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Tallgrass Prairie Creation and Evaluation, With Particular Interest in Species Response and Economic Feasibility, at Rose Lake Wildlife Research Area, Clinton County, Michigan

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Ruth C. Hefty

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TALLGRASS PRAIRIE CREATION AND EVALUATION, WITH PARTICULAR INTEREST IN SPECIES RESPONSE AND ECONOMIC FEASIBILITY, AT ROSE LAKE WILDLIFE RESEARCH AREA, CLINTON COUNTY, MICHIGAN

By

Ruth C. Hefty

A THESIS

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ABSTRACT

TALLGRASS PRAIRIE CREATION AND EVALUATION, WITH PARTICULAR INTEREST IN SPECIES RESPONSE AND ECONOMIC FEASIBILITY, AT ROSE LAKE WILDLIFE RESEARCH AREA, CLINTON COUNTY, MICHIGAN

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The tallgrass prairie has decreased to an estimated 4% of its original area in North America, mainly as a result of agriculture. Today, only small remnants exist, with many associated wildlife and plant species showing alarming declines. To preserve the tallgrass prairie ecosystems that have historically occurred in portions of Michigan, it is necessary to develop prairie creation techniques to assist in the creation and restoration of prairie patches. The primary goal of this project was to determine which of 4 prairie creation techniques (burning, mowing, plowing, planting of winter wheat) resulted in the highest quality native tallgrass prairie. During the first field season of this project, from May to August 1998, baseline data on the structure and composition of vegetation, and the abundance of small mammals, birds, and insects was gathered. From May to August 1999, after the implementation of the prairie creation techniques, the species inventory was repeated to evaluate any changes that may have occurred as a result of the management activities. An increase in native prairie plant and wildlife species and a decrease in invading non-prairie species was used as an indicator of the quality of a prairie patch. A secondary goal was to determine the economic feasibility of each treatment to encourage private landowners to create prairie patches. My results indicate that the burn and winter wheat treatments were the most successful in establishing planted prairie plant species and controlling invading non-prairie annuals. Avian abundance decreased between 1998 and 1999 on the manipulated areas. The changes in the wildlife species composition are likely the results of the removal of most above-ground vegetation, and did not assist in determining the quality of the prairie patches.

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I would also like to thank my intern, Amy Matusz, and my technical assistant, Tameka Dandridge, for their enthusiastic help in the field and with data entry. The help of volunteers Paul Thornton and Jeff Stetz was invaluable in getting the data that we needed in a timely fashion. I would also like to thank Paul Thornton, my best friend, for all your patience, understanding, and help throughout many stressful times. I couldn't have done this without you.

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INTRODUCTION

Grasslands, which are characterized by the dominance of grasses (family Poaceae) and the absence of trees, constitute approximately 24% of the plant cover of the world. Grasslands cover approximately 17% of the vegetation in North America (Risser et al. 1981, Brown 1985), and are the largest vegetational unit in North America (Risser et al. 1981). Several types of grassland are recognized in North America, including California grasslands, intermountain grasslands, desert grasslands, and prairies, which are differentiated by the dominance of different species of grass (Axelrod 1985, Brown 1985). One type of grassland is the prairie, which is often referred to as one of the most endangered ecosystems in North America (Samson and Knopf 1996). Before European settlement in North America, prairies extended from Canada to the Mexican border and from the foothills of the Rocky Mountains to Ohio (Samson and Knopf 1996). Three types of prairies are generally recognized throughout the United States. The shortgrass prairie, starting just east of the Rocky Mountains, is dominated by vegetation species such as blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), western wheatgrass (*Agropyron smithii*), and junegrass (*Koeleria macrantha*; Brown 1985, Weaver et al. 1996). As rainfall increases towards the east, the mixed-grass or mid-grass prairie emerges, and can be distinguished from the shortgrass prairie by the dominance of grasses such as little bluestem (*Schizachyrium scoparius*), western wheatgrass, blue grama, switchgrass (*Panicum virgatum*), needlegrass (*Stipa spartea*), Kentucky bluegrass (*Poa pratensis*), and buffalo grass (Brown 1985, Bragg and Steuter 1996). This prairie then yields to the tallgrass prairie, which extends east to Indiana and Michigan and into Ohio (Madson 1995). The tallgrass prairie is dominated by big bluestem (*Andropogon gerardii*), switchgrass, Indian grass (*Sorghastrum nutans*), and prairie dropseed (*Sporobolus heterolepis*; Risser et al. 1981, Brown 1985, Steinauer and Collins 1996).

North America's prairies are generally thought to be a relatively young ecosystem, having evolved 5 to 7 million years ago (Risser et al. 1981, Axelrod 1985, Kline 1997). The prairie probably did not attain its current vegetational composition until after the last ice age (Axelrod 1985), and fossil records do not identify the prairie until approximately 11,000 years ago (Risser et al. 1981). Characteristics of a prairie include: soils rich in organic matter, generally slightly alkaline, and very fertile (Brown 1985, Kline 1997); average annual precipitation between 25 and 99 cm (between 64 and 99 cm in the tallgrass prairie; Brown 1985); precipitation concentrated in peak periods, with a maximum amount of precipitation generally between May and September and a minimum amount between October and April (Transeau 1935, Risser et al. 1981, Brown 1985, Hayden 1998). Another factor that characterizes grasslands in general is the great climatic variability, especially in regard to precipitation, among years (Risser et al. 1981, Knapp and Seastedt 1998).

Disturbances such as drought, fire, and grazing were an integral part of the evolution of the prairie (Risser et al. 1981, Reichman 1987, Ryan 1990, Kline 1997), and prevented the invasion of trees and shrubs in most areas (Transeau 1935, Risser et al. 1981). Grasslands are generally considered to be a subclimax stage, which would eventually give way to invading shrubs and trees, especially in areas where precipitation and other climatic factors are sufficient for the maintenance of trees (Transeau 1935, Knapp and Seastedt 1998), and in the absence of fire and grazing, which inhibit the growth of young shrubs and trees (Transeau 1935, Risser et al. 1981). Accordingly, it would be expected that in areas where sufficient precipitation exists to support forest vegetation, trees and shrubs would eventually take over all grassland areas, especially in the absence of large grazers or fire.

Patches of tallgrass prairie remain in Michigan and Ohio and as far west as Pennsylvania, a region which also supports forests (Transeau 1935). Patches of prairie have also been reported as far east as Long Island, New York (Risser et al. 1981), and as far north as Newaygo County, Michigan (Hauser 1953) and Ontario, Canada (Faber-Langendoen and Maycock 1994). These prairie patches are regarded as being part of the prairie peninsula (Risser et al. 1981), which was first described by Transeau (1935). The prairie peninsula is generally regarded as being a part of the tallgrass prairie, due to the predominance of tallgrass prairie grasses and forbs and other similarities, even though it does not exhibit the vast open spaces of prairie as the prairie belt (Transeau 1935, Thompson 1975, Risser et al. 1981, Brown 1985, Packard and Mutel 1997). The prairie peninsula consists of surprisingly stable patches of prairie coexisting with patches of oak (*Quercus sp.*) or oak-hickory (*Quercus sp.-Carya sp.*) forests (Transeau 1935), with usually relatively abrupt boundaries unlike ecotones that form a gradual transition between two ecosystems (Brown 1985).

Today, only an estimated 4% of the original tallgrass prairie remains after most of it was plowed for agriculture (Steinauer and Collins 1996), or lost to the invasion of trees and shrubs as a result of fire suppression (Axelrod 1985). Throughout the remainder of the former range of the tallgrass prairie, only small and scattered remnants exist within the landscape (Steinauer and Collins 1996), most of these located in obscure places along rivers, steep banks, railroads, and cemeteries (Shirley 1994).

As a result of the fragmentation of the prairie habitat, many species of animals and plants associated with these areas are listed as either Federally threatened or endangered. Various survey results indicate that, as a group, grassland birds have shown a steep and geographically widespread decline during the past decades as a result of habitat loss (Herkert 1994a, Knopf 1996). To preserve the prairie ecosystem and its plant and animal species, it is imperative to reduce the fragmentation of this habitat type by restoring or creating prairie patches throughout the former range of the prairie.

How to go about restoring native tallgrass prairie and what to restore it to are controversial problems. Much of the tallgrass prairie was extirpated prior to extensive ecological study (Knapp and Seastedt 1986, Steinauer and Collins 1996), and profound effects of European modifications of the prairie and prairie peninsula vegetation had been reported as early as 1815 (Williams 1981). Questions as basic as the vegetation composition, the role of cool-season grasses in the tallgrass prairie, and the frequency and nature of disturbances and their interactions are still unsettled (Hamilton 1996, Steinauer and Collins 1996). Because of the relatively small size of most prairie remnants, these sites are subject to increased edge effects, which increases the likelihood of invasion by exotic or other undesirable species (Steinauer and Collins 1996). Small sizes added to the isolation of many prairie remnants also make them more susceptible to low genetic diversity, increased extinction rates of individual species, and a reduction of the amount of gene flow between remnants (Steinauer and Collins 1996).

Many studies have been conducted to try to determine the most effective methods for the restoration and creation of tallgrass prairies, starting with the University of Wisconsin-Madison Arboretum's Curtis prairie, started in 1936 (Kindscher and Tieszen 1998). Soil bed preparation may be one of the most critical steps in creating a successful prairie restoration, as the removal of undesired plants, usually referred to as "weeds," is often one of the most difficult parts of a prairie restoration (Landers et al. 1970, Cottam 1987, Kline and Howell 1987, Anderson 1994, Masters et al. 1996, Wilson and Stubbendieck 1996). If the site is extremely degraded, with little or no native prairie vegetation present, the appropriate technique is often to eliminate all present vegetation (Cottam 1987). This can be accomplished by herbiciding the restoration site, burning, mowing, grazing, or a combination of these techniques (Masters et al. 1992, Masters et al. 1996, Mitchell et al. 1996, Davison and Kindscher 1999, Washburn et al. 1999). Each of these techniques or combination of techniques, depending on other factors (i. e. climate (Collins and Gibson 1990), moisture conditions (Vassar et al. 1981, Collins and Gibson 1990, Cuomo et al. 1996), amount of litter present (Ehrenreich and Aikman 1963, Howe 1994, Cuomo et al. 1996), and number and species of prairie plants seeded (Howell and Kline 1994, Tilman and Downing 1994)), results in a unique vegetation composition.

Even with the most carefully planned project, however, it generally takes 3 to 5 years for a prairie restoration to take on the appearance of a native tallgrass prairie (Landers et al. 1970, Kline and Howell 1987).

Once a restoration project is completed and the vegetation composition resembles that of a native tallgrass prairie, it is usually necessary to continue to provide disturbances. Prairie grasses produce more biomass than can be decomposed (Ehrenreich and Aikman 1963, Anderson 1990), and this excess biomass needs to be removed to prevent a decrease in productivity (Ehrenreich and Aikman 1963, Knapp and Seastedt 1986, Hulbert 1988). Regular maintenance is also necessary to prevent the encroachment of woody species onto a prairie (Pendergrass et al. 1998). More studies are needed to investigate the effects of prairie restoration and creation techniques, especially in the prairie peninsula, to be able to successfully create prairie patches that will help preserve the prairie peninsula ecosystem.

Rose Lake Wildlife Research Area (RLWRA), located in Clinton and Shiawassee Counties in central Michigan (managed by the Michigan Department of Natural Resources (MDNR)), provides a unique opportunity to investigate prairie creation opportunities. Although RLWRA never contained patches of prairie (Transeau 1935, Ankney 1988), it is located in the range of the prairie peninsula, and prairie patches exist in nearby Eaton, Barry, Calhoun, and Kalamazoo counties (Transeau 1935, Chapman and Pleznac 1981). RLWRA has several fallow fields that support a variety of wildlife and vegetation species. It may be possible to create native tallgrass prairies in these areas that will improve and develop prairie creation techniques that can be used to create other prairie patches in Michigan. As the creation sites never contained patches of prairie, these activities are not restoration efforts, but rather tallgrass prairie creations that would reintroduce the diverse mosaic of forest and prairie patches that has historically existed in parts of the lower peninsula of Michigan. Providing examples of prairie creation techniques and educating private landowners in tallgrass prairie creation may encourage

them to create native tallgrass prairie plots on their land, thereby providing valuable habitat for species that have historically used the habitats of the prairie peninsula. To encourage landowners to emulate the prairie creation techniques conducted during this project, techniques were chosen according to their practicality and affordability. Therefore, the goals of this project were to create a native tallgrass prairie within RLWRA and to demonstrate practical and cost-effective management activities for native tallgrass prairie creation to private landowners in the area.

This was a two-year project with the main goal of assessing the vegetation and animal species abundance and composition before and after the implementation of tallgrass prairie creation activities. The first field season of the project was completed from May to August 1998, during which baseline data on the vegetation and animal species abundance and presence in several fallow fields in RLWRA was gathered. Manipulations to convert these grasslands to a native tallgrass prairie were implemented between August 1998 and May 1999, and any changes in the plant and wildlife species composition and abundance that may have occurred as a result of the management activities were assessed during the second field season of this project, from May to August 1999.

OBJECTIVES

Specific objectives of this study were to:

1) determine the presence and relative abundance of birds, small mammals, and insects, and the vegetation composition and structure of selected grassland areas in RLWRA from May to August 1998, 1999;

2) recommend management activities to be implemented on the selected study sites between August 1998 and May 1999, based on data collected in 1998 and MDNR objectives, to convert the selected grasslands to native tallgrass prairies;

3) evaluate the effectiveness of the prairie creation techniques in establishing a native tallgrass prairie community on the selected grassland areas by assessing changes that may have occurred in the presence and relative abundance of birds, small mammals, and insects, and vegetation composition and structure;

   H_o: The composition and relative abundance of animals and the vegetation composition and structure has changed as a result of the management activities;

   H_a: The composition and relative abundance of animals and the vegetation composition and structure has not changed as a result of the management activities; and

4) recommend future maintenance activities to maintain native tallgrass prairies on the selected grassland areas.

STUDY SITE

RLWRA is located in Clinton and Shiawassee Counties, Michigan, and is approximately 1,476 ha in size (B. Loper, MDNR, pers. commun.). Due to the limited number of sites available for use for this project in RLWRA, only 4 fields were selected. The 4 fields ranged from 2.0 - 6.8 ha in size, and were located in Clinton County. The largest of these, Field 1 (6.8 ha), was located directly north of RLWRA Headquarters (Figure 1). Field 2 (4.8 ha) was located approximately 0.5 km north of the largest field, while Field 3 (4.0 ha) was located approximately 1 km southwest of the Headquarters (Figure 1). The smallest of the 4 fields, Field 4 (2.0 ha), was approximately 1 km east of the Headquarters (Figure 1). These grassy fields have been idle for at least 5 years before prairie creation techniques were implemented (B. Loper, MDNR, pers. commun.).

Soils in each of the fields include: Field 1: Boyer sandy loam (0-12% slopes, coarse-loamy mixed mesic typic hapludalf) and Adrian muck (sandy or sandy-skeletal mixed euic mesic terric medisaprist); Field 2: Boyer sandy loam (0-12% slopes, coarse-loamy mixed mesic typic hapludalf); Field 3: Marlette loam (2-12% slopes, fine-loamy mixed mesic glossoboric hapludalf), Washtenaw loam (fine-loamy mixed nonacid mesic typic haplaquent), and Spinks loamy sand (0-12% slopes, sandy mixed mesic psammentic hapludalf); Field 4: Matherton loam (0-3% slopes, fine-loamy over sandy-skeletal mixed mesic udollic ochraqualf), Wasepi sandy loam (0-3% slopes, coarse-loamy mixed mesic aquollic hapludalf), Thetford loamy sand (0-3% slopes, sandy mixed mesic psammaquentic hapludalf), and Gilford sandy loam (coarse-loamy mixed mesic typic haplaquoll; U.S.D.A. 1978).

Rose Lake Wildlife Research Area is located in the range of the Boyer-Marlette-Houghton Soil Association, which is characterized by well drained and moderately well

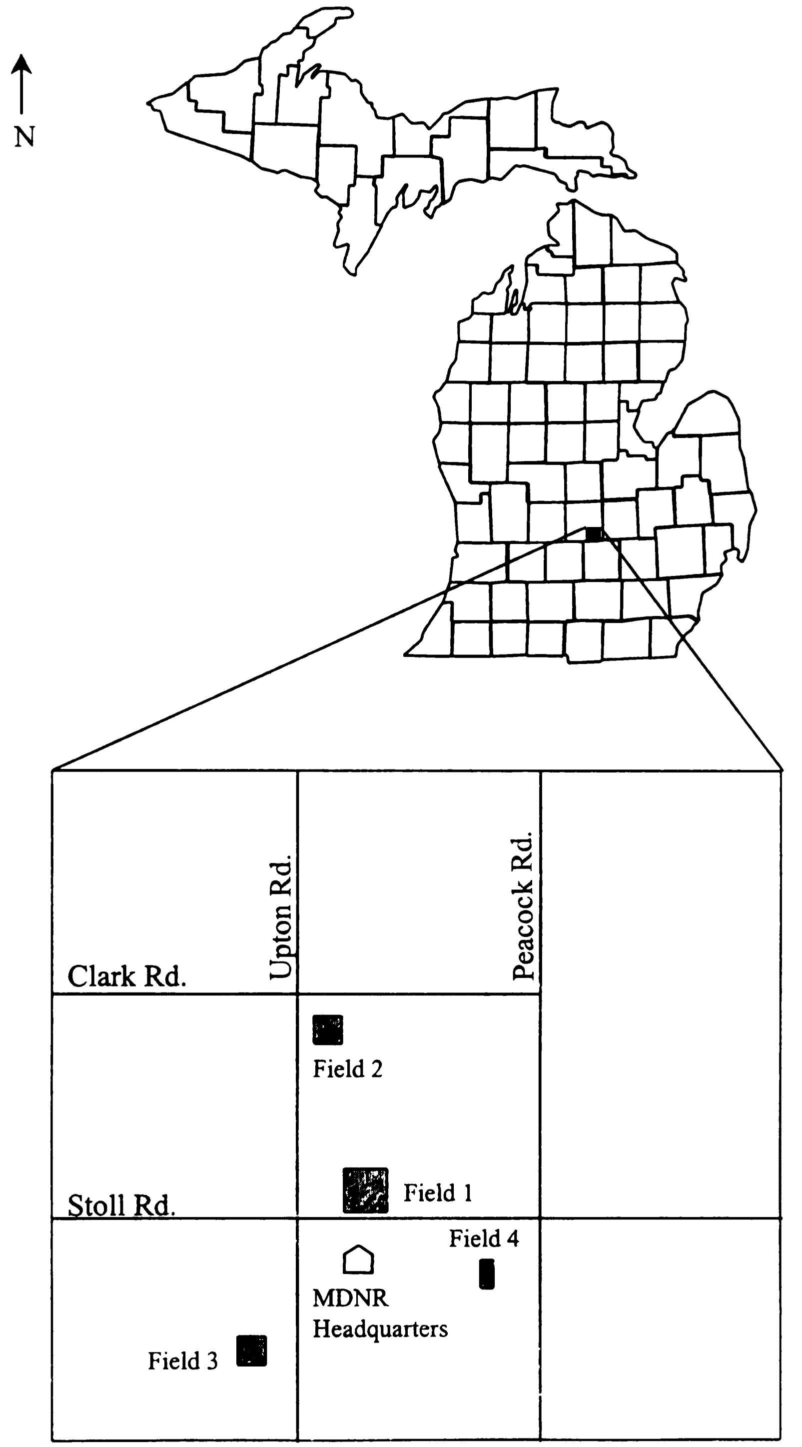


Fig. 1. Location of 4 grassland study sites in Rose Lake Wildlife Research Area in Clinton County, Michigan.

drained, gently sloping to steep loamy sands and loams on moraines and very poorly drained muck in depressions (U.S.D.A. 1978).

