98,R98	BT,SW	58
	Membracidae	<i>Stictocephala</i>	<i>lutea</i> (Walker)	I98,N98,R98	SW	19
Hymenoptera	Andrenidae	<i>Calliopsis</i>	species 1	N98	SW	1
	Anthophoridae	<i>Habropoda</i>	<i>laboriosa</i>	I98	MN	1
	Anthophoridae	<i>Melissodes</i>	species 1	I98	SW	1
	Anthophoridae	<i>Xylocopa</i>	<i>virginica</i> (Linnaeus)	I98	ML,MN	3
	Aphelinidae	<i>Aphelinus</i>	<i>mali</i> Haldeman	I98	EG	1
	Apidae	<i>Apis</i>	<i>mellifera</i> Linnaeus	I97,N98	SW	2
	Apidae	<i>Bombus</i>	<i>pennsylvanicus</i> DeGeer	I98,N98	DI,EG,MN	3
	Apidae	<i>Bombus</i>	species 1	I97,I98,N97,N98	DI,PF,SW	7
	Braconidae	<i>Apanteles</i>	<i>congregatus</i> Say	R98	ML	4
	Braconidae	<i>Apanteles</i>	<i>glomeratus</i> Linnaeus	R98	ML	2
	Braconidae	<i>Meteorus</i>	species 1	N98	EG,ST	4
	Ceraphronidae	Genus	species 1	N98	EG	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Hymenoptera	Chalcididae	<i>Comura</i>	species 1	N98	SW	1
	Chalcididae	<i>Comura</i>	species 2	I98,N98	BT,ML,SW	3
	Chrysididae	<i>Chrysis</i>	<i>coerulans</i> Fabricius	I98,N98,R98	ML,MN	14
	Diapriidae	Genus	species 1	N98	EG,LI	3
	Encyrtidae	<i>Ooencyrtus</i>	species 1	R98	EG	1
	Eucoilidae	Genus	species 1	I97	LI	1
	Eulophidae	<i>Hemiptarsenus</i>	<i>anemenus</i> Walker	I98	ST,SW	8
	Eumenidae	<i>Odynerus</i>	<i>pennsylvanicus</i> DeSaussure	I98,N98,R98	ML,SW	12
	Eupelmidae	<i>Anastatus</i>	<i>disparus</i> Ruschka	N98	PF	1
	Formicidae	<i>Aphaenogaster</i>	<i>fulva</i> Roger	I98,N98,R98	PF,SW	4
	Formicidae	<i>Aphaenogaster</i>	<i>lamellidens</i> Mayr	R98	PF	1
	Formicidae	<i>Aphaenogaster</i>	<i>treatae</i> Forel	I97,I98,N97,N98,R98	BT,LI,ML,PF	128
	Formicidae	<i>Camponotus</i>	<i>ferrugineus</i> (Fabricius)	I97,I98,N97,N98,R98	EG,ML,PF,SW	20
	Formicidae	<i>Camponotus</i>	species 5	R98	SW	1
	Formicidae	<i>Crematogaster</i>	<i>cerasi</i> (Fitch)	I97	PF	1
	Formicidae	<i>Crematogaster</i>	<i>lineolata</i> (Say)	I97,I98,N97,N98,R98	BT,LI,PF,SW	77
	Formicidae	<i>Dolichoderus</i>	<i>mariae</i> Forel	N97,R98	BT,PF	103
	Formicidae	<i>Formica</i>	<i>fusca</i> Linnaeus	I97,I98,N97,N98,R98	BT,PF,SW	46
	Formicidae	<i>Formica</i>	<i>pallidefulva niticliventri</i> Emery	I97,I98,N97,N98,R98	BT,PF,SW	8
	Formicidae	<i>Formica</i>	<i>rubicunda</i> Emery	I97,N97	BT,PF	2
	Formicidae	<i>Formica</i>	<i>schaufussi schaufussi</i> Mayr	I97,I98,N97,N98,R98	BT,EG,LI,ML,MN,PF,SW	137
	Formicidae	<i>Formica</i>	species 2	I98	SW	1
	Formicidae	<i>Lasius</i>	<i>alienus</i> (Foerster)	N98,R98	LI,PF	48
	Formicidae	<i>Monomorium</i>	<i>destructor</i> (Jerdon)	N98,R98	BT,PF	2
	Formicidae	<i>Monomorium</i>	<i>minimum</i> (Buckley)	I97,I98,N98,R98	PF	51
	Formicidae	<i>Paratrechina</i>	<i>melanderi</i> (Wheeler)	I97,R98	LI,PF	19
	Formicidae	<i>Paratrechina</i>	<i>parvula</i> (Mayr)	I98	PF	2

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Hymenoptera	Formicidae	<i>Pheidole</i>	<i>bicarinata vinelandica</i> Forel	I97,N97,R98	LI,PF	15
	Formicidae	<i>Pheidole</i>	<i>dentata</i> Mayr	I97,I98,N97,N98,R98	LI,PF	175
	Formicidae	<i>Pheidole</i>	<i>sitarches soritis</i> Wheeler	R98	PF	2
	Formicidae	<i>Pheidole</i>	<i>xerophila</i> Wheeler	R98	PF	1
	Formicidae	<i>Ponera</i>	<i>coarctata pennsylvanica</i> Buckley	I97,N97,N98,R98	LI,PF	6
	Formicidae	<i>Prenolepsis</i>	<i>imparis</i> (Say)	I97	LI	1
	Formicidae	<i>Solenopsis</i>	<i>molesta</i> (Say)	N98,R98	LI,PF	6
	Formicidae	<i>Sysphincta</i>	<i>pergandei</i> Emery	R98	PF	2
	Formicidae	<i>Tapinoma</i>	<i>sessile</i> (Say)	I97,I98,N97,N98,R98	LI,LT,PF,SW	123
	Formicidae	<i>Tetramorium</i>	<i>caespitum</i> (Linnaeus)	N97,N98	BT,PF	2
	Formicidae	<i>Trachymyrmex</i>	<i>septentrionalis obscurior</i> Wheeler	N97,R98	PF	2
	Formicidae	<i>Wasmannia</i>	<i>auropunctata</i> (Roger)	R98	PF	2
	Halictidae	<i>Augochlorella</i>	species 1	I98,R98	BT,ML,SW	7
	Halictidae	<i>Dialictus</i>	species 1	I98,N98,R98	BT,DI,EG,ML,SW	90
	Halictidae	<i>Halictus</i>	species 1	I97,I98,N98,R98	BT,ML,SW	16
	Ichneumonidae	<i>Ceratogastra</i>	<i>ornata</i> Say	N98	ML	1
	Ichneumonidae	<i>Cryptus</i>	<i>albitarsis</i> Cresson	R98	ML	2
	Ichneumonidae	<i>Ophion</i>	species 1	I98	LT	1
	Ichneumonidae	<i>Trogus</i>	<i>penmator</i> Fabricius	I98	ML	2
	Megachilidae	<i>Megachile</i>	<i>latimanus</i> Say	I97,I98,N98,R98	BT,LT,ML,MN,SW	11
	Megachilidae	<i>Megachile</i>	species 1	I98	SW	2
	Megachilidae	<i>Osmia</i>	<i>lignaria</i> Say	I98	SW	1
	Pamphiliidae	<i>Anoplolyda</i>	<i>pallimacula</i> Norton	N98	ST	1
	Platygastridae	<i>Platygaster</i>	species 1	N98	ML	1
	Pompilidae	<i>Entypus</i>	species 1	N98	SW	1
	Pteromalidae	Genus	species 1	I98	EG	1
	Scelionidae	<i>Idris</i>	species 1	R98	SW	1