In Clinton County, the yearly average daily maximum temperature is 14.7°C, and the yearly average daily minimum temperature is 2.9°C. Precipitation averages 76.3 cm per year. June receives an average of 8.8 cm of precipitation, and is the wettest month. The crop season, May through October, receives an average of 45.3 cm, 59% of the average annual precipitation. Summer precipitation is mainly in the form of afternoon showers and thunderstorms. The growing season in Clinton County averages 143 days (U.S.D.A. 1978).

At the time of European settlement, the vegetation of Clinton County consisted mainly of dense, mostly deciduous forest. Prairies, small oak openings, were interspersed throughout the forests. Sugar maple and associated hardwoods were on the better drained loamy uplands; the percentage of oak increased where the soils were more sandy. Farming is the main industry, with corn, field beans, wheat, soybeans, sugar beets, and alfalfa comprising the major crops (U.S.D.A. 1978).

METHODS

Vegetation Structure and Composition

Study Sites

To evaluate the extent to which the vegetation composition and structure of the 4 fields corresponded to that of a native tallgrass prairie in 1998, and to evaluate any changes that may have occurred as a result of management activities in 1999, vegetation composition and structure were determined along 6 permanent 100 m transects randomly established in each field. Using a 50 cm x 50 cm modified Daubenmire frame (Daubenmire 1959), species composition, relative frequency, percent canopy cover (live, dead, grasses, forbs, and woody vegetation), and litter depth were determined at 6 points placed at equal distances along each transect. In 1999, percent bare ground was also determined. Horizontal cover was assessed using a Robel pole (Robel et al. 1970), and the maximum height of live and dead standing vegetation was recorded using a meter stick. Henceforth, maximum live and maximum dead standing vegetation will be referred to as live height and dead height, respectively. Compositional information was collected by estimating the relative frequency of each vegetation species present for each sampling point. Vegetation measurements were made in mid-to-late June, coinciding with birds producing young. They were also taken in late July/early August to determine how the vegetation variables change during a growing season.

Areas Adjacent to Study Sites

Qualitative data on the vegetation, including approximate height of the vegetation, dominant type of vegetation, and vegetation species present in the surrounding vegetation types were gathered. Areas surrounding the 4 study sites are different vegetation types than the selected study sites themselves; it was therefore imperative to assess these differences to determine the potential influence of outside vegetation on the species

composition and diversity of the study sites. Dominant vegetation types were categorized according to the compositional and structural characteristics of the area (Table 1).

Small Mammal Relative Abundance

Small mammals have been shown to have a significant impact on vegetation structure and composition in grasslands they inhabit (Golley et al. 1975). Brown and Heske (1990) found that removing 3 species of kangaroo rats (*Dipodomys* spp.) from their study plots resulted in a transition of desert to arid grassland habitat. These long-term changes were primarily the effects of soil disturbance from the burrowing activities of these animals. Small mammals are also good indicators of changes in habitat conditions. The species composition of small mammals is therefore an important aspect to consider when attempting a tallgrass prairie creation project.

The relative abundance and species composition of small mammals were evaluated using large Sherman live-traps (Sherman aluminum folding live-traps, Forestry Suppliers, Inc., Jackson, Mississippi). Thirty-six trapping stations were distributed at regular intervals on each study site, to cover the entire field in a grid pattern. Two traps were placed at each station (adapted from Smith et al. 1975). Bait consisted of a mixture of whole oats and anise extract. Setting and baiting of traps took place for 5 consecutive nights during each month (Furrow 1994) from May - August 1998, 1999. Traps were checked each morning while the traps were set, trapped mammals were identified by species and gender, and toeclip numbers, if any, were recorded; unmarked animals were toeclipped with a unique combination. All animals were subsequently released. All capturing and marking procedures were reviewed and approved by the Michigan State University's All-University Committee on Animal Use and Care (AUF# 02/98-039-00).

Table 1. Characteristics of dominant vegetation types in areas immediately surrounding the 4 study sites in RLWRA, Clinton County, Michigan.

Vegetation Type	Characteristics/description
Grassland	Dominated by grasses and forbs, very little if any woody vegetation present.
Shrubland	Codominance of woody and herbaceous vegetation.
Woods	Trees or tall shrubs (> approximately 4 m) dominating the vegetation.
Agricultural	Cultured fields. Type of crop will be given for this category.
Residential	Human habitation.

Avian Relative Abundance and Productivity

Study Sites

Since birds are important indicators of changes in habitat conditions, avian relative abundance was determined by conducting census counts from sunrise to approximately 3 hours after sunrise (Millenbah 1993). Thirty-minute point counts were used to assess avian abundance (Hanaburgh 1995). One or 2 census points, depending on the size and shape of the field, were placed on each study site, and the species, gender, and location of birds were recorded. Censuses took place twice per month from May - August 1998, 1999.

Areas Adjacent to Study Sites

Qualitative data on the avian species composition in adjacent areas was also determined. As stated previously, at least parts of the surrounding areas of all 4 study sites consisted of vegetation entirely different from the study sites. Accordingly, the avian species composition may be different in surrounding habitats compared to the study

sites. To monitor the potential influence of outside bird communities on the avian composition and abundance of the study sites, qualitative data on the bird composition in the area surrounding each study site was gathered. Census points in adjacent areas were located 50 m from the boundary of each grassland study site, spaced 150 m apart along the boundary. Where fencing or dense vegetation made it impossible to conduct censuses at a distance of 50 m from the boundary, census points were placed as far as possible from the boundary. Censuses were conducted using 10-minute point counts. Censuses of adjacent fields took place twice per month from May - August 1998, 1999.

Avian Productivity

Avian productivity was estimated by conducting nest searches at least two times during each field season. Observers walked parallel to each other, approximately 3 m apart, to locate any nests in the field. Nest locations and species of birds were recorded. Nests were revisited every 2 - 4 days until the chicks fledged or the nest was abandoned or destroyed (Best et al. 1997). The numbers of eggs, chicks, and fledglings, if possible, for each nest were recorded per visit, as well as the final outcome for each nest.

Insect Abundance

Insects are important dietary staples of a variety of insectivorous and omnivorous small mammals (Jones and Birney 1988) and birds (Ehrlich et al. 1988). Insects are important and often essential pollinators of plants, and some plants can only be pollinated by specific species of insects. Additionally, insects are excellent indicators of changes in habitat conditions, and their presence or absence often precipitates changes in species composition of other groups of animals and plants (Borror and White 1970).

Insect sweepnetting

Insects were surveyed using the sweepnet technique (Ruesink and Haynes 1973) at 10 randomly established 10 m permanent transects on each field. Surveys took place 3 times during each field season: 1) in early June to quantify insect composition and

abundance when birds are nesting, 2) in July when chicks are hatching and fledging, and 3) in August when neotropical migrants are preparing for migration. Insects were identified to Order. Insects were dried at 60°C for 48 hours to determine the insect dry biomass available to insectivorous birds and mammals during each of the sample times.

Lepidoptera

The Order Lepidoptera was the primary focus of the insect component of this study, as requested by the MDNR. To survey moths, one portable battery-powered blacklight trap was placed in the center of each field during the night. The traps were placed and activated by sunset and checked at sunrise for moths and butterflies (Thomas 1996). Lepidoptera surveys took place at the same times when other insects were sampled. Traps ran for 2 consecutive nights during each survey period. Lepidoptera were identified to Family, Genus, or Species, if possible.

Expenditures

To inform landowners of the cost associated with the different management activities, the following information was collected on each of the treatments: 1) equipment needed; 2) cost of herbicides, fuel, and equipment repair; 3) cost of prairie grass and forb seeds per ha; and 4) cost of manipulations. These data were supplied by the MDNR. The purpose of this information was to enable landowners to make informed decisions on which treatment to choose, according to their own needs, abilities, and financial constraints.

Soil Samples

To determine any liming or fertilizing requirements of the treatment fields, soil samples were taken in April 1999 and analyzed at the Michigan State University Soil and Plant Nutrient Laboratory. The laboratory analyzed the samples for the pH and the nutrients Phosphorus, Potassium, Calcium, and Magnesium.

All fields were limed according to recommendations given by the Michigan State University Soil and Plant Nutrient Laboratory, to reach a pH of 6.5 on all fields that received prairie creation techniques. This required liming at rate of 2.5 tons/ha, 5.0 tons/ha, and 6.2 tons/ha on Fields Burn/Wheat, Plow, and Mow/Control, respectively. These fields were fertilized with Nitrogen at a rate of 45 kg/ha, as recommended.

Manipulations

Several factors were taken into consideration to determine which management activities to implement to create a native tallgrass prairie: 1) preliminary data on the animal and plant species composition of the study sites during 1998, 2) proximity of study sites to residential areas, 3) equipment needed for implementation of the management activities, 4) costs associated with the activities, and 5) MDNR objectives. After discussions with the MDNR, the following treatments were selected: Field 1: till and plant winter wheat in the fall; no-till planting of prairie grasses and forbs in the spring. Field 2: mow in the fall; plowing, disking, and cultipacking with subsequent no-till planting of grasses and forbs in the spring. Field 3: control, left idle. Field 4: mow in the fall, no-till planting of prairie grasses and forbs in the spring. All fields, except for the control field, received an application of each of the herbicides Round-Up® and Plateau® in April and May, respectively, to kill any vegetation present before planting with prairie grasses and forbs. Management activities were randomly assigned to each field, except for Field 2. A row of shrubs and trees ran down the center of this field, and it was decided that this field would be plowed and disked in the spring. During this treatment the line of shrubs and trees was removed.

However, due to miscommunication with the MDNR, two of the fields received more than one treatment. The eastern part (2.6 ha) of Field 1 was determined to be too steep to be tilled and planted with winter wheat, and was burned in the spring. The eastern part (0.6 ha) of Field 4 was determined to be too shrubby to be mowed and was

left untreated, creating a control area (Table 2). This resulted in 2 study sites each receiving 2 treatments, and 2 study sites each receiving 1 treatment, a total of 6 treatments. Unfortunately, these manipulations occurred before MSU personnel could rectify the situation.

Hereafter, each of the 4 grassland sites in this study will be referred to as "fields," while each of the 6 treatment areas will be referred to as "treatments." The burned treatment on Field 1 will be identified as Treatment Burn, the winter wheat treatment on Field 1 will be identified as Treatment Wheat. Field 1 will be identified as Field Burn/Wheat. The mowed treatment on Field 4 will be identified as Treatment Mow, and the control treatment on Field 4 will be identified as Treatment Part-control. Field 4 will be identified as Field Mow/Control. Field 2, which was plowed, will be referred to as Treatment Plow or Field Plow when referring to tests among treatments or fields, respectively. Field 3, the control field, will be referred to as Treatment Control or Field Control when referring to tests among treatments or fields, respectively.

The same mixture of prairie grasses and forbs was planted for each prairie creation technique. To avoid planting a monoculture of grasses, a grass-to-forb ratio of 70:30 was planted (Table 3), which provides a high enough density of forbs to resemble a native prairie while keeping the cost of the project low by planting a majority of cheaper grass seeds (Diboll 1997). The seeds were no-till planted in early May 1999 in rows spaced 20 cm apart, at a rate of 7.1 kg/ha for grasses and 0.76 kg/ha for forbs. The winter wheat treatment was planted at a rate of 2.5 bushels/ha. Round-Up® was applied in April 1999 at a rate of 3.5 l/ha. Approximately two weeks after planting, in May 1999, Plateau® herbicide was applied at a rate of 420 g/ha.

Table 2. Prairie creation techniques for each of the grassland study sites in RLWRA, Clinton County, Michigan.

Field #	Technique
1	*Western part*: till and plant winter wheat in the fall; application of Round-Up®, no-till planting of prairie grasses and forbs, and application of Plateau® in the spring
	Eastern part: burn, application of Round-Up®, no-till planting of prairie grasses and forbs, and application of Plateau® in the spring
2	Mow in the fall. Application of Round-Up®; plowing, disking, and cultipacking; no-till planting of prairie grasses and forbs; and application of Plateau® in the spring
3	Control, untreated
4	*Western part*: mow in the fall; application of Round-Up®, no-till planting of prairie grasses and forbs, and application of Plateau® in the spring
	Eastern part: control, untreated

Data Analyses

Some variables were compared among treatments, while others were compared among fields. Since the division of fields was not anticipated during the 1998 field season, all data were collected for entire fields, and it was difficult to assign data from bird censuses and Lepidoptera censuses to a specific treatment on Fields Burn/Wheat and Mow/Control. Additionally, small mammal data could not be divided into treatments, as small mammals were often captured and recaptured in 2 different treatments of Fields 1 and 4. Vegetation and insect sweepnetting data were easy to divide, as they were collected on stationary transects whose positions were known; these data were

Table 3. Seed mix planted on the treatment fields in May 1999 in RLWRA, Clinton County, Michigan.

Common Name	Scientific Name	# Seeds per gram	Total PLS[a] grams planted	Ratio of mix	Total # PLS[a] seeds planted/m^2
Black-eyed susan	*Rudbeckia hirta*	3770	1,966.86	0.2085	57.04
Lance-leaved coreopsis	*Coreopsis lanceolata*	487	1,966.86	0.0269	7.37
Purple coneflower	*Echinacea purpurea*	258	1,966.86	0.0143	3.90
Perennial lupine	*Lupinus perennis*	50	1,966.86	0.0028	0.76
Gray-headed coneflower	*Ratibida pinnata*	950	1,966.86	0.0525	14.37
TOTAL FORBS			9,834.29	0.3050	83.44
Big bluestem	*Andropogon gerardii*	290	25,989.48	0.2119	57.98
Little bluestem	*Andropogon scoparius*	310	30,269.41	0.2638	72.18
Indian grass	*Sorghastrum nutans*	300	25,987.56	0.2192	59.97
TOTAL GRASSES			82,246.45	0.6950	190.13
OVERALL TOTAL			92,080.73	1.00	273.57

[a] Pure live seed

retroactively separated into respective treatments for 1998 data as well. During the 1999 field season all data was collected and assigned to respective treatment areas.

The nonparametric Kruskal-Wallis one-way analysis-of-variance ($\alpha = 0.10$, Siegel 1956) was used to compare vegetation structure characteristics and insect abundances among treatments for 1998, and small mammal, avian, and Lepidoptera abundances among fields for 1998. This test was also used to compare small mammal and Lepidoptera abundances among months for each field and year, insect abundances among months for each treatment and year, and avian abundances among censuses for each field and year. If significant differences ($\alpha = 0.10$) were observed, a Kruskal-Wallis analysis-of-variance multiple-comparison Bonferroni z-value test (NCSS 2000 software, Kaysville, Utah) was used to determine which variables differed significantly from one another. Differences among variables in avian abundance among censuses in 1999 were considered significant with a z-value > 2.91 ($P = 0.10$). Differences among variables in vegetation composition and structure among treatments, avian abundance among censuses in 1998, and insect abundance among treatments were considered significant with a z-value > 2.71 ($P = 0.10$). Differences among variables in small mammal abundances among fields and among months, avian abundances among fields, and Lepidoptera abundances among fields were considered significant with a z-value > 2.39 ($P = 0.10$). Differences among variables in Lepidoptera among months and insects among months were considered significant with a z-value > 2.13 ($P = 0.10$).

The nonparametric Wilcoxon matched-pairs signed-ranks test (Siegel 1956) was used to determine differences in vegetation characteristics and insect abundances between years, and for vegetation characteristics between months ($\alpha = 0.10$). The nonparametric Mann-Whitney U Test (Siegel 1956) was used to compare small mammal, avian, and Lepidoptera abundances between years on all fields ($\alpha = 0.10$).

Evaluation Procedures

The purpose of the study was to determine whether the creation activities were effective in establishing a tallgrass prairie on the study sites. An increase in the number of species and abundance of native prairie fauna and flora and a decrease in exotic or non-prairie species were considered a success in establishing a native tallgrass prairie in the study sites. This is similar to other studies on grasslands, where floristic quality was used to describe the "quality" of a prairie/grassland site. Swengel (1996) based floristic quality on the relative abundance of exotic species and woody invasion, and the diversity of native prairie flora. Therefore, a decrease in the relative abundance of exotic species and an increase in the diversity and abundance of native prairie vegetation species constitutes an increase in the quality of the native prairie and will be considered a successful prairie creation. Similarly, an increase in the relative abundance and diversity of native prairie wildlife species was considered a success.

RESULTS

Vegetation Structure and Composition

Study Sites

1998

June

In June 1998, all vegetation characteristics differed among treatments ($P \leq 0.10$, $z \geq 2.71$; Table 4). These data are pre-treatment to determine how similar treatments were in 1998, before any manipulations occurred. Treatment Plow had higher live height than Treatments Part-control ($z = 3.17$) and Mow ($z = 3.18$; Appendix A Figure 1). Treatments Burn and Plow had higher dead height than Treatments Part-control ($z = 3.84$ and 3.37, respectively) and Mow ($z = 3.65$ and 3.22, respectively). Treatment Control had higher horizontal cover than Treatments Burn ($z = 4.08$) and Mow ($z = 2.86$), and Treatments Plow and Part-control had higher horizontal cover than Treatment Burn ($z = 3.04$ and 3.12, respectively). Treatment Part-control had greater percent live cover than Treatments Plow ($z = 4.28$) and Burn ($z = 2.77$), and Treatments Control, Mow, and Wheat had greater percent live cover than Treatment Plow ($z = 3.66$, 2.85, and 3.67, respectively). Percent dead cover was greater on Treatment Burn than all other treatments (Wheat ($z = 4.64$), Plow ($z = 2.96$), Control ($z = 4.15$), Part-control ($z = 4.80$), and Mow ($z = 5.79$)). Percent dead cover was also greater on Treatment Plow than on Treatments Mow ($z = 4.03$) and Part-control ($z = 2.92$). Percent grass cover was greater on Treatment Burn than all other treatments (Wheat ($z = 3.62$), Plow ($z = 4.30$), Control ($z = 3.86$), Part-control ($z = 3.25$), and Mow ($z = 2.80$)). Treatment Burn had less percent forb cover than all other treatments (Wheat ($z = 4.94$), Plow ($z = 4.48$), Control ($z = 4.79$), Part-control ($z = 4.60$), and Mow ($z = 3.40$)). Percent woody cover was greater on Treatment Part-control than on Treatments Burn ($z = 2.90$), Wheat ($z = 2.95$), Plow ($z = 3.26$), and Control ($z = 2.99$). As percent bare ground was not determined in 1998,

Table 4. Mean (SE) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in June 1998.