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Hymenoptera	Scelionidae	<i>Trissolcus</i>	<i>euschisti</i> Ashmead	R98	EG	1
	Sphecidae	<i>Ammophila</i>	species 1	I98	DI	1
	Sphecidae	<i>Bicyrtes</i>	species 1	N98	SW	1
	Sphecidae	<i>Bicyrtes</i>	species 2	R98	SW	1
	Sphecidae	<i>Cerceris</i>	species 1	I98,N97,N98,R98	BT,DI,ML,SW	14
	Sphecidae	<i>Chalybion</i>	<i>californicum</i> Saussure	I98,N98	DI,MN	32
	Sphecidae	<i>Chlorion</i>	<i>ichneumoneum</i> Linnaeus	I98	MN	8
	Sphecidae	<i>Lyroda</i>	species 1	N98	BT	1
	Sphecidae	<i>Lyroda</i>	species 2	N98,R98	PF	2
	Sphecidae	<i>Prionyx</i>	<i>atratus</i> LePeletier	N98	ML	1
	Sphecidae	<i>Sceliphron</i>	<i>caementarium</i> Drury	I98	MN	2
	Sphecidae	<i>Sphex</i>	<i>ichneumoneus</i> Linnaeus	I98,R98	MN,SW	2
	Sphecidae	<i>Sphex</i>	<i>pensylvanicus</i>	R98	DI	1
	Sphecidae	<i>Tachytes</i>	species 1	I98	ML,MN	2
	Sphecidae	<i>Tachytes</i>	species 2	I98	MN	1
	Sphecidae	<i>Trypoxylon</i>	<i>politum</i> Say	I98,N98	ML,MN	4
	Tenthredinidae	<i>Caliroa</i>	<i>cerasi</i> Linnaeus	N98,R98	ML,SW	3
	Tenthredinidae	<i>Endelomyia</i>	<i>aethiops</i> Fabricius	R98	SW	2
	Tiphiidae	<i>Myzinum</i>	<i>quinquecinctum</i> Fabricius	R98	ML,SW	2
	Tiphiidae	<i>Myzinum</i>	species 1	N98,R98	ML,PF,SW	6
	Vespidae	<i>Monobia</i>	<i>quadridens</i>	N98	ML	2
	Vespidae	<i>Polistes</i>	<i>annularis</i> (Linnaeus)	I98	MN	1
	Vespidae	<i>Polistes</i>	<i>exclamans</i> Viereck	I98,R98	MN,SW	3
	Vespidae	<i>Polistes</i>	<i>pallipes</i> LePeletier	I98	MN	1
	Vespidae	<i>Polistes</i>	species 1	I98,N97	ML,SW	2
	Vespidae	<i>Polistes</i>	<i>variatus</i> Cresson	R98	ML	1
	Vespidae	<i>Vespa</i>	<i>crabro</i> Linnaeus	N98	DI,LT	2

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Hymenoptera	Vespidae	<i>Vespula</i>	<i>maculifrons</i> Buysson	I98	SW	1
Isoptera	Rhinotermitidae	<i>Reticulitermes</i>	<i>flavipes</i> Kollar	R98	LI	20
Lepidoptera	Arctiidae	<i>Apantesis</i>	<i>phalerata</i> (Harris)	R98	LT	3
	Arctiidae	<i>Apantesis</i>	<i>vittata</i> (Fabricius)	I98,R98	LT,ML	15
	Arctiidae	Genus	species 1	I98,N98,R98	EG	5
	Arctiidae	<i>Cisseps</i>	<i>fulvicollis</i> (Hubner)	R98	LT	1
	Arctiidae	<i>Estigmene</i>	<i>acrea</i> (Drury)	N98	LT	2
	Arctiidae	<i>Grammia</i>	<i>phyllira</i> (Drury)	R98	LT	2
	Arctiidae	<i>Halysidota</i>	<i>tessellaris</i> (J.E. Smith)	R98	LT	3
	Arctiidae	<i>Haploa</i>	<i>lecontei</i> (Guerin-Meneville)	N98	DI	1
	Arctiidae	<i>Pyrrharctia</i>	<i>isabella</i> (J.E.Smith)	R98	LT	1
	Arctiidae	<i>Spilosoma</i>	<i>virginica</i> (Fabricius)	R98	LT	1
	Geometridae	<i>Euchlaena</i>	<i>amoenaria</i> (Guenee)	I98	MN	1
	Geometridae	Genus	species 1	R98	EG	1
	Geometridae	Genus	species 2	N98,R98	EG	2
	Geometridae	<i>Hydria</i>	<i>prunivorata</i> (Ferguson)	I98	MN	1
	Geometridae	<i>Semiothisa</i>	<i>eremiata</i> (Guenee)	I98	MN	1
	Hesperiidae	<i>Atalopedes</i>	<i>campestris</i> (Boisduval)	I97,I98,R98	DI	5
	Hesperiidae	<i>Epargyreus</i>	<i>clarus clarus</i> (Cramer)	I98,R98	DI	2
	Hesperiidae	<i>Thorybes</i>	<i>bathyllus</i> (J.E. Smith)	I97,N98,R98	DI,ST	5
	Hesperiidae	<i>Thorybes</i>	<i>confusus</i> Bell	I98	DI	1
	Libytheidae	<i>Libytheana</i>	<i>bachmanii</i> (Kirtland)	I97	DI	1
	Megalopygidae	<i>Lagoa</i>	<i>pixidifera</i> (J.E. Smith)	N98	DI	2
	Megalopygidae	<i>Megalopyge</i>	<i>opercularis</i> (J.E.Smith)	R98	LT	1
	Noctuidae	<i>Caenurgina</i>	<i>erechtea</i> (Cramer)	R98	LT	3
	Noctuidae	<i>Helicoverpa</i>	<i>zea</i> (Boddie)	R98	DI	1
	Noctuidae	<i>Plathypena</i>	<i>scabra</i> (Fabricius)	I98	MN	14