Characteristic	Burn	Wheat	Plow	Control	Mow	Part-control
Max. live veg. height (cm)*	83.67 ^{ABa} (3.62)	87.67^{AB} (6.09)	97.75 ^{A} (2.45)	94.50 ^{A} (3.51)	84.54 ^{B} (3.01)	81.08 ^{B} (2.89)
Max. dead veg. height (cm)*	51.58 ^{A} (6.04)	32.42^{AB} (7.12)	39.97 ^{A} (5.61)	33.28 ^{A} (5.72)	13.79 ^{B} (5.11)	3.83 ^{B} (3.40)
Horizontal cover (dm)*	5.38 ^{A} (0.29)	6.88^{AB} (0.39)	7.58 ^{B} (0.42)	8.24 ^{B} (0.40)	6.50^{AC} (0.38)	7.85 ^{B} (0.50)
% live cover*	74.17 ^{AC} (6.60)	86.42^{BC} (3.11)	72.00 ^{A} (2.87)	85.19 ^{B} (2.62)	86.08 ^{B} (1.79)	93.33 ^{B} (1.67)
% dead cover*	13.50 ^{A} (6.34)	0.83 ^{B} (0.34)	3.14 ^{B} (0.72)	2.44 ^{B} (0.86)	0.21^{C} (0.21)	0.42 ^{C} (0.42)
% grass cover*	73.58 ^{A} (6.61)	28.83 ^{B} (5.90)	21.75 ^{B} (3.89)	30.94 ^{B} (5.36)	41.08 ^{B} (7.48)	21.42 ^{B} (5.59)
% forb cover*	0.58 ^{A} (0.58)	57.17 ^{B} (6.54)	49.56 ^{B} (4.81)	53.50 ^{B} (5.26)	40.00 ^{B} (7.65)	63.58 ^{B} (6.09)
% woody cover*	0.00 ^{A} (0.00)	0.42 ^{A} (0.42)	0.69 ^{A} (0.69)	0.75 ^{A} (0.70)	4.92^{AB} (3.39)	8.33 ^{B} (4.19)
% litter cover and bare ground*	12.33 ^{A} (4.76)	12.75 ^{A} (3.14)	24.86 ^{B} (2.69)	12.36 ^{A} (2.17)	13.71^{AB} (1.84)	6.25 ^{A} (1.75)
Litter depth (cm)*	5.92 ^{A} (0.38)	2.61 ^{B} (0.32)	4.38 ^{A} (0.39)	4.36 ^{B} (0.51)	2.99^{BC} (0.26)	3.13 ^{B} (0.30)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among treatments.

[a] Among treatments within a row, means with the same letter are not significantly different.

percent litter cover and bare ground could not be distinguished. For comparisons within 1998 and comparisons between 1998 and 1999, therefore, percent litter cover and bare ground will be treated as one category. Only for comparisons within 1999 will percent litter cover and percent bare ground be analyzed separately. Percent litter cover/bare ground was greater on Treatment Plow than on Treatments Burn ($z = 3.11$), Wheat ($z = 3.40$), Control ($z = 3.55$), and Part-control ($z = 3.81$). Litter depth was greater on Treatment Burn than on Treatments Wheat ($z = 4.55$), Control ($z = 2.99$), Part-control ($z = 3.39$), and Mow ($z = 4.16$), and greater on Treatment Plow than on Treatment Wheat ($z = 3.01$).

August

In August 1998, all vegetation characteristics except dead height differed ($P \leq 0.10$, $z \geq 2.71$) among treatments (Table 5). Treatment Plow had greater live height than Treatments Burn ($z = 3.90$), Part-control ($z = 3.00$), and Mow ($z = 3.34$), and Treatment Control had greater live height than Treatment Burn ($z = 3.13$). Treatment Burn had less horizontal cover than Treatments Wheat ($z = 3.68$), Plow ($z = 4.52$), and Part-control ($z = 2.72$), and Treatment Control had higher horizontal cover than Treatments Burn ($z = 4.99$) and Mow ($z = 2.97$). Percent live cover was greater in Treatments Control and Mow than Treatments Wheat ($z = 3.79$ and 3.87, respectively) and Plow ($z = 4.21$ and 4.21, respectively). Percent dead cover was greater on Treatments Wheat, Plow, and Part-control than in Treatment Control ($z = 3.52$, 3.72, and 2.79, respectively). Treatment Burn had greater percent grass cover than all other treatments (Wheat ($z = 3.75$), Plow ($z = 4.25$), Control ($z = 3.86$), Part-control ($z = 3.05$), and Mow ($z = 4.21$)). Treatment Burn also had less percent forb cover than all other treatments (Wheat ($z = 3.29$), Plow ($z = 4.41$), Control ($z = 4.95$), Part-control ($z = 4.98$), and Mow ($z = 3.85$)). Percent woody cover was greater on Treatment Part-control than on Treatments Burn ($z = 2.83$), Plow ($z = 3.18$), and Control ($z = 3.21$). Percent litter cover and bare ground was greater on Treatments Wheat and Plow than on Treatments Control ($z = 3.05$ and 3.34,

Table 5. Mean (SE) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in August 1998.

Characteristic	Burn	Wheat	Plow	Control	Mow	Part-control
Max. live veg. height (cm)*	81.83 [Aa] (3.30)	101.21 [BC] (7.15)	108.72 [B] (3.11)	103.92 [BC] (3.86)	90.04 [AC] (2.93)	87.17 [AC] (4.15)
Max. dead veg. height (cm)	53.33 (7.11)	62.79 (6.51)	50.11 (5.13)	51.72 (4.77)	43.67 (4.73)	39.08 (7.24)
Horizontal cover (dm)*	5.19 [A] (0.15)	9.35 [BC] (0.81)	9.59 [BC] (0.38)	10.39 [B] (0.65)	7.75 [AC] (0.58)	8.54 [BC] (0.44)
% live cover*	81.08 [AB] (3.06)	68.54 [A] (4.20)	70.69 [A] (2.75)	85.83 [B] (2.61)	88.67 [B] (2.22)	84.17 [AB] (4.96)
% dead cover*	2.58 [AB] (0.47)	5.50 [B] (1.32)	5.25 [B] (1.50)	1.19 [A] (0.37)	2.92 [AB] (1.07)	8.67 [B] (4.09)
% grass cover*	78.17 [A] (4.63)	31.79 [B] (6.31)	24.44 [B] (3.61)	34.25 [B] (5.60)	41.46 [B] (7.94)	14.58 [B] (3.51)
% forb cover*	2.92 [A] (2.17)	36.17 [B] (5.56)	45.69 [B] (3.73)	51.53 [B] (4.95)	42.42 [B] (7.63)	62.50 [B] (4.87)
% woody cover*	0.00 [B] (0.00)	0.58 [AB] (0.30)	0.56 [B] (0.56)	0.06 [B] (0.06)	4.79 [AB] (3.37)	7.08 [A] (3.77)
% litter cover and bare ground*	16.33 [AB] (3.01)	25.96 [A] (3.86)	24.06 [A] (2.60)	12.97 [B] (2.48)	8.42 [B] (2.06)	7.17 [B] (3.48)
Litter depth (cm)*	4.02 [C] (0.23)	1.81 [B] (0.23)	3.26 [AC] (0.34)	2.84 [AB] (0.35)	3.21 [AC] (0.31)	2.24 [AB] (0.28)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among treatments.
[a] Among treatments within a row, means with the same letter are not significantly different.

respectively), Part-control ($z = 3.56$ and 3.72, respectively), and Mow ($z = 3.96$ and 4.28, respectively). Litter depth was greater on Treatment Burn than on Treatments Wheat ($z = 4.57$), Control ($z = 3.02$), and Part-control ($z = 3.14$), and greater on Treatments Plow and Mow than on Treatment Wheat ($z = 3.36$ and 3.11, respectively).

Between Months

Live height and horizontal cover increased ($P \leq 0.10$) between June and August, 1998, on Treatments Wheat (both variables $P = 0.01$), Plow (both variables $P = 0.00$), Control (both variables $P = 0.00$), and Mow ($P = 0.01$ and 0.02, respectively; Table 6). Live height also increased between June and August on Treatment Part-control ($P = 0.08$). Dead height increased from June to August on Treatments Wheat ($P = 0.01$), Control ($P = 0.01$), Part-control ($P = 0.01$), and Mow ($P = 0.00$). Percent live cover decreased during the summer of 1998 on Treatments Wheat ($P = 0.00$) and Part-control ($P = 0.06$), and increased on Treatment Mow ($P = 0.08$). Percent dead cover increased on Treatments Wheat ($P = 0.00$), Part-control ($P = 0.01$), and Mow ($P = 0.00$) between June and August, but decreased on Treatment Burn ($P = 0.01$) in that period. Percent grass cover and percent woody cover showed no difference ($P > 0.10$) between June and August, 1998, in any of the treatments. Percent forb cover decreased on Treatment Wheat ($P = 0.00$) between June and August. Percent litter cover and bare ground increased on Treatment Wheat ($P = 0.01$) and decreased on Treatment Mow ($P = 0.02$). Litter depth decreased on Treatments Burn ($P = 0.01$), Wheat ($P = 0.01$), Plow ($P = 0.00$), Control ($P = 0.00$), and Part-control ($P = 0.03$) between June and August 1998.

1999

No comparisons were made among treatments in 1999. In 1998, comparisons among treatments were made to determine how similar the fields were to one another before manipulations were made. Each treatment received different prairie creation techniques between August 1998 and May 1999, and treatments were evaluated by comparing each treatment between years.

Table 6. Mean (SE) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	June	August	June	August	June	August	June	August	June	August	June	August
Max. live veg. height (cm)	83.67 (3.62)	81.83 (3.30)	87.67 (6.09)	101.21* (7.15)	97.75 (2.45)	108.72* (3.11)	94.50 (3.51)	103.92* (3.86)	84.54 (3.01)	90.04* (2.93)	81.08 (2.89)	87.17* (4.15)
Max. dead veg. height (cm)	51.58 (6.04)	53.33 (7.11)	32.42 (7.12)	62.79* (6.51)	39.97 (5.61)	50.11 (5.13)	33.28 (5.72)	51.72* (4.77)	13.79 (5.11)	43.67* (4.73)	3.83 (3.40)	39.08* (7.24)
Horizontal cover (dm)	5.38 (0.29)	5.19 (0.15)	6.88 (0.39)	9.35* (0.81)	7.58 (0.42)	9.59* (0.38)	8.24 (0.40)	10.39* (0.65)	6.50 (0.38)	7.75* (0.58)	7.85 (0.50)	8.54 (0.44)
% live cover	74.17 (6.60)	81.08 (3.06)	86.42 (3.11)	68.54* (4.20)	72.00 (2.87)	70.69 (2.75)	85.19 (2.62)	85.83 (2.61)	86.08 (1.79)	88.67* (2.22)	93.33 (1.67)	84.17* (4.96)
% dead cover	13.50 (6.34)	2.58* (0.47)	0.83 (0.34)	5.50* (1.32)	3.14 (0.72)	5.25 (1.50)	2.44 (0.86)	1.19 (0.37)	0.21 (0.21)	2.92* (1.07)	0.42 (0.42)	8.67* (4.09)
% grass cover	73.58 (6.61)	78.17 (4.63)	28.83 (5.90)	31.79 (6.31)	21.75 (3.89)	24.44 (3.61)	30.94 (5.36)	34.25 (5.60)	41.08 (7.48)	41.46 (7.94)	21.42 (5.59)	14.58 (3.51)
% forb cover	0.58 (0.58)	2.92 (2.17)	57.17 (6.54)	36.17* (5.56)	49.56 (4.81)	45.69 (3.73)	53.50 (5.26)	51.53 (4.95)	40.00 (7.65)	42.42 (7.63)	63.58 (6.09)	62.50 (4.87)
% woody cover	0.00 (0.00)	0.00 (0.00)	0.42 (0.42)	0.58 (0.30)	0.69 (0.69)	0.56 (0.56)	0.75 (0.70)	0.06 (0.06)	4.92 (3.39)	4.79 (3.37)	8.33 (4.19)	7.08 (3.77)

Table 6 (cont'd).

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	June	August	June	August	June	August	June	August	June	August	June	August
% litter cover and bare ground	12.33 (4.76)	16.33 (3.01)	12.75 (3.14)	25.96* (3.86)	24.86 (2.69)	24.06 (2.60)	12.36 (2.17)	12.97 (2.48)	13.71 (1.84)	8.42* (2.06)	6.25 (1.75)	7.17 (3.48)
Litter depth (cm)	5.92 (0.38)	4.02* (0.23)	2.61 (0.32)	1.81* (0.23)	4.38 (0.37)	3.26* (0.34)	4.36 (0.51)	2.84* (0.35)	2.99 (0.26)	3.21 (0.31)	3.13 (0.30)	2.24* (0.28)

* Significant ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between months.

Between Months

In 1999, live height increased ($P \leq 0.10$) on Treatments Burn ($P = 0.00$), Wheat ($P = 0.00$), Plow ($P = 0.00$), Part-control ($P = 0.00$), and Mow ($P = 0.00$) between June and August (Table 7). Dead height decreased on Treatments Burn ($P = 0.04$), Wheat ($P = 0.02$), Plow ($P = 0.00$), and Mow ($P = 0.00$). Horizontal cover increased on Treatments Wheat ($P = 0.00$), Plow ($P = 0.00$), and Mow ($P = 0.00$) during the summer. Percent live cover increased on all treatments from June to August (Burn ($P = 0.00$), Wheat ($P = 0.00$), Plow ($P = 0.00$), Control ($P = 0.06$), Part-control ($P = 0.01$), and Mow ($P = 0.00$)). Treatments Burn ($P = 0.00$), Wheat ($P = 0.00$), Plow ($P = 0.00$), Part-control ($P = 0.08$), and Mow ($P = 0.00$) showed a decrease in percent dead cover between June and August, while Treatment Control ($P = 0.02$) showed an increase in that time period. Percent grass cover increased in Treatments Burn ($P = 0.00$), Wheat ($P = 0.00$), Plow ($P = 0.04$), Control ($P = 0.09$), and Mow ($P = 0.00$) between June and August 1999. Percent forb cover increased between June and August on Treatments Wheat, Plow, and Mow (all treatments $P = 0.00$). Percent litter cover decreased on Treatments Burn ($P = 0.07$), Control ($P = 0.06$), Part-control ($P = 0.02$), and Mow ($P = 0.05$). Percent bare ground decreased from June to August 1999 on Treatments Burn ($P = 0.02$), Wheat ($P = 0.00$), Plow ($P = 0.00$), and Mow ($P = 0.01$). Treatments Control ($P = 0.10$) and Mow ($P = 0.05$) showed a decrease in litter depth from June to August.

Between 1998 and 1999

June

Horizontal cover and litter depth changed ($P \leq 0.10$) on all treatments between June 1998 and June 1999 (Table 8). Horizontal cover decreased on Treatments Burn ($P = 0.00$), Wheat ($P = 0.00$), Plow ($P = 0.00$), Part-control ($P = 0.02$), and Mow ($P = 0.00$), and increased on Treatment Control ($P = 0.00$) between 1998 and 1999. Litter depth decreased on all treatments between years (all treatments $P = 0.00$). Live height decreased on all treatments that were manipulated by prairie creation techniques,

Table 7. Mean (SE) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in summer 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	June	August	June	August	June	August	June	August	June	August	June	August
Max. live veg. height (cm)	7.33 (2.26)	23.08* (5.20)	15.25 (1.91)	47.25* (3.91)	33.97 (2.98)	110.06* (5.15)	108.17 (3.84)	108.31 (4.73)	23.50 (2.65)	43.96* (5.83)	82.08 (4.22)	90.17* (4.17)
Max. dead veg. height (cm)	8.67 (1.14)	5.17* (0.88)	6.25 (1.36)	5.83* (2.04)	2.83 (0.61)	1.61* (0.97)	59.36 (7.11)	58.17 (6.20)	17.71 (0.99)	13.46* (1.70)	72.92 (5.53)	67.42 (7.25)
Horizontal cover (dm)	0.23 (0.11)	1.23 (0.79)	0.23 (0.09)	2.77* (0.53)	2.15 (0.38)	13.17* (0.52)	10.01 (0.39)	10.03 (0.51)	0.74 (0.19)	2.92* (0.74)	6.08 (0.59)	7.67 (0.63)
% live cover	6.17 (4.90)	14.92* (6.70)	6.96 (1.79)	37.38* (4.51)	41.53 (5.58)	82.64* (3.39)	93.22 (1.05)	93.94* (2.04)	14.00 (4.32)	43.00* (7.46)	93.83 (1.35)	97.42* (0.56)
% dead cover	6.92 (1.00)	1.83* (0.27)	5.92 (2.51)	1.75* (0.72)	0.64 (0.12)	0.00* (0.00)	1.69 (0.44)	2.75* (1.78)	15.04 (2.38)	2.46* (0.45)	1.42 (0.31)	0.75* (0.28)
% grass cover	3.79 (2.85)	10.42* (4.98)	2.27 (0.81)	14.17* (2.21)	1.64 (0.25)	7.17* (1.99)	32.78 (6.08)	35.08* (5.92)	1.40 (0.24)	6.71* (1.10)	13.92 (4.59)	17.25 (4.05)
% forb cover	2.38 (2.06)	4.50 (2.10)	4.69 (1.36)	23.21* (3.64)	39.89 (5.69)	75.47* (4.75)	59.19 (6.22)	58.03 (5.81)	12.60 (4.27)	36.00* (7.82)	75.92 (5.74)	72.67 (5.93)
% woody cover	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.25 (0.88)	0.83 (0.61)	0.00 (0.00)	0.29 (0.22)	4.00 (2.91)	7.50 (5.49)

Table 7 (cont'd).