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Lepidoptera	Noctuidae	<i>Xestia</i>	<i>dolosa</i> Franclemont	R98	LT	1
	Notodontidae	<i>Datana</i>	<i>drexelii</i> H. Edwards	R98	LT	3
	Notodontidae	<i>Datana</i>	species 1	N98	DI	2
	Nymphalidae	<i>Agraulis</i>	<i>vanillae</i> (Linnaeus)	I97	DI	1
	Nymphalidae	<i>Basilarchia</i>	<i>archippus</i> (Cramer)	I98	DI,MN	2
	Nymphalidae	<i>Basilarchia</i>	<i>arthemis astyanax</i> (Fabricius)	N98	DI	1
	Nymphalidae	<i>Euptoieta</i>	<i>claudia</i> (Cramer)	I97	DI	1
	Nymphalidae	<i>Junonia</i>	<i>coenia</i> (Hubner)	I97,I98	DI,MN	5
	Nymphalidae	Genus	species 1	N98	EG	1
	Nymphalidae	Genus	species 2	I98	EG	1
	Nymphalidae	Genus	species 3	R98	EG	1
	Nymphalidae	<i>Phyciodes</i>	<i>tharos</i> (Drury)	I98	ML,MN	15
	Nymphalidae	<i>Speyeria</i>	<i>cybele</i> (Fabricius)	I98	DI,MN	2
	Nymphalidae	<i>Vanessa</i>	<i>virginiensis</i> (Drury)	I98,R98	DI	2
	Papilionidae	<i>Papilio</i>	<i>glaucus</i> Linnaeus	I98	DI	1
	Papilionidae	<i>Papilio</i>	<i>troilus</i> Linnaeus	R98	DI	1
	Pieridae	<i>Colias</i>	<i>eurytheme</i> Boisduval	I97,I98	DI	2
	Pieridae	<i>Eurema</i>	<i>nicippe</i> (Cramer)	I97	DI	1
	Pieridae	<i>Pontia</i>	<i>protodice</i> (Bdv. & LeConte)	R98	DI	1
	Saturniidae	<i>Anisota</i>	<i>stigma</i> (Fabricius)	N98	DI	1
	Saturniidae	<i>Dryocampa</i>	<i>rubicunda</i> (Fabricius)	R98	LT	2
	Satyridae	<i>Cercyonis</i>	<i>pegala</i> (Fabricius)	I98	ML	1
	Sphingidae	<i>Darapsa</i>	<i>myron</i> (Cramer)	R98	LT	1
	Sphingidae	<i>Hemaris</i>	<i>diffinis</i> (Boisduval)	I98,N98	ML,MN	2
	Sphingidae	<i>Hemaris</i>	<i>gracilis</i> (Grote & Robinson)	I98	ML	1
	Sphingidae	<i>Hemaris</i>	<i>thysbe</i> (Fabricius)	I98,N98	DI,ML	5
	Thyrididae	<i>Thyris</i>	<i>sepulchralis</i> Guerin-Meneville	N98	DI	3