Characteristic	Burn		Wheat		Plow		Control		Mow		Part-control	
	June	August	June	August	June	August	June	August	June	August	June	August
% litter cover	37.75 (6.19)	46.25* (5.94)	9.00 (1.62)	8.88 (2.03)	2.06 (0.28)	3.08 (1.43)	4.97 (0.96)	3.31* (1.12)	64.75 (3.69)	51.00* (6.89)	4.67 (1.16)	1.83* (0.51)
% bare ground	49.17 (6.18)	37.00* (4.44)	78.13 (3.52)	52.00* (4.57)	55.78 (5.38)	14.28* (2.95)	0.11 (0.08)	0.00 (0.00)	6.21 (1.10)	3.54* (0.66)	0.08 (0.08)	0.00 (0.00)
Litter depth (cm)	0.42 (0.13)	0.33 (0.08)	0.19 (0.07)	0.13 (0.05)	0.01 (0.01)	0.01 (0.01)	2.77 (0.30)	2.26* (0.23)	1.59 (0.18)	1.18* (0.13)	1.95 (0.28)	2.42 (0.28)

* Significant at ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between months.

Table 8. Mean (SE) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in June 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Max. live veg. height (cm)	83.67 (3.62)	7.33* (2.26)	87.67 (6.09)	15.25* (1.91)	97.75 (2.45)	33.97* (2.98)	94.50 (3.51)	108.17* (3.84)	84.54 (3.01)	23.50* (2.65)	81.08 (2.89)	82.08 (4.22)
Max. dead veg. height (cm)	51.58 (6.04)	8.67* (1.14)	32.42 (7.12)	6.25* (1.36)	39.97 (5.61)	2.83* (0.61)	33.28 (5.72)	59.36* (7.11)	13.79 (5.11)	17.71* (0.99)	3.83 (3.40)	72.92* (5.53)
Horizontal cover (dm)	5.38 (0.29)	0.23* (0.11)	6.88 (0.39)	0.23* (0.09)	7.58 (0.42)	2.15* (0.38)	8.24 (0.40)	10.01* (0.39)	6.50 (0.38)	0.74* (0.19)	7.85 (0.50)	6.08* (0.59)
% live cover	74.17 (6.60)	6.17* (4.90)	86.42 (3.11)	6.96* (1.79)	72.00 (2.87)	41.53* (5.58)	85.19 (2.62)	93.22* (1.05)	86.08 (1.79)	14.00* (4.32)	93.33 (1.67)	93.83 (1.35)
% dead cover	13.50 (6.34)	6.92 (1.00)	0.83 (0.34)	5.92* (2.51)	3.14 (0.72)	0.64* (0.12)	2.44 (0.86)	1.69 (0.44)	0.21 (0.21)	15.04* (2.38)	0.42 (0.42)	1.42* (0.31)
% grass cover	73.58 (6.61)	3.79* (2.85)	28.83 (5.90)	2.27* (0.81)	21.75 (3.89)	1.64* (0.25)	30.94 (5.36)	32.78 (6.08)	41.08 (7.48)	1.40* (0.24)	21.42 (5.59)	13.92 (4.59)
% forb cover	0.58 (0.58)	2.38* (2.06)	57.17 (6.54)	4.69* (1.36)	49.56 (4.81)	39.89 (5.69)	53.50 (5.26)	59.19 (6.22)	40.00 (7.65)	12.60* (4.27)	63.58 (6.09)	75.92 (5.74)
% woody cover	0.00 (0.00)	0.00 (0.00)	0.42 (0.42)	0.00 (0.00)	0.69 (0.69)	0.00 (0.00)	0.75 (0.70)	1.25 (0.88)	4.92 (3.39)	0.00* (0.00)	8.33 (4.19)	4.00 (2.91)

Table 8 (cont'd).

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
% litter cover and bare ground	12.33 (4.76)	86.92* (4.56)	12.75 (3.14)	87.13* (2.98)	24.86 (2.69)	57.83* (5.53)	12.36 (2.17)	5.08* (3.31)	13.71 (1.84)	70.96* (3.68)	6.25 (1.75)	4.75 (1.23)
Litter depth (cm)	5.92 (0.38)	0.42* (0.13)	2.61 (0.32)	0.19* (0.07)	4.38 (0.37)	0.01* (0.01)	4.36 (0.51)	2.77* (0.30)	2.99 (0.26)	1.59* (0.18)	3.13 (0.30)	1.95* (0.28)

* Significant at ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between years.

Treatments Burn, Wheat, Plow, and Mow (all treatments $P = 0.00$), and increased on Treatment Control ($P = 0.00$) between June 1998 and June 1999. Dead height decreased on Treatments Burn, Wheat, and Plow (all treatments $P = 0.00$), and increased on Treatments Control ($P = 0.01$), Part-control ($P = 0.00$), and Mow ($P = 0.07$). Percent live cover and percent grass cover decreased on Treatments Burn (both variables $P = 0.00$), Wheat (both variables $P = 0.00$), Plow (both variables $P = 0.00$), and Mow (both variables $P = 0.00$). Percent live cover, however, increased on Treatment Control ($P = 0.01$). Percent dead cover increased on Treatments Wheat ($P = 0.00$), Part-control ($P = 0.05$), and Mow ($P = 0.00$), and decreased on Treatment Plow ($P = 0.00$) between June 1998 and June 1999. Treatment Burn ($P = 0.02$) had greater percent forb cover in June 1999 than June 1998, while Treatments Wheat ($P = 0.00$) and Mow ($P = 0.01$) had less percent forb cover in 1999 than 1998. Percent woody cover decreased on Treatment Mow ($P = 0.03$) between 1998 and 1999. Percent litter cover and bare ground increased on Treatments Burn, Wheat, Plow, and Mow (all treatments $P = 0.00$), and decreased on Treatment Control ($P = 0.00$).

August

Treatments Burn, Wheat, and Mow showed decreases ($P \leq 0.10$) in live height (all treatments $P = 0.00$), dead height (all treatments $P = 0.00$), horizontal cover (all treatments $P = 0.00$), percent live cover (all treatments $P = 0.00$), percent grass cover ($P = 0.00$, 0.02, and 0.00, respectively), and litter depth (all treatments $P = 0.00$), and increases in percent litter cover and bare ground (all treatments $P = 0.00$) between August 1998 and August 1999 (Table 9). Treatment Wheat also showed decreases in percent dead cover ($P = 0.04$), percent forb cover ($P = 0.05$), and percent woody cover ($P = 0.05$). Treatment Plow decreased in dead height ($P = 0.00$), percent dead cover ($P = 0.00$), percent grass cover ($P = 0.00$), and litter depth ($P = 0.00$), while horizontal cover ($P = 0.00$), percent live cover ($P = 0.00$), percent forb cover ($P = 0.00$), and percent litter cover and bare ground ($P = 0.08$) increased from 1998 to 1999. The only changes ($P \leq 0.10$) that

Table 9. Mean (SE) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in August, 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Max. live veg. height (cm)	81.83 (3.30)	23.08* (5.20)	101.21 (7.15)	47.25* (3.91)	108.72 (3.11)	110.06 (5.15)	103.92 (3.86)	108.31 (4.73)	90.04 (2.93)	43.96* (5.83)	87.17 (4.15)	90.17 (4.17)
Max. dead veg. height (cm)	53.33 (7.11)	5.17* (0.88)	62.79 (6.51)	5.83* (2.04)	50.11 (5.13)	1.61* (0.97)	51.72 (4.77)	58.17 (6.20)	43.67 (4.73)	13.46* (1.70)	39.08 (7.24)	67.42* (7.25)
Horizontal cover (dm)	5.19 (0.15)	1.23* (0.79)	9.35 (0.81)	2.77* (0.53)	9.59 (0.38)	13.17* (0.52)	10.39 (0.65)	10.03 (0.51)	7.75 (0.58)	2.92* (0.74)	8.54 (0.44)	7.67 (0.63)
% live cover	81.08 (3.06)	14.92* (6.70)	68.54 (4.20)	37.38* (4.51)	70.69 (2.75)	82.64* (3.39)	85.83 (2.61)	93.94* (2.04)	88.67 (2.22)	43.00* (7.46)	84.17 (4.96)	97.42* (0.56)
% dead cover	2.58 (0.47)	1.83 (0.27)	5.50 (1.32)	1.75* (0.72)	5.25 (1.50)	0.00* (0.00)	1.19 (0.37)	2.75 (1.78)	2.92 (1.07)	2.46 (0.45)	8.67 (4.09)	0.75* (0.28)
% grass cover	78.17 (4.63)	10.42* (4.98)	31.79 (6.31)	14.17* (2.21)	24.44 (3.61)	7.17* (1.99)	34.25 (5.60)	35.08 (5.92)	41.46 (7.94)	6.71* (1.10)	14.58 (3.51)	17.25 (4.05)
% forb cover	2.92 (2.17)	4.50 (2.10)	36.17 (5.56)	23.21* (3.64)	45.69 (3.73)	75.47* (4.75)	51.53 (4.95)	58.03 (5.81)	42.42 (7.63)	36.00 (7.82)	62.50 (4.87)	72.67 (5.93)
% woody cover	0.00 (0.00)	0.00 (0.00)	0.58 (0.30)	0.00* (0.00)	0.56 (0.56)	0.00 (0.00)	0.06 (0.06)	0.83 (0.61)	4.79 (3.37)	0.29 (0.22)	7.08 (3.77)	7.50 (5.49)

Table 9 (cont'd).

	Burn		Wheat		Plow		Control		Mow		Part-control	
Characteristic	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
% litter cover and bare ground	12.33 (4.76)	86.92* (4.56)	12.75 (3.14)	87.13* (2.98)	24.86 (2.69)	57.83* (5.53)	12.36 (2.17)	5.08* (3.31)	13.71 (1.84)	70.96* (3.68)	6.25 (1.75)	4.75* (1.23)
Litter depth (cm)	4.02 (0.23)	0.33* (0.08)	1.81 (0.23)	0.13* (0.05)	3.26 (0.34)	0.01* (0.01)	2.84 (0.35)	2.26 (0.23)	3.21 (0.31)	1.18* (0.13)	2.24 (0.28)	2.42 (0.28)

* Significant at ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between years.

occurred between August 1998 and 1999 on Treatment Control were an increase in percent live cover (P = 0.00) and a decrease in percent litter cover and bare ground (P = 0.00). The other control area, Treatment Part-control, increased in dead height (P = 0.03) and percent live cover (P = 0.00), while percent dead cover (P = 0.01) and percent litter cover and bare ground (P = 0.05) decreased from 1998 to 1999.

Species Composition

In 1998 and 1999, 84 plant species were identified on the 6 treatments (Appendix A Table 1). In 1998, 67 vegetation species were identified on the 6 treatments, and 54 species were identified in 1999. In 1998, Treatment Burn had the lowest species richness with 4 and 3 species in June and August, respectively (Table 10). Treatment Control had the greatest number of species of all treatments in June 1998, with 29 species. Overall, forb species were the most common type of vegetation present compared to grass or woody vegetation, except for Treatment Burn, which had an equal number of grass and forb species in June 1998. For the entire year, Treatment Wheat had the greatest number of species with 33, followed by Treatments Plow and Control with 31 species each. Treatment Part-control had 24 vegetation species in 1998, Treatment Mow had 16 vegetation species, and Treatment Burn had the lowest number of species of all treatments with 6 vegetation species.

In 1999, Treatment Burn had the lowest number of vegetation species present among all treatments, with 8 species present in June and August 1999, and a total of 11 vegetation species over the entire summer (Table 11). In 1999, Treatment Plow had the most species in August (n = 23) and over the entire summer (n = 25). Treatment Plow had the most species (n = 25), followed by Treatment Control (n = 23), Treatment Part-control (n = 22), Treatment Mow (n = 21), Treatment Wheat (n = 18), and Treatment Burn (n = 11). Forbs were the dominant type of vegetation present in all treatments except Treatment Burn in June, which had a greater number of grass species than forb species. Woody species had the lowest number of species compared to the other 2 type

Table 10. Number of species for each type of vegetation in grassland treatments at RLWRA, Clinton County, Michigan, in summer 1998.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Type of plant	June	August	June	August	June	August	June	August	June	August	June	August
Forb	2	2	20	22	18	20	20	16	8	10	11	13
Grass	2	1	3	3	4	3	5	4	2	2	3	2
Woody	0	0	2	2	1	2	4	4	3	3	4	4
Total	4	3	25	27	23	25	29	24	13	15	18	19
Total for year	6		33		31		31		16		24	

Table 11. Number of species for each vegetation type in grassland treatments at RLWRA, Clinton County, Michigan, in summer 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Type of plant	June	August	June	August	June	August	June	August	June	August	June	August
Forb	3	5	10	8	11	14	15	14	11	10	13	12
Grass	5	3	6	4	6	9	4	4	4	5	2	2
Woody	0	0	0	0	0	0	2	2	1	2	2	2
Total	8	8	16	12	17	23	21	20	16	17	17	16
Total for year	11		18		25		23		21		22	

of vegetations. Treatments Wheat, Plow, Control, and Part-control showed a decline in species richness from 1998 to 1999. All treatments (except for the controls) showed an increase in the number of grass species present in 1999 compared to 1998.

In all treatments and months, except Treatment Part-control in June and August 1998, Treatment Mow in August 1998, and Treatment Burn in August 1998, more species were present that are not native to the lower peninsula of Michigan (henceforth referred to as "exotic" species) than those that are native to the lower peninsula (henceforth referred to as "native" species; Table 12). On some treatments, including Treatments Burn in June and Wheat and Plow in both months, exotic species outnumbered native species by more than 2 to one.

In 1999, the only month and treatment that had more native than exotic vegetation species was Treatment Mow in August (Table 13). Treatments Burn and Mow had the same number of exotic and native species in June and August, respectively, in 1999. All other treatments had more exotic species than native species. Exotic species outnumbered native species by more than 2 to one in the following treatments: Wheat in August and Control in both June and August. Treatments Burn, Plow, and Mow showed an increase in the number of native species from 1998 to 1999 in both June and August, while the number of native species decreased in that time period in Treatments Wheat, Control, and Part-control.

Of the 8 species planted, all 3 grass species were present on all treatments in August 1999, and in Treatments Wheat and Plow in June 1999 (Table 14). Little bluestem was not present in any plots on Treatment Burn in June 1999 and Indian grass was not present in any plots in Treatment Mow in June 1999. A planted species was considered to be successfully established in this study if it was present in at least 25% of vegetation plots, which is the equivalent of at least one plant/m^2, a density often cited as the minimum establishment success of a prairie creation (Vassar et al. 1981, Masters 1997). Big bluestem was found in the greatest percentage of plots compared to the other

Table 12. Number of species exotic or native to the lower peninsula of Michigan that are present in grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Type	June	August	June	August	June	August	June	August	June	August	June	August
Exotic*	3	1	14	15	13	15	12	9	5	5	6	4
Native	0	1	6	7	5	7	9	6	4	6	8	11

* Plants that were only identified to genus are not included, as native status cannot be determined with certainty.

Table 13. Number of species exotic or native to the lower peninsula of Michigan that are present in grassland treatments in RLWRA, Clinton County, Michigan, in summer 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Type	June	August	June	August	June	August	June	August	June	August	June	August
Exotic*	2	5	7	7	7	12	10	11	6	6	7	6
Native	2	3	5	3	6	8	4	3	6	7	7	5

* Plants that were only identified to genus are not included, as native status cannot be determined with certainty.

Table 14. Percentage of sampling plots with planted species in grassland treatments in RLWRA, Clinton County, Michigan, in summer 1999.

	Burn		Wheat		Plow		Mow	
Species	June	August	June	August	June	August	June	August
Big bluestem	50	58	79	79	61	33	12	46
Little bluestem	0	42	58	42	11	11	8	4
Indian grass	25	50	50	46	47	61	0	21
Black-eyed susan	0	0	0	0	0	0	0	0
Lance-leaved coreopsis	0	0	0	0	0	0	0	0
Purple coneflower	0	0	0	0	0	0	0	0
Perennial lupine	0	0	4	0	3	3	4	4
Gray-headed coneflower	0	0	0	0	0	0	0	0
Any planted species	58	92	83	88	78	69	25	54

2 species of grass in all treatments and months except for Treatment Plow in August, when Indian grass was observed in the greatest percentage of plots. Indian grass was observed in more plots than little bluestem in all treatments and months except for Treatments Wheat and Mow in June. The only planted forb that was observed in any plots was perennial lupine in Treatment Wheat in August and Treatments Plow and Mow in both months. In June 1999, Treatment Wheat had the greatest percentage of plots with at least one planted species (83%), followed by Treatment Plow (78%), Treatment Burn (58%), and Treatment Mow (25%). By August, Treatment Burn had improved considerably, having the greatest percentage of plots with at least one planted species present (92%), followed by Treatment Wheat (88%), Treatment Plow (69%), and Treatment Mow (54%). All treatments showed an increase in the percentage of plots with at least one planted species between June and August, except for Treatment Plow, which showed a decline.

On Treatment Burn, the mean percentage of vegetation plots with smooth brome (*Bromus inermis*) declined between 1998 and 1999 from 100% of plots to 8% (Table 15). On Treatment Wheat, the percentage of plots with blue-joint (*Calamagrostis canadensis*), smooth brome, and wild carrot (*Daucus carota*) decreased considerably between 1998 and 1999, decreasing by 25%, 42%, and 33% of plots, respectively. The percentage of plots with common ragweed (*Ambrosia artemisiifolia*) and quack grass decreased by 6% and 14%, respectively, the percentage of plots with Canada thistle (*Cirsium arvense*) stayed the same, and the percentage of plots with lambs-quarters (*Chenopodium album*) increased by 19% between 1998 and 1999. Treatment Plow showed an increase in the percentage of plots of many non-prairie species. Common ragweed, lambs-quarters, and velvet-leaf (*Abutilon theophrasti*) were not present in any vegetation plots in 1998 and increased to being present in more than 50% of plots in 1999. Canada thistle also showed an increase in the percentage of plots on Treatment Plow from 1998 to 1999 increasing from not being present in any plots in 1998 to 3% of plots in 1999. The percentage of

Table 15. Mean percentage of sampling plots with the most undesired non-prairie plants in grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Species	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Blue-joint	0	0	27	2	14	1	18	26	40	2	100	100
Canada thistle	0	0	2	2	0	3	35	18	10	4	0	0
Common ragweed	0	0	6	0	0	53	0	0	0	0	0	0
Fringed loosestrife	0	0	0	0	0	0	0	0	0	0	4	0
Lambs-quarters	0	0	0	19	0	56	0	3	0	4	0	4
Quack grass	4	8	29	15	76	49	60	65	63	83	4	0
Smooth brome	100	8	44	2	8	3	3	3	0	8	0	0
Velvet-leaf	0	0	0	0	0	56	0	0	0	0	0	0
Wild carrot	0	0	33	0	53	3	18	28	4	8	0	8
Yellow sweet-clover	0	0	6	0	0	0	0	0	0	0	8	0

plots with blue-joint, quack grass, smooth brome, and wild carrot decreased by 13%, 27%, 5%, and 50% of plots, respectively, in that time period on Treatment Plow. Treatments Control and Part-control showed relatively few changes in the percentage of plots with non-prairie species. The percentage of plots with blue-joint, lambs-quarters, quack grass, and wild carrot increased by 8%, 3%, 5%, and 10% of plots, respectively, between 1998 and 1999 on Treatment Control. The percentage of plots with Canada thistle decreased by 17% of plots, while the percentage of plots with smooth brome stayed equal in that time period on Treatment Control. Treatment Part-control showed an increase in lambs-quarters and wild carrot by 4% and 8% of plots, respectively, while the percentage of plots with fringed loosestrife (*Lysimachia ciliata*), quack grass, and yellow sweet-clover (*Melilotus officinalis*) decreased by 4%, 4%, and 8% of plots, respectively. Blue-joint was present in all vegetation plots on Treatment Part-control in both years. Canada thistle and blue-joint decreased by 6% and 38% of plots, respectively, on Treatment Mow. The percentage of plots with lambs-quarters, quack grass, smooth brome, and wild carrot increased by 4%, 20%, 8%, and 4% of plots, respectively, on Treatment Mow between 1998 and 1999.

Adjacent Fields

The vegetation composition of adjacent areas differed considerably among fields. Field Burn/Wheat was surrounded by an agricultural field (planted to soybeans in 1998 and wheat in 1999), grasslands, and a woodlot. Field Plow was surrounded by grassland, shrubland, and a woodlot. Field Control was surrounded by an agricultural field (planted to corn in 1998 and soybeans in 1999), residential areas, and some shrubland and a woodlot. Field Mow/Control was surrounded by a woodlot on all sides. The grassland areas surrounding Fields Burn/Wheat and Plow were dominated by smooth brome, goldenrods (*Solidago sp.*), and wild carrot.

Small Mammal Relative Abundance

Nine mammalian species were captured in the 4 fields in 1998 and 1999 (Table 16; Appendix B Table 1). An additional species, the eastern mole (*Scalopus aquaticus*), was found dead, but not associated with a trap, in Field Control in 1998. Because deer mice (*Peromyscus maniculatus*) and white-footed mice (*Peromyscus leucopus*) are practically indistinguishable from each other in the field in this part of their range, these 2 species were grouped together as Peromyscus for this study.

1998

The mean abundance of meadow voles (*Microtus pennsylvanicus*), Peromyscus, thirteen-lined ground squirrels (*Citellus columbianus*), and total small mammals differed ($P \leq 0.10$, $z \geq 2.39$) among fields in 1998 (Table 16). Field Control had a greater abundance of meadow voles than Fields Burn/Wheat ($z = 3.36$) and Plow ($z = 2.63$). Field Burn/Wheat had a greater abundance of Peromyscus and thirteen-lined ground squirrels than Fields Control ($z = 3.07$ and 3.01, respectively) and Mow/Control ($z = 3.07$ and 3.01, respectively). Field Control had a greater number of small mammals than Field Plow ($z = 2.82$).

The number of small mammals captured on each field did not differ ($P > 0.10$) among trapping periods in 1998 (Table 17).

1999

No comparisons were made among fields in 1999, as fields received different manipulations. Fields were evaluated by comparing each field between years.

The number of small mammals captured on each field did not differ ($P > 0.10$) among trapping periods in 1999 (Table 18).

Between 1998 and 1999

Field Burn/Wheat had a greater abundance of meadow jumping mice ($P = 0.01$; *Zapus hudsonius*), masked shrews ($P = 0.01$; *Sorex cinereus*), and shorttail shrews ($P = 0.05$; *Blarina brevicauda*), and a lower abundance of Peromyscus ($P = 0.02$), in 1998

Table 16. Mean (SE) relative abundance of small mammals captured on grassland fields in RLWRA in Clinton County, Michigan, in summer 1998.

Species	Burn/Wheat	Plow	Control	Mow/Control
House mouse	0.25 (0.25)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Least weasel	0.00 (0.00)	0.00 (0.00)	0.25 (0.25)	0.00 (0.00)
Meadow jumping mouse	8.00 (2.92)	1.50 (0.96)	8.50 (2.75)	6.50 (3.62)
Masked shrew	2.25 (0.63)	2.75 (1.55)	1.50 (0.87)	1.00 (1.00)
Meadow vole*	0.00 Ba (0.00)	0.75 B (0.48)	50.75 A (10.87)	3.75 AB (1.03)
Peromyscus*	7.00 A (1.47)	1.75 AB (0.63)	0.00 B (0.00)	0.00 B (0.00)
Shorttail shrew	6.50 (2.90)	4.25 (2.46)	6.75 (2.02)	8.50 (3.75)
Thirteen-lined ground squirrel*	10.50 A (4.17)	0.75 AB (0.25)	0.00 B (0.00)	0.00 B (0.00)
All species*	34.50 AB (9.51)	11.75 A (3.90)	67.75 B (11.24)	19.75 AB (8.47)
Number of Species	6	6	5	4

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among fields within a row.

[a] Among fields within a row, means with the same letter are not significantly different.

Table 17. Number of small mammals captured per trapping period on grassland fields in RLWRA in Clinton County, Michigan, in summer 1998.

	Period			
Field	May 19 - June 15	June 16 - July 13	July 14 - August 10	August 11 - September 7
Burn/Wheat	14	33	31	60
Plow	2	9	19	17
Control	44	92	81	54
Mow/Control	1	12	26	40
All fields	61	146	157	171

Table 18. Number of small mammals captured per trapping period on grassland fields in RLWRA in Clinton County, Michigan, in summer 1999.

	Period			
Field	May 19 - June 15	June 16 - July 13	July 14 - August 10	August 11 - September 7
Burn/Wheat	15	18	29	36
Plow	0	5	12	15
Control	19	11	32	37
Mow/Control	7	2	8	12
All fields	41	36	81	100

compared to 1999 (Table 19, Appendix B Figure 1). Field Plow showed a decline in the abundance of masked shrews (P = 0.05) and thirteen-lined ground squirrels (P = 0.04) between 1998 and 1999. Field Control had a greater abundance of meadow voles (P = 0.02) and total small mammals (P = 0.02) in 1998 than in 1999. Field Mow/Control showed a decline in meadow voles (P = 0.02) and an increase in Peromyscus (P = 0.01) from 1998 to 1999.

All fields treated with a prairie creation technique showed an increase in Peromyscus, although this increase was only significant in 2 of these fields. Peromyscus were the most abundant small mammal species in 1999 in all fields except for Field Control, in which shorttail shrews were the most abundant small mammal. Peromyscus increased following the removal of vegetation on Fields Burn/Wheat and Mow/Control. They also increased on Field Plow, but the increase was not significant. The only treated field that showed a decrease in meadow voles was Field Mow/Control. The relative abundance of meadow voles decreased on Field Plow, although the difference was not significant, and meadow voles were not present on Field Burn/Wheat in 1998 or 1999. Meadow voles also decreased on Field Control from 1998 to 1999, decreasing from a mean of 50.75 meadow voles captured per month in 1998 to only 5.50 meadow voles captured per month in 1999. Fields Burn/Wheat and Plow showed a decrease in the number of small mammal species from 1998 to 1999, decreasing from 6 species on both fields in 1998 to 2 species on Field Burn/Wheat and one species on Field Plow in 1999.

Comparisons of small mammals among treatments were qualititative only, as treatments on Fields Burn/Wheat and Mow/Control could not be separated statistically. Several small mammals were captured and recaptured in different treatments on these fields, which prevented statistical analyses for treatments (Table 20). Peromyscus were the most abundant species in 1999 on all treatments that received prairie creation techniques. On Treatment Plow, Peromyscus was the only small mammal captured in 1999 over the entire trapping period. On Treatments Burn, Wheat, and Mow, only 2

Table 19. Mean (SE) relative abundance of small mammals captured on grassland fields in RLWRA in Clinton County, Michigan, in summer 1998, 1999.

	Burn/Wheat		Plow		Control		Mow/Control	
Species	1998	1999	1998	1999	1998	1999	1998	1999
House mouse	0.25 (0.25)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Longtail weasel	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.25)	0.00 (0.00)	0.00 (0.00)
Least weasel	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.25)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Meadow jumping mouse	8.00 (2.92)	0.00* (0.00)	1.50 (0.96)	0.00 (0.00)	8.50 (2.75)	5.75 (2.06)	6.50 (3.62)	0.75 (0.48)
Masked shrew	2.25 (0.63)	0.00* (0.00)	2.75 (1.55)	0.00* (0.00)	1.50 (0.87)	2.00 (0.58)	1.00 (1.00)	0.00 (0.00)
Meadow vole	0.00 (0.00)	0.00 (0.00)	0.75 (0.48)	0.00 (0.00)	50.75 (10.87)	5.50* (1.85)	3.75 (1.03)	0.25* (0.25)
Peromyscus	7.00 (1.47)	23.00* (4.97)	1.75 (0.63)	8.00 (3.39)	0.00 (0.00)	0.75 (0.48)	0.00 (0.00)	5.00* (1.78)
Shorttail shrew	6.50 (2.90)	0.00* (0.00)	4.25 (2.46)	0.00 (0.00)	6.75 (2.02)	10.50 (4.94)	8.50 (3.75)	1.25 (0.63)
Thirteen-lined ground squirrel	10.50 (4.17)	1.50 (0.29)	0.75 (0.25)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
All Species	34.50 (9.51)	24.50 (4.87)	11.75 (3.90)	8.00 (3.39)	67.75 (11.24)	24.75* (5.95)	19.75 (8.47)	7.25 (2.06)
Total number of species	6	2	6	1	5	6	4	4

* Significant ($\alpha = 0.10$; Mann-Whitney U Test) within a field between years.

Table 20. Number of small mammals captured from May to August in grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Species	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
House mouse	1	0	0	0	0	0	0	0	0	0	0	0
Longtail weasel	0	0	0	0	0	0	0	1	0	0	0	0
Least weasel	0	0	0	0	0	0	1	0	0	0	0	0
Meadow jumping mouse	10	0	17(3)*	0	5	0	30	21	20(4)	0	7	3
Masked shrew	3	0	6	0	11	0	6	8	3	0	1	0
Meadow vole	0	0	0	0	2	0	155	17	6(1)	0	7	1
Peromyscus	5	24	16(1)	37(12)	4	26	0	2	0	12(5)	0	7
Shorttail shrew	12	0	11(1)	0	19	0	25	36	17(2)	3	9	2
Thirteen-lined ground squirrel	6	2	24(4)	4	2	0	0	0	0	0	0	0
Number of Species	6	2	5	2	6	1	5	6	4	2	4	4

* Numbers in parentheses indicate the number of small mammals that were captured in both treatments of the same field in the same year.

species of small mammals were captured in 1999. These treatments showed a decline in species richness from 1998 to 1999. Neither of the 2 control treatments showed a decline in species richness from 1998 to 1999.

Avian Relative Abundance and Productivity

Study Sites

1998

Twenty bird species were identified on the 4 fields in 1998 (Table 21; Appendix C Table 1). The following bird species differed ($P \leq 0.10$, $z \geq 2.39$) in mean relative abundances among fields in 1998: American goldfinch (*Carduelis tristis*), bobolink (*Dolichonyx oryzivorus*) cedar waxwing (*Bombycilla cedrorum*), eastern kingbird (*Tyrannus tyrannus*), field sparrow (*Spizella pusilla*), house wren (*Troglodytes aedon*), indigo bunting (*Passerina cyanea*), red-winged blackbird (*Agelaius phoenicus*), and song sparrow (*Melospiza melodia*). Field Burn/Wheat had more American goldfinches than Fields Plow ($z = 3.06$) and Mow/Control ($z = 3.12$). Although a significant difference among fields was detected for bobolinks, eastern kingbirds, and house wrens using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where these differences existed. Field Mow/Control had more cedar waxwings than Fields Burn/Wheat, Plow, and Control ($z = 2.56$ for the 3 fields). Fields Burn/Wheat and Plow had more field sparrows than Field Control ($z = 2.74$ and 2.48, respectively). Field Plow had more indigo buntings than all other fields ($z = 3.02$ for all fields). Field Control had more red-winged blackbirds than Field Mow/Control ($z = 3.65$). Field Burn/Wheat had more song sparrows than Field Control ($z = 2.68$). Field Burn/Wheat had the greatest species richness ($n = 14$), followed by Field Plow ($n = 13$), and Fields Control and Mow/Control ($n = 7$ each) in 1998.

Table 21. Mean (SE) relative abundance of birds (birds/census point) in grassland fields in RLWRA in Clinton County, Michigan, in summer 1998.

	Field			
Species	Burn/Wheat	Plow	Control	Mow/Control
American crow	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
American goldfinch*	3.00^{Aa} (0.39)	0.50^{B} (0.26)	1.67^{AB} (0.56)	0.50^{B} (0.34)
American robin	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)
Barn swallow	1.25 (0.98)	0.42 (0.33)	0.50 (0.34)	0.00 (0.00)
Blue jay	0.00 (0.00)	0.17 (0.17)	0.00 (0.00)	0.00 (0.00)
Bobolink*	0.17^{A} (0.11)	0.00^{A} (0.00)	0.00^{A} (0.00)	0.00^{A} (0.00)
Cedar waxwing*	0.00^{A} (0.00)	0.00^{A} (0.00)	0.00^{A} (0.00)	1.17^{B} (0.65)
Common yellowthroat	0.67 (0.21)	2.75 (0.94)	1.17 (0.60)	1.00 (0.45)
Eastern kingbird*	0.42^{A} (0.27)	0.00^{A} (0.00)	0.00^{A} (0.00)	0.00^{A} (0.00)
Field sparrow*	0.92^{A} (0.24)	1.42^{A} (0.71)	0.00^{B} (0.00)	1.33^{AB} (0.80)
Gray catbird	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)
Hairy woodpecker	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
House wren*	0.08^{A} (0.08)	0.33^{A} (0.17)	0.00^{A} (0.00)	0.00^{A} (0.00)

Table 21 (cont'd).

	Field			
Species	Burn/Wheat	Plow	Control	Mow/Control
Indigo bunting*	0.00 [A] (0.00)	0.67 [B] (0.31)	0.00 [A] (0.00)	0.00 [A] (0.00)
Northern cardinal	0.17 (0.17)	0.33 (0.17)	0.00 (0.00)	0.67 (0.42)
Red-winged blackbird*	1.67 [AB] (0.51)	0.42 [AB] (0.27)	11.33 [A] (3.56)	0.00 [B] (0.00)
Savanna sparrow	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.00 (0.00)
Song sparrow*	3.75 [A] (0.83)	3.17 [AB] (0.46)	1.00 [B] (0.26)	2.83 [AB] (0.98)
Tree swallow	0.08 (0.08)	0.25 (0.17)	0.33 (0.21)	0.33 (0.33)
Tufted titmouse	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
All species	12.42 (1.69)	10.58 (1.91)	16.17 (3.73)	7.83 (2.21)
Number of species	14	13	7	7

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among fields.

[a] Among fields within a row, means with the same letter are not significantly different.

In 1998, the relative abundance of birds differed ($P \leq 0.10$, $z \geq 2.71$) among census periods for all fields combined (Table 22). Although a significant difference among census periods was detected using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where these differences existed.

1999

No comparisons were made among fields in 1999, as fields received different manipulations. Fields were evaluated by comparing each field between years.

No difference ($P > 0.10$, $z < 2.91$) in the relative abundance of birds was detected among census periods in 1999 (Table 23).

Between 1998 and 1999

Field Burn/Wheat had greater ($P \leq 0.10$) mean relative abundances of American goldfinches ($P = 0.00$), bobolinks ($P = 0.09$), common yellowthroats ($P = 0.01$), red-winged blackbirds ($P = 0.03$), song sparrows ($P = 0.01$), and overall birds ($z = 0.01$) in 1998 compared to 1999 (Table 24; Appendix C Figures 1 and 2). Field Plow had greater mean relative abundances of barn swallows ($P = 0.09$; *Hirundo rustica*), common yellowthroats ($P = 0.00$), field sparrows ($P = 0.02$), house wrens ($P = 0.03$), indigo buntings ($P = 0.03$, *Passerina cyanea*), tree swallows ($P = 0.09$; *Iridoprocne bicolor*), and overall birds ($P = 0.01$) in 1998 compared to 1999. Field Control showed no significant differences in mean relative abundances for any bird species between 1998 and 1999. Field Mow/Control had greater mean relative abundances of cedar waxwings ($P = 0.03$), common yellowthroats ($P = 0.09$), song sparrows ($P = 0.02$), and overall birds ($P = 0.05$) in 1998 compared to 1999. Field Plow showed a decrease in number of bird species from 1998 to 1999, Fields Burn/Wheat and Mow/Control had more species of birds in 1999 than in 1998, and the number of bird species observed during census counts stayed the same in Field Control between years.

Table 22. Mean relative abundance (birds/census point) of birds for each census count in grassland fields in RLWRA, Clinton County, Michigan, in summer 1998.

	Census Period					
Field	May 17-May 30	June 14-27	June 28-July 11	July 12-25	July 26-August 8	August 9-22
Burn/Wheat	13	11.5	14	17.5	13.5	5
Plow	8	8.5	15	16.5	11.5	4
Control	17	21	29	18	9	3
Mow/Control	7	2	6	17	11	4
Overall*	45 ^{Aa}	43 ^{A}	64 ^{A}	69 ^{A}	45 ^{A}	16 ^{A}

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among census periods.
[a] Among censuses within a row, means with the same letter are not significantly different.

Table 23. Mean relative abundance (birds/census point) of birds for each census count in grassland fields in RLWRA, Clinton County, Michigan, in summer 1999.

	Census Period							
Field	May 17 - 30	May 31 - June 13	June 14 - 27	June 28 - July 11	July 12 - 25	July 26 - August 8	August 9 - 22	August 23 - 29
Burn/Wheat	2	3	2	5.5	5.5	1	6.5	1
Plow	0	0	2	7	3.5	9.5	1.5	5
Control	17	31	28	43	22	12	9	1
Mow/Control	4	2	4	4	3	4	3	3
Overall	23	36	36	59.5	34	26.5	20	10

Table 24. Mean (SE) relative abundance of birds (birds/census point) in grassland fields in RLWRA in Clinton County, Michigan, in summer 1998, 1999.