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Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Mantodea	Mantidae	<i>Stagmomantis</i>	<i>carolina</i> Johannson	I98,N97,N98	BT,SW	7
	Mantidae	<i>Tenodera</i>	<i>augustipennis</i> Saussure	I98	SW	1
Mecoptera	Panorpidae	<i>Panorpa</i>	<i>nebulosa</i> Westwood	I98	ML	1
Neuroptera	Chrysopidae	<i>Chrysopa</i>	<i>carnea</i> Stephens	I97,I98,N98	BT,EG,SW	5
	Chrysopidae	<i>Chrysopa</i>	<i>oculata</i> Say	I98,N98,R98	BT,SW	4
Odonata	Gomphidae	<i>Hagenius</i>	<i>brevistylus</i> Selys	I98	DI	1
	Lestidae	<i>Lestes</i>	<i>disjunctus australis</i> Walker	N98	DI	1
	Lestidae	<i>Lestes</i>	<i>rectangularis</i> Say	I98	SW	2
	Libellulidae	<i>Celithemis</i>	<i>elisa</i> (Hagen)	I98	DI	1
	Libellulidae	<i>Celithemis</i>	<i>eponina</i> (Drury)	N98	DI	1
	Libellulidae	<i>Libellula</i>	<i>cyanea</i> Fabricius	I98	DI	1
	Libellulidae	<i>Libellula</i>	<i>semifasciata</i> Burmeister	I98	DI	1
	Orthoptera	Acrididae	<i>Arphia</i>	species 1	I97,R98	PF,SW
Acrididae		<i>Arphia</i>	<i>sulphurea</i> (Fabricius)	I98,N98,R98	DI,ML,PF	5
Acrididae		<i>Chortophaga</i>	<i>viridifasciata</i> (DeGeer)	I98,N98,R98	BT,DI,EG,ML,PF,SW	16
Acrididae		<i>Dichromorpha</i>	<i>viridis</i> (Scudder)	I98,N98,R98	ML,PF,SW	25
Acrididae		<i>Dissosteira</i>	<i>carolina</i> (Linnaeus)	R98	DI	1
Acrididae		<i>Hippiscus</i>	<i>ocelote</i> (Saussure)	I98,R98	BT,DI,EG	5
Acrididae		<i>Melanoplus</i>	<i>bivitattus</i> Say	R98	DI	1
Acrididae		<i>Melanoplus</i>	<i>differentialis</i> Thomas	I97,I98,N98,R98	DI,EG,ST	9
Acrididae		<i>Melanoplus</i>	<i>femurrubrum propinquus</i> DeGeer	I97,I98,N97,N98,R98	BT,DI,EG,ML,PF,SW	144
Acrididae		<i>Melanoplus</i>	<i>scudderi</i> Uhler	I98,N97,N98,R98	BT,ML,PF,SW	28
Acrididae		<i>Melanoplus</i>	sp.	I98,N98,R98	BT,EG,ML,PF,SW	229
Acrididae		<i>Melanoplus</i>	<i>viridipes</i> Scudder	R98	PF	2
Acrididae		<i>Metaleptea</i>	<i>brevicornis</i> (Johannson)	I97,I98,N97,N98,R98	BT,DI,ML,PF,SW	14
Acrididae		<i>Psinidia</i>	<i>fenestralis</i> Serville	I98	DI	1
Acrididae		<i>Schistocerca</i>	<i>americana</i> Drury	I98,N98,R98	DI,EG,SW	5