	Burn/Wheat		Plow		Control		Mow/Control	
Species	1998	1999	1998	1999	1998	1999	1998	1999
American crow	0.08 (0.08)	0.19 (0.13)	0.00 (0.00)	0.63 (0.63)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
American goldfinch	3.00 (0.39)	0.56* (0.27)	0.50 (0.26)	0.19 (0.13)	1.67 (0.56)	1.63 (0.78)	0.50 (0.34)	0.88 (0.40)
American robin	0.00 (0.00)	0.13 (0.08)	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Barn swallow	1.25 (0.98)	0.19 (0.13)	0.42 (0.33)	0.00* (0.00)	0.50 (0.34)	0.88 (0.40)	0.00 (0.00)	0.00 (0.00)
Black-capped chickadee	0.00 (0.00)	0.13 (0.13)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.16)
Blue jay	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.25)
Bobolink	0.17 (0.11)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Cedar waxwing	0.00 (0.00)	0.13 (0.13)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.17 (0.65)	0.00* (0.00)
Chipping sparrow	0.00 (0.00)	0.06 (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.16)
Cliff swallow	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.13 (0.13)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Common yellowthroat	0.67 (0.21)	0.06* (0.06)	2.75 (0.94)	0.25* (0.25)	1.17 (0.60)	1.00 (0.50)	1.00 (0.45)	0.13* (0.13)
Eastern kingbird	0.42 (0.27)	0.38 (0.21)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Field sparrow	0.92 (0.24)	0.38 (0.18)	1.42 (0.71)	0.19* (0.19)	0.00 (0.00)	0.13 (0.13)	1.33 (0.80)	0.50 (0.27)

Table 24 (cont'd).

	Burn/Wheat		Plow		Control		Mow/Control	
Species	1998	1999	1998	1999	1998	1999	1998	1999
Gray catbird	0.00 (0.00)	0.00 (0.00)	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Hairy woodpecker	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
House wren	0.08 (0.08)	0.00 (0.00)	0.33 (0.17)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Indigo bunting	0.00 (0.00)	0.00 (0.00)	0.67 (0.31)	0.06* (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.25 (0.25)
Northern cardinal	0.17 (0.17)	0.13 (0.08)	0.33 (0.17)	0.19 (0.19)	0.00 (0.00)	0.00 (0.00)	0.67 (0.42)	0.13 (0.13)
Red-winged blackbird	1.67 (0.51)	0.25* (0.13)	0.42 (0.27)	0.25 (0.25)	11.33 (3.56)	15.50 (5.60)	0.00 (0.00)	0.25 (0.16)
Sandhill crane	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.13 (0.13)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Savanna sparrow	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.17 (0.17)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Song sparrow	3.75 (0.83)	0.63* (0.49)	3.17 (0.46)	1.56 (0.78)	1.00 (0.26)	1.13 (0.40)	2.83 (0.98)	0.50* (0.19)
Tree swallow	0.08 (0.08)	0.06 (0.06)	0.25 (0.17)	0.00* (0.00)	0.33 (0.21)	0.13 (0.13)	0.33 (0.33)	0.00 (0.00)
Tufted titmouse	0.08 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Yellow-shafted flicker	0.00 (0.00)	0.06 (0.06)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
All species	12.42 (1.69)	3.31* (0.78)	10.58 (1.91)	3.56* (1.20)	16.17 (3.73)	20.38 (4.77)	7.83 (2.21)	3.38* (0.26)
Number of species	14	15	13	10	7	7	7	10

* Significant ($\alpha = 0.10$; Mann-Whitney U Test) within a field between years.

Areas Adjacent to Study Sites

Forty-two bird species were observed in areas adjacent to fields in 1998 and 1999 (Table 25, Appendix C Table 2). No statistical tests were done on bird censuses in adjacent areas, since this information was qualitative only. In 1998, song sparrows dominated adjacent areas of Fields Burn/Wheat and Plow with means of 9.50 and 6.50 observed per census count, respectively. Red-winged blackbirds dominated adjacent areas of Field Control with a mean of 20.60 observed per census count, and American goldfinches dominated adjacent areas of Field Mow/Control with a mean of 3.33 observed per census count. In 1999, red-winged blackbirds dominated adjacent areas of Fields Burn/Wheat, Plow, and Control with means of 28.25, 17.57, and 17.13 observed per census count, respectively. Gray catbirds (*Dumetella carolinensis*) dominated adjacent areas of Field Mow/Control with a mean of 2.75 observed per census count.

The number of bird species observed in all adjacent areas was relatively similar, with 22, 21, 23, and 19 bird species observed in 1998 in Fields Burn/Wheat, Plow, Control, and Mow/Control, respectively. In 1999, 29, 23, 26, and 24 bird species were observed in Fields Burn/Wheat, Plow, Control, and Mow/Control, respectively (Table 25).

Productivity

Six bird species were found nesting on the 6 treatment areas in 1998 and 1999: common yellowthroat, mallard (*Anas platyrhynchos*), mourning dove (*Zenaida macroura*), red-winged blackbird, song sparrow, and wild turkey (*Meleagris gallopavo*). In 1998, 18 nests were found on the 4 fields (Table 26). Treatment Burn had one nest, Treatment Wheat had 3 nests, Treatment Plow had 4 nests, and Treatment Control had 10 nests. No nests were located on Treatments Part-control and Mow in 1998. In 1999, 3 nests were found on the 4 fields. Treatment Control had 2 nests and Treatment Part-control had one nest (Table 27). No nests were located on the other 4 treatments. A nest was considered to be successful if at least one chick fledged. The mean nesting success

Table 25. Mean number of birds observed in areas adjacent to fields in RLWRA, Clinton County, Michigan, in summer 1998, 1999.

	Burn/Wheat		Plow		Control		Mow/Control	
Species	1998	1999	1998	1999	1998	1999	1998	1999
American crow	4.67	3.50	4.17	6.71	0.60	1.00	0.83	0.38
American goldfinch	3.33	2.63	0.67	0.71	2.60	2.38	3.33	2.63
American robin	1.33	1.25	1.00	0.57	1.20	0.63	0.33	0.88
Bank swallow	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Barn swallow	1.50	0.63	0.00	0.14	0.20	1.75	0.00	0.00
Black-capped chickadee	1.67	2.50	3.00	3.86	0.40	0.50	1.83	2.13
Blue jay	0.33	0.75	0.50	2.71	0.00	0.88	0.17	2.00
Bobolink	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Brown thrasher	0.17	0.38	0.00	0.00	0.00	0.13	0.00	0.00
Brown-headed cowbird	0.00	0.25	0.33	0.00	0.20	0.00	0.00	0.00
Canada goose	0.00	3.75	0.00	0.00	0.00	1.88	0.00	0.00
Cedar waxwing	0.00	0.38	0.00	0.00	0.20	0.75	0.83	1.38
Chimney swift	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chipping sparrow	0.00	1.50	0.00	0.14	0.00	0.00	0.00	0.25
Common yellowthroat	3.67	4.88	4.67	4.71	3.80	3.00	1.67	2.25
Downy woodpecker	0.00	0.13	0.00	0.29	0.00	0.25	0.00	0.38
Eastern kingbird	0.50	0.75	0.00	0.00	0.00	0.00	0.00	0.00
Eastern pewee	0.00	0.25	0.00	0.43	0.00	0.00	0.67	0.00
Field sparrow	2.67	7.75	5.50	6.43	0.60	1.13	1.00	2.38
Gray catbird	2.33	2.00	3.33	2.86	0.20	0.38	2.17	2.75
House wren	0.50	0.00	0.17	0.00	0.00	0.00	0.00	0.00

Table 25 (cont'd).

	Burn/Wheat		Plow		Control		Mow/Control	
Species	1998	1999	1998	1999	1998	1999	1998	1999
Indigo bunting	0.33	0.13	1.67	1.14	0.00	0.13	0.17	0.25
Killdeer	0.17	0.00	0.33	0.00	0.20	0.50	0.33	0.00
Mallard	0.00	0.00	0.00	0.00	1.40	0.63	0.33	0.00
Marsh wren	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Mourning dove	0.67	0.25	0.50	0.29	4.00	1.38	0.00	0.13
Northern cardinal	0.50	1.88	2.33	3.86	0.40	0.50	0.50	1.50
Red-tailed hawk	0.00	0.00	0.00	0.00	0.20	0.25	0.00	0.00
Red-winged blackbird	9.33	28.25	2.83	17.57	20.60	17.13	2.33	1.25
Ring-necked pheasant	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00
Rock dove	0.00	0.00	0.67	0.00	0.00	0.38	0.00	0.00
Rufous-sided towhee	0.00	0.00	0.17	1.00	0.00	0.00	0.00	0.63
Sandhill crane	0.83	0.88	0.83	0.43	0.80	0.25	0.17	0.00
Savanna sparrow	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00
Song sparrow	9.50	7.75	6.50	6.86	4.20	3.50	1.50	1.38
Tree swallow	0.33	0.13	0.00	0.14	1.00	0.13	0.00	0.13
Tufted titmouse	0.17	0.50	0.83	0.86	0.20	0.25	0.00	0.50
Veery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
White-breasted nuthatch	0.00	0.50	0.00	1.14	0.00	0.00	0.00	0.25
Wood thrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Yellow warbler	0.00	0.38	0.33	1.14	0.00	0.38	0.33	0.13
Yellow-shafted flicker	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.25

Table 25 (cont'd).

	Burn/Wheat		Plow		Control		Mow/Control	
Species	1998	1999	1998	1999	1998	1999	1998	1999
All species	44.67	66.63	35.83	49.86	38.40	38.88	18.67	24.00
Number of species	22	29	21	23	23	26	19	24

Table 26. Number of nests, number of successful nests, percent of successful nests, and relative density of nests found in RLWRA, Clinton County, Michigan, in summer 1998.

Treatment	Number of nests	Number of successful nests	Percentage of successful nests	Relative density of nests (nests/ha)
Burn	1	0	0	0.38
Wheat	3	3	100	0.71
Plow	4	2	50	0.83
Control	10	6	67	2.50
Mow	0	0	0	0.00
Part-control	0	0	0	0.00
Total	18	11	-	-
Mean	3	1.83	65	1.02

Table 27. Number of nests, number of successful nests, percent of successful nests, and relative density of nests found in RLWRA, Clinton County, Michigan, in summer 1999.

Treatment	Number of nests	Number of successful nests	Percentage of successful nests	Relative density of nests (nests/ha)
Burn	0	0	0	0.00
Wheat	0	0	0	0.00
Plow	0	0	0	0.00
Control	2	1	50	0.50
Mow	0	0	0	0.00
Part-control	1	1	100	1.67
Total	3	2	-	-
Mean	0.50	0.33	0.67	0.17

for all treatments was 0.65 in 1998 and 0.67 in 1999. The relative density of nests for all treatments was 1.02 nests/ha in 1998 and 0.17 nests/ha in 1999. Although 10 nests were found on Field Control in 1998, one of these was found after the nest had hatched or was destroyed. A mallard nest was found with only broken eggshells, so that the nesting success of this particular nest could not be determined. This nest was, therefore, not included in the number of successful nests category, and the percent successful nests was determined without counting this nest.

Insect Abundance

Insect sweepnetting

1998

June

In June 1998, the following insect Order biomasses showed differences ($P \leq 0.10$, $z \geq 2.71$) among treatments: Arachnids (Class Arachnida; scorpions, mites, ticks, daddy-long-legs, and spiders), Coleoptera (beetles), Diptera (flies), Hemiptera (bugs), Homoptera (aphids, hoppers, cicadas, and others), Hymenoptera (wasps and bees), Orthoptera (grasshoppers, crickets, and cockroaches), and insects overall (Table 28). Although Arachnids are not in the Class Insecta, they are included in this study with the insect analyses for the sake of simplicity. Arachnids are a common Arthropod Class in grasslands, and are an important prey of many birds (Ehrlich et al. 1988) and small mammals (Baker 1983). Treatment Part-control had a greater biomass of Arachnids than Treatment Control ($z = 3.14$). Treatments Control and Mow had a greater biomass of Coleoptera than Treatment Burn ($z = 4.11$ and 3.18, respectively). Although a significant difference among treatments for the biomass of Diptera and Hemiptera was detected using the Kruskal-Wallis one-way analysis-of-variance showed, the multiple-comparison test did not assist in determining where these differences existed among treatments. Treatment Burn had a greater biomass of Homoptera than Treatments Plow ($z = 3.11$) and

Table 28. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, Michigan, in June 1998.

	Treatment					
Order	Burn	Wheat	Plow	Control	Mow	Part-control
Arachnid*	9.4^{ABa}	11.5^{AB}	5.1^{AB}	2.4^{A}	19.8^{AB}	15.2^{B}
	(3.6)	(4.5)	(2.5)	(0.9)	(8.8)	(1.7)
Coleoptera*	0.9^{A}	9.5^{AB}	7.5^{AB}	36.3^{BC}	19.5^{BC}	7.8^{AB}
	(0.6)	(9.5)	(1.8)	(8.5)	(4.9)	(2.7)
Diptera*	5.4^{A}	10.5^{A}	2.3^{A}	7.2^{A}	6.8^{A}	6.2^{A}
	(1.6)	(5.5)	(0.5)	(1.5)	(1.9)	(2.6)
Ephemeroptera	1.4	0.0	0.0	0.8	2.8	0.0
	(1.4)	(0.0)	(0.0)	(0.6)	(2.8)	(0.0)
Hemiptera*	61.9^{A}	37.5^{A}	41.3^{A}	33.5^{A}	87.5^{A}	67.5^{A}
	(13.1)	(22.5)	(11.6)	(14.2)	(8.2)	(13.4)
Homoptera*	2486.9^{A}	135.0^{AB}	412.6^{B}	255.3^{B}	1955.3^{AB}	965.2^{AB}
	(424.5)	(19.0)	(156.8)	(100.8)	(856.1)	(548.6)
Hymenoptera*	0.6^{A}	2.0^{AB}	5.9^{AB}	5.6^{B}	5.8^{AB}	11.3^{AB}
	(0.3)	(2.0)	(3.8)	(1.4)	(2.8)	(6.5)
Lepidoptera	7.0	8.0	10.5	10.4	4.5	4.8
	(4.6)	(3.0)	(4.0)	(8.7)	(2.6)	(2.4)
Mecoptera	2.3	0.0	0.0	0.0	0.0	0.0
	(2.3)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Neuroptera	3.4	0.0	1.0	3.0	0.0	0.0
	(3.4)	(0.0)	(1.0)	(1.5)	(0.0)	(0.0)
Odonata	2.1	0.0	0.8	0.0	0.0	2.3
	(1.5)	(0.0)	(0.8)	(0.0)	(0.0)	(1.5)
Orthoptera*	24.6^{AB}	37.0^{AB}	39.2^{AB}	3.0^{A}	57.5^{AB}	52.3^{B}
	(14.1)	(5.0)	(16.2)	(2.9)	(29.7)	(25.4)

Table 28 (cont'd).

	Treatment					
Order	Burn	Wheat	Plow	Control	Mow	Part-control
All orders*	2605.8^{A} (434.7)	251.0^{AB} (22.0)	526.2^{B} (152.3)	357.5^{B} (100.9)	2159.3^{AB} (875.1)	1132.7^{AB} (567.9)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among treatments.

[a] Among treatments within a row, means with the same letter are not significantly different.

Control ($z = 3.62$). Treatment Control had a greater biomass of Hymenoptera than Treatment Burn ($z = 2.74$). Treatment Part-control had a greater biomass of Orthoptera than Treatment Control ($z = 3.04$). Treatment Burn had a greater biomass of overall insects than Treatments Plow ($z = 3.11$) and Control ($P = 3.70$).

July

In July 1998, the following insect Order biomasses differed ($P \leq 0.10$, $z \geq 2.71$) among treatments: Coleoptera, Ephemeroptera (mayflies), Hemiptera, Homoptera, Odonata (dragonflies and damselflies), Orthoptera, and overall insects (Table 29). Treatment Part-control had a greater biomass of Coleoptera than Treatments Burn ($z = 4.00$) and Plow ($z = 3.02$). Treatment Control had a greater biomass of Coleoptera than Treatment Burn ($z = 3.20$). Treatment Mow had a greater biomass of Ephemeroptera than all other treatments (Burn ($z = 4.06$), Wheat ($z = 2.87$), Plow ($z = 4.20$), Control ($z = 3.66$), and Part-control ($z = 3.85$)). Treatment Burn had a greater biomass of Hemiptera than Treatments Control ($z = 3.25$) and Part-control ($z = 3.17$). Treatment Burn had a greater biomass of Homoptera than Treatments Plow ($z = 3.00$), Control ($z = 4.60$), and Part-control ($z = 3.50$). Treatment Part-control had a greater biomass of Odonata than Treatments Burn ($z = 3.07$), Plow ($z = 3.21$), and Control ($z = 3.21$). Treatment Plow had a greater biomass of Orthoptera than Treatment Control ($z = 3.41$). Treatment Burn had a greater biomass of overall insects than Treatments Plow ($z = 3.39$) and Control ($z = 3.53$).

August

In August 1998, the following Order biomasses differed ($P \leq 0.10$, $z \geq 2.71$) among treatments: Coleoptera, Ephemeroptera, Hemiptera, Homoptera, and Plecoptera (stoneflies; Table 30). Treatments Plow and Control had a greater biomass of Coleoptera than Treatment Burn ($z = 3.09$ and 3.82, respectively). Treatment Mow had a greater biomass of Ephemeroptera than Treatments Burn ($z = 2.98$), Plow ($z = 3.04$), and Part-control ($z = 2.83$). Treatment Plow had a greater biomass of Hemiptera than Treatment Part-control ($z = 2.95$). Treatment Plow had a greater biomass of Homoptera than

Table 29. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, Michigan, in July 1998.