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Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Orthoptera	Acrididae	<i>Schistocerca</i>	<i>damnifica</i> Saussure	I97,N98,R98	BT,SW	8
	Acrididae	<i>Trachyrhachys</i>	<i>kiowa</i> (Thomas)	I98	DI	1
	Decticinae	<i>Pediocetes</i>	<i>americanus</i> Saussure	I97	BT	1
	Gryllacrididae	<i>Camptonotus</i>	<i>carolinensis</i> Gerstaecker	I98	PF	1
	Gryllacrididae	<i>Ceuthophilus</i>	<i>brevipes</i> Scudder	I98	PF	2
	Gryllacrididae	<i>Ceuthophilus</i>	<i>maculatus</i> Harris	I97,I98,R98	PF,SW	4
	Gryllidae	<i>Acheta</i>	<i>assimilis</i> (Fabricius)	I97,I98,N97,N98,R98	ML,PF	102
	Gryllidae	<i>Gryllus</i>	<i>pennsylvanicus</i> Burmeister	I97,I98,N98,R98	LT,ML,PF	22
	Gryllidae	<i>Miogryllus</i>	<i>verticalis</i> Serville	I97,I98,N97,N98,R98	BT,PF	72
	Gryllidae	<i>Oecanthus</i>	<i>fultoni</i> Walker	N98	SW	1
	Gryllidae	<i>Oecanthus</i>	<i>nigricornis quadripunctatus</i> Beutenmuller	N98,R98	SW	16
	Gryllotalpidae	<i>Gryllotalpa</i>	<i>hexadactyla</i> Perty	R98	PF	1
	Tetrigidae	<i>Neotettix</i>	<i>proavus</i> Rehn & Hebard	N98	SW	2
	Tetrigidae	<i>Nomotettix</i>	<i>cristatus compressus</i> Morse	N98,R98	BT,LT,PF,SW	5
	Tetrigidae	<i>Tettigidea</i>	<i>lateralis</i> (Say)	I98,N97,N98,R98	BT,PF,SW	8
	Tettigonidae	<i>Conocephalus</i>	<i>strictus</i> Scudder	I97,I98,N97,N98,R98	BT,ML,PF,SW	41
	Tettigonidae	<i>Microcentrum</i>	<i>rhombifolium</i> Saussure	I98,N98,R98	SW	6
	Tettigonidae	<i>Neoconocephalus</i>	<i>ensiger</i> Harris	I97,N98,R98	DI,ML,SW	17
	Tettigonidae	<i>Neoconocephalus</i>	species 1	R98	SW	1
	Tettigonidae	<i>Orchelimum</i>	<i>vulgare</i> Harris	I97,I98,N97,N98,R98	BT,EG,ML,SW	258
	Tettigonidae	<i>Scudderia</i>	<i>furcata</i> Brunner von Wattenwyl	I97,I98,N98,R98	BT,DI,EG,SW	15
Phasmida	Heteronemiidae	<i>Diapheromera</i>	<i>femorata</i> Say	I97,I98,R98	BT,SW	3
Psocoptera	Psocidae	<i>Hyalopsocus</i>	<i>striatus</i> Walker	N98	LT	1
Thysanoptera	Phlaeothripidae	<i>Haplothrips</i>	<i>leucantheni</i> Schrank	N97	LI	1
Trichoptera	Hydropsychidae	<i>Cheumatopsyche</i>	<i>oxa</i> Ross	R98	LT	1
	Hydropsychidae	<i>Cheumatopsyche</i>	<i>pettiti</i> (Banks)	R98	LT	1
	Leptoceridae	<i>Ceraclea</i>	<i>nepha</i> (Ross)	R98	LT	4

Appendix B. Arthropod species collected (n = 709) in 1997 and 1998 at all grassland barrens sites, Arnold AFB, Tullahoma, TN.

Order	Family	Genus	species/ subspecies Author	Sites ^a	Sampling Method ^b	No. ^c
Trichoptera	Leptoceridae	<i>Ceraclea</i>	<i>protonepha</i> Morse & Ross	R98	LT	16
	Leptoceridae	<i>Leptocerus</i>	<i>americanus</i> (Banks)	R98	LT	1
	Leptoceridae	<i>Oecetis</i>	<i>cinerascens</i> (Hagen)	R98	LT	1
	Leptoceridae	<i>Oecetis</i>	<i>inconspicua</i> (Walker)	R98	LT	4
	Leptoceridae	<i>Oecetis</i>	species 1	R98	LT	6
	Polycentropodidae	<i>Polycentropus</i>	<i>centralis</i> Banks	R98	LT	1
	Polycentropodidae	<i>Polycentropus</i>	species 1	R98	LT	1

^a Site codes are: I97 = Initial burn 1997; N97 = Non-burn 1997; I98 = Initial burn 1998; N98 = Non-burn 1998; R98 = Recent burn 1998.

^b Sampling methods are: BT = Beat sheets; DI = Direct; EG = Eggert's sunflower observations; LI = Leaf litter; LT = Light trap; ML = Malaise; MN = Manitoba; PF = Pitfall traps; ST = Sticky traps; SW = Sweep net.

^c Number of specimens of each species collected.

VITA

Derek Lee Puckett was born in Macon, Georgia on November 16, 1973. He received his high school diploma from Ringgold High School in Ringgold, Georgia, in 1991 and attended Georgia College & State University in Milledgeville, Georgia. There he received a Bachelor of Science in Biology in June 1997. In August, he was accepted into the Department of Entomology and Plant Pathology at The University of Tennessee, Knoxville. Under the direction of Dr. Jerome Franklin Grant, he completed the requirements for a Master of Science degree in Entomology and Plant Pathology in August 1999. He is a member of the Entomological Society of America, Tennessee Entomological Society, Torrey Botanical Club, American Museum of Natural History, Gamma Sigma Delta Agricultural Honor Society, Phi Kappa Phi Honor Society, and Gamma Beta Phi Honor Society.

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