	Treatment					
Order	Burn	Wheat	Plow	Control	Mow	Part-control
Arachnid	6.9 (2.3)	25.0 (14.0)	7.8 (3.9)	0.7 (0.4)	5.3 (3.1)	7.3 (5.1)
Coleoptera*	6.9 ^{Aa} (3.5)	19.5 ^{A} (2.5)	16.9 ^{AB} (4.0)	356.3 ^{BC} (196.7)	159.5 ^{AC} (136.6)	418.8 ^{C} (205.6)
Diptera	9.0 (1.6)	21.5 (15.5)	5.4 (1.6)	6.8 (1.6)	22.3 (10.6)	5.2 (1.9)
Ephemeroptera*	0.0 ^{A} (0.0)	0.0 ^{A} (0.0)	0.0 ^{A} (0.0)	1.0 ^{A} (1.0)	6.8 ^{B} (2.7)	0.0 ^{A} (0.0)
Hemiptera*	80.5 ^{A} (20.3)	49.0 ^{A} (5.0)	29.5 ^{AB} (4.3)	28.8 ^{B} (19.5)	12.5 ^{AB} (5.1)	11.2 ^{B} (4.3)
Homoptera*	943.4 ^{A} (66.3)	104.5 ^{A} (85.5)	211.1 ^{B} (51.1)	73.7 ^{B} (18.2)	365.8 ^{AB} (103.0)	147.8 ^{B} (89.2)
Hymenoptera	5.3 (1.2)	11.0 (7.0)	5.2 (1.7)	6.9 (2.3)	6.0 (2.4)	5.5 (3.4)
Lepidoptera	4.5 (2.6)	0.0 (0.0)	6.1 (1.8)	1.3 (0.7)	2.5 (2.5)	1.7 (1.0)
Neuroptera	0.6 (0.6)	0.0 (0.0)	0.2 (0.2)	4.2 (3.2)	5.8 (3.4)	1.0 (1.0)
Odonata*	0.0 ^{B} (0.0)	0.0 ^{A} (0.0)	0.0 ^{B} (0.0)	0.0 ^{B} (0.0)	2.0 ^{AB} (2.0)	10.0 ^{A} (6.4)
Orthoptera*	58.4 ^{A} (19.4)	69.5 ^{A} (36.5)	90.8 ^{A} (18.3)	11.8 ^{B} (3.5)	33.5 ^{AB} (23.6)	54.8 ^{AB} (17.7)
Plecoptera	0.0 (0.0)	0.0 (0.0)	0.5 (0.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Table 29 (cont'd).

	Treatment					
Order	Burn	Wheat	Plow	Control	Mow	Part-control
All orders*	1115.4 [A] (69.9)	300.0 [AB] (156.0)	373.5 [B] (65.3)	491.5 [B] (183.6)	621.8 [AB] (123.0)	663.3 [AB] (184.1)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among treatments.
[a] Among treatments within a row, means with the same letter are not significantly different.

Table 30. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, Michigan, in August 1998.

	Treatment					
Order	Burn	Wheat	Plow	Control	Mow	Part-control
Arachnid	5.1 (1.9)	3.0 (3.0)	6.4 (2.4)	3.9 (1.2)	9.8 (2.4)	10.8 (6.0)
Coleoptera*	0.9 ^{Aa} (0.6)	28.0 ^{AB} (28.0)	51.0 ^{B} (12.4)	77.6 ^{B} (17.9)	110.5 ^{AB} (107.2)	62.3 ^{A} (30.1)
Diptera	1.1 (0.7)	1.5 (1.5)	3.6 (1.2)	5.2 (1.8)	6.5 (2.2)	2.2 (0.7)
Ephemeroptera*	0.0 ^{A} (0.0)	0.0 ^{AB} (0.0)	0.0 ^{A} (0.0)	0.7 ^{AB} (0.7)	2.8 ^{B} (1.7)	0.0 ^{A} (0.0)
Hemiptera*	11.8 ^{A} (5.7)	17.0 ^{AB} (14.0)	34.0 ^{A} (6.8)	13.2 ^{AB} (4.5)	18.8 ^{AB} (8.4)	6.0 ^{B} (3.0)
Homoptera*	7.1 ^{A} (2.1)	9.5 ^{AB} (7.5)	28.7 ^{B} (5.1)	22.7 ^{AB} (4.0)	14.3 ^{AB} (2.4)	14.7 ^{A} (4.8)
Hymenoptera	0.6 (0.4)	2.0 (2.0)	4.7 (2.0)	3.8 (1.2)	2.8 (1.7)	2.0 (1.5)
Lepidoptera	0.8 (0.8)	7.5 (7.5)	0.0 (0.0)	1.5 (1.0)	3.8 (2.3)	2.3 (1.8)
Neuroptera	0.0 (0.0)	0.0 (0.0)	1.8 (1.2)	1.2 (0.9)	0.0 (0.0)	0.3 (0.3)
Odonata	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4.3 (4.3)	0.0 (0.0)	0.8 (0.8)
Orthoptera	88.0 (28.0)	32.5 (32.5)	39.9 (19.8)	25.5 (10.5)	30.5 (1.6)	41.3 (26.3)
Plecoptera*	1.9 ^{A} (1.9)	0.0 ^{AB} (0.0)	10.6 ^{A} (7.0)	0.0 ^{A} (0.0)	0.0 ^{AB} (0.0)	14.8 ^{B} (5.8)

Table 30 (cont'd).

	Treatment					
Order	Burn	Wheat	Plow	Control	Mow	Part-control
All orders	117.3 (32.4)	101.0 (27.0)	180.6 (18.5)	159.6 (21.3)	199.5 (113.3)	157.7 (52.9)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among treatments.

[a] Among treatments within a row, means with the same letter are not significantly different.

Treatment Burn ($z = 3.11$). Treatment Part-control had a greater biomass of Plecoptera than Treatment Control ($z = 3.17$).

Among Months

In 1998, the following insect Orders differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Burn: Diptera, Hemiptera, Homoptera, Hymenoptera, Orthoptera, and overall insects (Table 31). The biomass of Diptera, Hemiptera, Homoptera, and overall insects was lower in August than in June ($z = 2.15$, 2.55, 4.14, and 4.10, respectively) and July ($z = 3.34$, 2.98, 2.65, and 2.69, respectively). The biomass of Hymenoptera was greater in July than in June ($z = 2.69$) and August ($z = 2.88$). The biomass of Orthoptera was greater in August than in June ($z = 2.22$). Coleoptera, Homoptera, Lepidoptera, Orthoptera, and overall insects differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Plow. The biomass of Coleoptera was greater in August than in June ($z = 3.26$). The biomass of Homoptera, Lepidoptera, and overall insects was greater in June ($z = 3.18$, 2.78, and 2.18, respectively) and July ($z = 3.00$, 2.81, and 2.14, respectively) than in August. Although a significant difference among months was detected for the biomass of Hemiptera using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where this difference existed among months. Homoptera and Orthoptera differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Control. The biomass of Homoptera was greater in June than in August ($z = 2.77$). Although a significant difference among months was detected for the biomass of Orthoptera using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where this difference existed among months. Coleoptera, Hemiptera, Homoptera, Plecoptera, and overall insects differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Part-control. The biomass of Coleoptera was greater in July than in June ($z = 3.14$). The biomass of Hemiptera was greater in June than in July ($z = 2.27$) and August ($z = 3.25$). The biomass of Homoptera and overall

Table 31. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, MI, in summer 1998.

	Burn			Wheat			Plow		
Order	June	July	August	June	July	August	June	July	August
Arachnid	9.4 (3.6)	6.9 (2.3)	5.1 (1.9)	11.5 (4.5)	25.0 (14.0)	3.0 (3.0)	5.1 (2.5)	7.8 (3.9)	6.4 (2.4)
Coleoptera	0.9 (0.6)	6.9 (3.5)	0.9 (0.6)	9.5 (9.5)	19.5 (2.5)	28.0 (28.0)	7.5* ^{A} (1.8)	16.9 ^{AB} (4.0)	51.0 ^{B} (12.4)
Diptera	5.4* ^{Aa} (1.6)	9.0 ^{A} (1.6)	1.1 ^{B} (0.7)	10.5 (5.5)	21.5 (15.5)	1.5 (1.5)	2.3 (0.5)	5.4 (1.6)	3.6 (1.2)
Ephemeroptera	1.4 (1.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hemiptera	61.9* ^{A} (13.1)	80.5 ^{A} (20.3)	11.8 ^{B} (5.7)	37.5 (22.5)	49.0 (5.0)	17.0 (14.0)	41.3 (11.6)	29.5 (4.3)	34.0 (6.8)
Homoptera	2486.9* ^{A} (424.5)	943.4 ^{A} (66.3)	7.1 ^{B} (2.1)	135.0 (19.0)	104.5 (85.5)	9.5 (7.5)	412.6* ^{A} (156.8)	211.1 ^{A} (51.1)	28.7 ^{B} (5.1)
Hymenoptera	0.6* ^{A} (0.3)	5.3 ^{B} (1.2)	0.6 ^{A} (0.4)	2.0 (2.0)	11.0 (7.0)	2.0 (2.0)	5.9 (3.8)	5.2 (1.7)	4.7 (2.0)
Lepidoptera	7.0 (4.6)	4.5 (2.6)	0.8 (0.8)	8.0 (3.0)	0.0 (0.0)	7.5 (7.5)	10.5* ^{A} (4.0)	6.1 ^{A} (1.8)	0.0 ^{B} (0.0)

Table 31 (cont'd).

	Burn			Wheat			Plow		
Order	June	July	August	June	July	August	June	July	August
Mecoptera	2.3 (2.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Neuroptera	3.4 (3.4)	0.6 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	0.2 (0.2)	1.8 (1.2)
Odonata	2.1 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.8 (0.8)	0.0 (0.0)	0.0 (0.0)
Orthoptera	24.6* ^{A} (14.1)	58.4 ^{AB} (19.4)	88.0 ^{B} (28.0)	37.0 (5.0)	69.5 (36.5)	32.5 (32.5)	39.2* ^{A} (16.2)	90.8 ^{A} (18.3)	39.9 ^{A} (19.8)
Plecoptera	0.0 (0.0)	0.0 (0.0)	1.9 (1.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (0.5)	10.6 (7.0)
All orders	2605.8* ^{A} (434.7)	1115.4 ^{A} (69.9)	117.3 ^{B} (32.4)	251.0 (22.0)	300.0 (156.0)	101.0 (27.0)	526.2* ^{A} (152.3)	373.5 ^{A} (65.3)	180.6 ^{B} (18.5)

Table 31 (cont'd).

Order	Control			Mow			Part-control		
	June	July	August	June	July	August	June	July	August
Arachnid	2.4 (0.9)	0.7 (0.4)	3.9 (1.2)	19.8 (8.8)	5.3 (3.1)	9.8 (2.4)	15.2 (1.7)	7.3 (5.1)	10.8 (6.0)
Coleoptera	36.3 (8.5)	356.3 (196.7)	77.6 (17.9)	19.5 (4.9)	159.5 (136.6)	110.5 (107.2)	7.8* (2.7)	418.8 (205.6)	62.3 (30.1)
Diptera	7.2 (1.5)	6.8 (1.6)	5.2 (1.8)	6.8 (1.9)	22.3 (10.6)	6.5 (2.2)	6.2 (2.6)	5.2 (1.9)	2.2 (0.7)
Ephemeroptera	0.8 (0.6)	1.0 (1.0)	0.7 (0.7)	2.8 (2.8)	6.8 (2.7)	2.8 (1.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hemiptera	33.5 (14.2)	28.8 (19.5)	13.2 (4.5)	87.5*^{A} (8.2)	12.5^{B} (5.1)	18.8^{B} (8.4)	67.5*^{A} (13.4)	11.2^{B} (4.3)	6.0^{B} (3.0)
Homoptera	255.3*^{A} (100.8)	73.7^{AB} (18.2)	22.7^{B} (4.0)	1955.3*^{A} (856.1)	365.8^{AB} (103.0)	14.3^{B} (2.4)	965.2*^{A} (548.6)	147.8^{A} (89.2)	14.7^{B} (4.8)
Hymenoptera	5.6 (1.4)	6.9 (2.3)	3.8 (1.2)	5.8 (2.8)	6.0 (2.4)	2.8 (1.7)	11.3 (6.5)	5.5 (3.4)	2.0 (1.5)
Lepidoptera	10.4 (8.7)	1.3 (0.7)	1.5 (1.0)	4.5 (2.6)	2.5 (2.5)	3.8 (2.3)	4.8 (2.4)	1.7 (1.0)	2.3 (1.8)

Table 31 (cont'd).

	Control			Mow			Part-control		
Order	June	July	August	June	July	August	June	July	August
Mecoptera	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Neuroptera	3.0 (1.5)	4.2 (3.2)	1.2 (0.9)	0.0 (0.0)	5.8 (3.4)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	0.3 (0.3)
Odonata	0.0 (0.0)	0.0 (0.0)	4.3 (4.3)	0.0 (0.0)	2.0 (2.0)	0.0 (0.0)	2.3 (1.5)	10.0 (6.4)	0.8 (0.8)
Orthoptera	3.0* [A] (2.9)	11.8 [A] (3.5)	25.5 [A] (10.5)	57.5 (29.7)	33.5 (23.6)	30.5 (1.6)	52.3 (25.4)	54.8 (17.7)	41.3 (26.3)
Plecoptera	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0* [A] (0.0)	0.0 [A] (0.0)	14.8 [B] (5.8)
All orders	357.5 (100.9)	491.5 (183.6)	159.6 (21.3)	2159.3* [A] (875.1)	621.8 [AB] (123.0)	199.5 [B] (113.3)	1132.7* [A] (567.9)	663.3 [A] (184.1)	157.7 [B] (52.9)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among months within a treatment.
[a] Among treatments within a row, means with the same letter are not significantly different.

insects was greater in June ($z = 3.30$ and 2.27, respectively) and July ($z = 2.22$ and 2.60, respectively) than in August. The biomass of Plecoptera was greater in August than in June ($z = 2.67$) and July ($z = 2.67$). In 1998, Hemiptera, Homoptera, and overall insects differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Mow. The biomass of Hemiptera was greater in June than in July ($z = 2.55$) and August ($z = 2.16$). The biomass of Homoptera and overall insects was greater in June than in August ($z = 2.85$ and 2.75, respectively).

1999

No comparisons were made among treatments for each month in 1999, as fields received different manipulations. Treatments were evaluated by comparing each treatment between years.

<u>Among months</u>

In 1999, Coleoptera and Homoptera differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Burn (Table 32). The biomass of Coleoptera was greater in August than in June ($z = 2.24$). The biomass of Homoptera was greater in August than in June ($z = 2.67$) and July ($z = 2.36$). Diptera, Hemiptera, and Orthoptera differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Wheat. Although a significant difference among months was detected for the biomasses of Diptera, Hemiptera, and Orthoptera using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where these differences existed. Arachnids, Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera, and overall insects differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Plow. The biomass of Arachnids was greater in August than in June ($z = 2.45$). The biomass of Coleoptera, Homoptera, Hymenoptera, and overall insects was greater in July ($z = 3.80$, 3.52, 2.94, and 3.04, respectively) and August ($z =$ 2.77, 3.26, 3.19, and 4.58, respectively) than in June. The biomass of Diptera was greater in August than June ($z = 4.29$) and July ($z = 3.75$). The biomass of Hemiptera was

Table 32. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, Michigan, in summer 1999.

	Burn			Wheat			Plow		
Order	June	July	August	June	July	August	June	July	August
Arachnid	3.4	5.9	1.3	0.0	40.0	0.5	0.0* ^{A}	1.1 ^{AB}	4.4 ^{B}
	(2.3)	(5.9)	(1.3)	(0.0)	(40.0)	(0.5)	(0.0)	(0.7)	(3.3)
Coleoptera	0.4* ^{Aa}	1.9 ^{AB}	5.0 ^{B}	3.5	2.0	13.0	0.8* ^{A}	14.8 ^{B}	8.4 ^{B}
	(0.4)	(1.6)	(1.7)	(3.5)	(2.0)	(4.0)	(0.8)	(4.7)	(2.8)
Diptera	5.5	2.5	3.1	0.0* ^{A}	0.0 ^{A}	1.5 ^{A}	0.5* ^{A}	1.0 ^{A}	17.8 ^{B}
	(4.0)	(1.3)	(1.4)	(0.0)	(0.0)	(0.5)	(0.3)	(0.5)	(3.1)
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Hemiptera	0.1	10.3	8.0	0.0* ^{A}	0.0 ^{A}	11.5 ^{A}	0.0* ^{A}	13.2 ^{B}	56.3 ^{C}
	(0.1)	(10.3)	(6.4)	(0.0)	(0.0)	(9.5)	(0.0)	(5.2)	(14.4)
Homoptera	0.4* ^{A}	0.8 ^{A}	3.1 ^{B}	0.0	1.5	3.0	0.0* ^{A}	4.0 ^{B}	4.8 ^{B}
	(0.3)	(0.5)	(1.6)	(0.0)	(1.5)	(2.0)	(0.0)	(1.2)	(2.3)
Hymenoptera	0.0	0.0	0.4	0.0	4.5	0.5	0.0* ^{A}	3.5 ^{B}	5.0 ^{B}
	(0.0)	(0.0)	(0.3)	(0.0)	(2.5)	(0.5)	(0.0)	(1.5)	(2.2)
Lepidoptera	0.6	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0
	(0.6)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(3.2)	(0.0)

Table 32 (cont'd).

	Burn			Wheat			Plow		
Order	June	July	August	June	July	August	June	July	August
Neuroptera	0.0 (0.0)	0.0 (0.0)	2.0 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)
Odonata	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)
Orthoptera	6.4 (5.8)	2.6 (2.1)	6.5 (4.7)	0.0* ^{A} (0.0)	7.0 ^{A} (2.0)	0.0 ^{A} (0.0)	0.0 (0.0)	12.6 (8.1)	5.4 (2.4)
All orders	16.8 (7.9)	23.9 (18.8)	29.4 (11.9)	3.5 (3.5)	55.0 (41.0)	30.0 (16.0)	1.3* ^{A} (1.1)	53.6 ^{B} (13.9)	102.3 ^{B} (14.6)

Table 32 (cont'd).

	Control			Mow			Part-control		
Order	June	July	August	June	July	August	June	July	August
Arachnid	18.4*^{A} (6.2)	4.7^{AB} (2.0)	4.7^{B} (2.0)	1.5 (1.5)	0.0 (0.0)	0.0 (0.0)	27.7 (12.3)	7.7 (4.6)	10.3 (4.9)
Coleoptera	6.3*^{A} (2.4)	231.0^{B} (145.8)	133.0^{B} (41.6)	0.0 (0.0)	17.5 (17.5)	1.3 (0.5)	15.3*^{A} (5.0)	652.3^{A} (365.0)	193.5^{A} (48.6)
Diptera	4.7*^{A} (0.8)	2.2^{A} (0.9)	2.6^{A} (1.6)	6.8 (6.4)	0.3 (0.3)	3.5 (3.5)	6.0 (2.2)	7.7 (0.9)	3.5 (1.6)
Ephemeroptera	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.8 (1.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hemiptera	49.8*^{A} (13.1)	9.2^{B} (3.1)	14.2^{B} (6.5)	1.3 (1.3)	0.0 (0.0)	3.5 (3.2)	40.0 (17.7)	14.5 (4.9)	10.2 (2.0)
Homoptera	88.4*^{A} (22.6)	41.8^{A} (6.9)	13.1^{B} (3.4)	3.3*^{A} (1.3)	0.0^{B} (0.0)	1.5^{AB} (0.6)	22.0 (5.9)	7.5 (3.2)	14.0 (5.7)
Hymenoptera	4.1 (1.0)	2.8 (1.1)	6.5 (2.8)	0.3 (0.3)	0.5 (0.5)	0.0 (0.0)	4.3 (1.2)	11.2 (10.8)	15.0 (10.4)
Lepidoptera	0.8 (0.4)	0.2 (0.2)	0.1 (0.1)	1.5 (1.5)	0.0 (0.0)	0.8 (0.8)	0.8 (0.8)	0.8 (0.8)	3.2 (2.0)

Table 32 (cont'd).

	Control			Mow			Part-control		
Order	June	July	August	June	July	August	June	July	August
Neuroptera	0.5 (0.5)	0.7 (0.5)	1.6 (0.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Odonata	1.7 (1.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	2.2 (2.2)	1.5 (1.0)
Orthoptera	0.0* ^{A} (0.0)	5.2 ^{B} (1.9)	0.5 ^{A} (0.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	8.2* ^{A} (4.1)	84.0 ^{B} (25.4)	32.0 ^{AB} (15.1)
All orders	174.7 (34.5)	297.8 (145.2)	176.3 (45.4)	16.3 (7.7)	18.3 (17.3)	10.5 (7.0)	125.3 (36.9)	787.8 (377.1)	283.2 (54.9)

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among months within a treatment.
[a] Among months within a treatment, means with the same letter are not significantly different.

greater in August than June ($z = 4.70$) and July ($z = 2.31$), and greater in July than June ($z = 2.39$). Arachnids, Coleoptera, Diptera, Hemiptera, Homoptera, and Orthoptera differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Control in 1999. The biomass of Arachnids was greater in June than August ($z = 2.26$). The biomass of Coleoptera was greater in July ($z = 2.65$) and August ($z = 3.46$) than June. Although a significant difference was detected among months for the biomass of Diptera using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where this difference existed. The biomass of Hemiptera was greater in June than July ($z = 2.85$) and August ($z = 2.38$). The biomass of Homoptera was greater in June ($z = 3.71$) and July ($z = 2.65$) than August. The biomass of Orthoptera was greater in July than June ($z = 3.41$) and August ($z = 2.91$). Coleoptera and Orthoptera differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Part-control. Although a significant difference among months was detected for the biomass of Coleoptera using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where this difference existed. The biomass of Orthoptera was greater in July than June ($z = 2.47$). Homoptera differed ($P \leq 0.10$, $z \geq 2.13$) among months on Treatment Mow. The biomass of Homoptera was greater in June than July ($z = 2.31$).

Between 1998 and 1999

June

The biomass of Hemiptera ($P = 0.01$), Homoptera ($P = 0.01$), Hymenoptera ($P = 0.08$), and overall insects ($P = 0.01$) decreased from June 1998 to June 1999 on Treatment Burn (Table 33). The biomass of Arachnids ($P = 0.03$), Coleoptera ($P = 0.01$), Diptera ($P = 0.02$), Hemiptera ($P = 0.01$), Homoptera ($P = 0.01$), Hymenoptera ($P = 0.02$), Lepidoptera ($P = 0.02$; moths and butterflies), Orthoptera ($P = 0.01$), and overall insects ($P = 0.01$) decreased on Treatment Plow between years. The biomass of Arachnids ($P = 0.03$) increased on Treatment Control, while the biomass of Coleoptera ($P = 0.01$),

Table 33. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, MI, in June 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Order	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Arachnid	9.4 (3.6)	3.4 (2.3)	11.5 (4.5)	0.0 (0.0)	5.1 (2.5)	0.0* (0.0)	2.4 (0.9)	18.4* (6.2)	19.8 (8.8)	1.5* (1.5)	15.2 (1.7)	27.7 (12.3)
Coleoptera	0.9 (0.6)	0.4 (0.4)	9.5 (9.5)	3.5 (3.5)	7.5 (1.8)	0.8* (0.8)	36.3 (8.5)	6.3* (2.4)	19.5 (4.9)	0.0* (0.0)	7.8 (2.7)	15.3 (5.0)
Diptera	5.4 (1.6)	5.5 (4.0)	10.5 (5.5)	0.0 (0.0)	2.3 (0.5)	0.5* (0.3)	7.2 (1.5)	4.7 (0.8)	6.8 (1.9)	6.8 (6.4)	6.2 (2.6)	6.0 (2.2)
Ephemeroptera	1.4 (1.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.8 (0.6)	0.0 (0.0)	2.8 (2.8)	1.8 (1.8)	0.0 (0.0)	0.0 (0.0)
Hemiptera	61.9 (13.1)	0.1* (0.1)	37.5 (22.5)	0.0 (0.0)	41.3 (11.6)	0.0* (0.0)	33.5 (14.2)	49.8 (13.1)	87.5 (8.2)	1.3* (1.3)	67.5 (13.4)	40.0 (17.7)
Homoptera	2,486.9 (424.5)	0.4* (0.3)	135.0 (19.0)	0.0 (0.0)	412.6 (156.8)	0.0* (0.0)	255.3 (100.8)	88.4* (22.6)	1,955.3 (856.1)	3.3* (1.3)	965.2 (548.6)	22.0* (5.9)
Hymenoptera	0.6 (0.3)	0.0* (0.0)	2.0 (2.0)	0.0 (0.0)	5.9 (3.8)	0.0* (0.0)	5.6 (1.4)	4.1 (1.0)	5.8 (2.8)	0.3* (0.3)	11.3 (6.5)	4.3 (1.2)
Lepidoptera	7.0 (4.6)	0.6 (0.6)	8.0 (3.0)	0.0 (0.0)	10.5 (4.0)	0.0 (0.0)	10.4 (8.7)	0.8 (0.4)	4.5 (2.6)	1.5 (1.5)	4.8 (2.4)	0.8 (0.8)

Table 33 (cont'd).

Order	Burn 1998	Burn 1999	Wheat 1998	Wheat 1999	Plow 1998	Plow 1999	Control 1998	Control 1999	Mow 1998	Mow 1999	Part-control 1998	Part-control 1999
Mecoptera	2.3 (2.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Neuroptera	3.4 (3.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	0.0 (0.0)	3.0 (1.5)	0.5 (0.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Odonata	2.1 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.8 (0.8)	0.0 (0.0)	0.0 (0.0)	1.7 (1.7)	0.0 (0.0)	0.0 (0.0)	2.3 (1.5)	1.0 (1.0)
Orthoptera	24.6 (14.1)	6.4 (5.8)	37.0 (5.0)	0.0 (0.0)	39.2 (16.2)	0.0* (0.0)	3.0 (2.9)	0.0 (0.0)	57.5 (29.7)	0.0* (0.0)	52.3 (25.4)	8.2* (4.1)
All orders	2605.8 (434.7)	16.8* (7.9)	251.0 (22.0)	3.5 (3.5)	526.2 (152.3)	1.3* (1.1)	357.5 (100.9)	174.7* (34.5)	2,159.3 (875.1)	16.3* (7.7)	1132.7 (567.9)	125.3* (36.9)
Number of orders	12	7	8	1	10	2	10	9	9	7	9	9

* Significant ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between years.

Homoptera (P = 0.02), and overall insects (P = 0.01) decreased on Treatment Control between June 1998 and June 1999. On Treatment Part-control, the biomass of Homoptera (P = 0.03), Orthoptera (P = 0.03), and overall insects (P = 0.07) decreased. On Treatment Mow, the biomass of Arachnids (P = 0.09), Coleoptera (P = 0.07), Hemiptera (P = 0.07), Homoptera (P = 0.07), Hymenoptera (P = 0.09), Orthoptera (P = 0.09), and overall insects (P = 0.01) decreased between June 1998 and 1999. In June 1998, Treatment Burn had the greatest number of Orders with 12, followed by Treatments Plow and Control with 10 Orders each, Treatments Part-control and Mow with 9 Orders each, and Treatment Wheat with 8 Orders. In June 1999, Treatments Control and Part-control had the greatest number of Orders with 9 each, followed by Treatments Burn and Mow with 7 Orders each, Treatment Plow with 2 Orders, and Treatment Wheat with one Order.

July

The biomass of Diptera (P = 0.04), Hemiptera (P = 0.01), Homoptera (P = 0.02), Hymenoptera (P = 0.01), Lepidoptera (P = 0.09), Orthoptera (P = 0.02), and overall insects (P = 0.01) decreased from July 1998 to July 1999 on Treatment Burn (Table 34). The biomass of Diptera (P = 0.02), Hemiptera (P = 0.06), Homoptera (P = 0.01), Orthoptera (P = 0.01), and overall insects (P = 0.01) decreased on Treatment Plow. The biomass of Arachnids (P = 0.04) increased on Treatment Control, while the biomass of Coleoptera (P = 0.03), Diptera (P = 0.01), Hymenoptera (P = 0.01), Lepidoptera (P = 0.08), and overall insects (P = 0.01) decreased between years in July. The biomass of Homoptera (P = 0.03) decreased on Treatment Part-control. The biomass of Coleoptera (P = 0.07), Diptera (P = 0.07), Ephemeroptera (P = 0.09), Hemiptera (P = 0.07), Homoptera (P = 0.07), Hymenoptera (P = 0.09), Orthoptera (P = 0.09), and overall insects (P = 0.07) decreased on Treatment Mow between July 1998 and July 1999. In July 1998, Treatment Mow had the greatest number of Orders with 11, followed by Treatment Plow, Control, and Part-control with 10 Orders each, Treatment Burn with 9

Table 34. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, MI, in July 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Order	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Arachnid	6.9	5.9	25.0	40.0	7.8	1.1	0.7	4.7*	5.3	0.0	7.3	7.7
	(2.3)	(5.9)	(14.0)	(40.0)	(3.9)	(0.7)	(0.4)	(2.0)	(3.1)	(0.0)	(5.1)	(4.6)
Coleoptera	6.9	1.9	19.5	2.0	16.9	14.8	356.3	231.0*	159.5	17.5*	418.8	652.3
	(3.5)	(1.6)	(2.5)	(2.0)	(4.0)	(4.7)	(196.7)	(145.8)	(136.6)	(17.5)	(205.6)	(365.0)
Diptera	9.0	2.5*	21.5	0.0	5.4	1.0*	6.8	2.2*	22.3	0.3*	5.2	7.7
	(1.6)	(1.3)	(15.5)	(0.0)	(1.6)	(0.5)	(1.6)	(0.9)	(10.6)	(0.3)	(1.9)	(0.9)
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	6.8	0.0*	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(1.0)	(0.0)	(2.7)	(0.0)	(0.0)	(0.0)
Hemiptera	80.5	10.3*	49.0	0.0	29.5	13.2*	28.8	9.2	12.5	0.0*	11.2	14.5
	(20.3)	(10.3)	(5.0)	(0.0)	(4.3)	(5.2)	(19.5)	(3.1)	(5.1)	(0.0)	(4.3)	(4.9)
Homoptera	943.4	0.8*	104.5	1.5	211.1	4.0*	73.7	41.8	365.8	0.0*	147.8	7.5*
	(66.3)	(0.5)	(85.5)	(1.5)	(51.1)	(1.2)	(18.2)	(6.9)	(103.0)	(0.0)	(89.2)	(3.2)
Hymenoptera	5.3	0.0*	11.0	4.5	5.2	3.5	6.9	2.8*	6.0	0.5*	5.5	11.2
	(1.2)	(0.0)	(7.0)	(2.5)	(1.7)	(1.5)	(2.3)	(1.1)	(2.4)	(0.5)	(3.4)	(10.8)
Lepidoptera	4.5	0.0*	0.0	0.0	6.1	3.3	1.3	0.2*	2.5	0.0	1.7	0.8
	(2.6)	(0.0)	(0.0)	(0.0)	(1.8)	(3.2)	(0.7)	(0.2)	(2.5)	(0.0)	(1.0)	(0.8)

Table 34 (cont'd).

	Burn		Wheat		Plow		Control		Mow		Part-control	
Order	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Neuroptera	0.6 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.0 (0.0)	4.2 (3.2)	0.7 (0.5)	5.8 (3.4)	0.0 (0.0)	1.0 (1.0)	0.0 (0.0)
Odonata	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	2.0 (2.0)	0.0 (0.0)	10.0 (6.4)	2.2 (2.2)
Orthoptera	58.4 (19.4)	2.6* (2.1)	69.5 (36.5)	7.0 (2.0)	90.8 (18.3)	12.6* (8.1)	11.8 (3.5)	5.2 (1.9)	33.5 (23.6)	0.0* (0.0)	54.8 (17.7)	84.0 (25.4)
Plecoptera	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (0.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
All orders	1115.4 (69.9)	23.9* (18.8)	300.0 (156.0)	55.0 (41.0)	373.5 (65.3)	53.6* (13.9)	491.5 (183.6)	297.8* (145.2)	621.8 (123.0)	18.3* (17.3)	663.3 (184.1)	787.8 (377.1)
Number of orders	9	6	7	5	10	9	10	9	11	3	10	9

* Significant ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between years.

Orders, and Treatment Wheat with 7 Orders. In July 1999, Treatments Plow, Control, and Part-control had the greatest number of Orders with 9 each, followed by Treatment Burn with 6 Orders, Treatment Wheat with 5 Orders, and Treatment Mow with 3 Orders.

August

The biomass of Arachnids (P = 0.02), Orthoptera (P = 0.04), and overall insects (P = 0.07) decreased between August 1998 and August 1999 on Treatment Burn, while the biomass of Coleoptera (P = 0.09) increased (Table 35). The biomass of Diptera (P = 0.01) increased on Treatment Plow, while the biomass of Coleoptera (P = 0.02), Homoptera (P = 0.02), Neuroptera (P = 0.05; fishflies, snakeflies, lacewings, and antlions), and overall insects (P = 0.02) decreased. The biomass of Coleoptera (P = 0.07) increased between August 1998 and August 1999 on Treatment Control, while the biomass of Homoptera (P = 0.07) and Orthoptera (P = 0.03) increased. The biomass of Coleoptera (P = 0.05) increased on Treatment Part-control, while the biomass of Plecoptera (P = 0.05) decreased. The biomass of Arachnids (P = 0.07), Homoptera (P = 0.07), Orthoptera (P = 0.07), and overall insects (P = 0.07) decreased on Treatment Mow between August 1998 and August 1999. In August 1998, Treatments Control and Part-control had the greatest number of Orders with 11 each, followed by Treatments Burn, Plow, and Mow with 9 Orders each, and Treatment Plow with 8 Orders. In August 1999, Treatments Control and Part-control had the greatest number of Orders with 9 each, followed by Treatments Burn and Plow with 8 Orders each, Treatment Wheat with 6 Orders, and Treatment Mow with 5 Orders.

Months Combined

When comparing between years instead of individual months between years, the comparisons of biomass of insect Orders on each field become clearer (Figure 2). In 1998, Homoptera had the greatest biomass of all Orders on Treatments Burn, Wheat, Plow, Part-control, and Mow. On Treatment Control, Coleoptera had the greatest biomass. In 1999, Hemiptera had the greatest biomass on Treatments Burn and Plow,

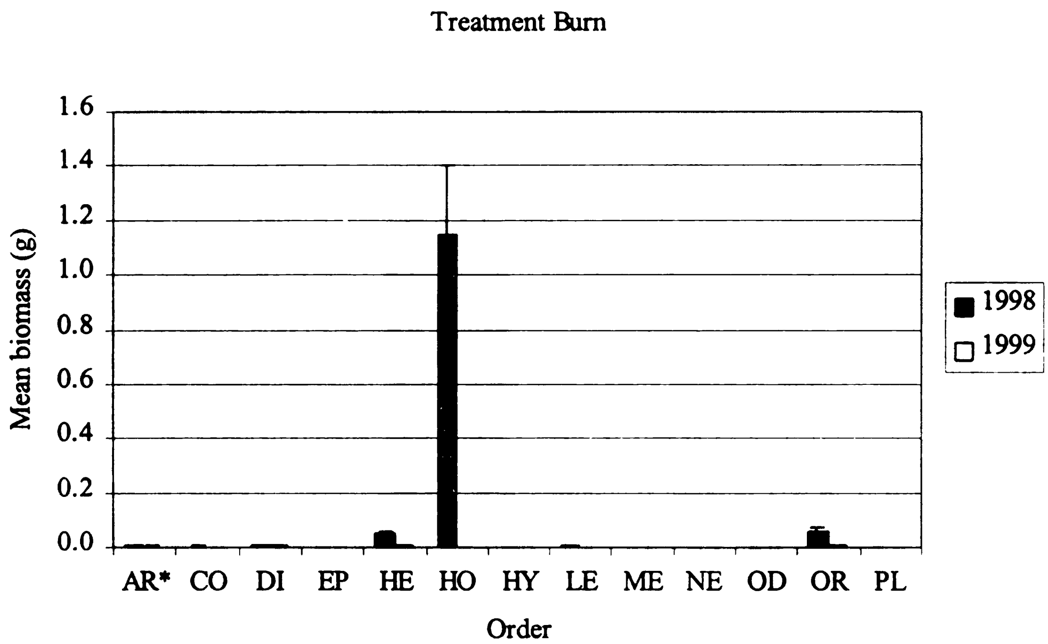
Table 35. Mean (SE) insect biomass (mg) on grassland treatments in RLWRA, Clinton County, MI, in August 1998, 1999.

	Burn		Wheat		Plow		Control		Mow		Part-control	
Order	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Arachnid	5.1	1.3*	3.0	0.5	6.4	4.4	3.9	4.7	9.8	0.0*	10.8	10.3
	(1.9)	(1.3)	(3.0)	(0.5)	(2.4)	(3.3)	(1.2)	(2.0)	(2.4)	(0.0)	(6.0)	(4.9)
Coleoptera	0.9	5.0*	28.0	13.0	51.0	8.4*	77.6	133.0*	110.5	1.3	62.3	193.5*
	(0.6)	(1.7)	(28.0)	(4.0)	(12.4)	(2.8)	(17.9)	(41.6)	(107.2)	(0.5)	(30.1)	(48.6)
Diptera	1.1	3.1	1.5	1.5	3.6	17.8*	5.2	2.6	6.5	3.5	2.2	3.5
	(0.7)	(1.4)	(1.5)	(0.5)	(1.2)	(3.1)	(1.8)	(1.6)	(2.2)	(3.5)	(0.7)	(1.6)
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	2.8	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.7)	(0.0)	(1.7)	(0.0)	(0.0)	(0.0)
Hemiptera	11.8	8.0	17.0	11.5	34.0	56.3	13.2	14.2	18.8	3.5	6.0	10.2
	(5.7)	(6.4)	(14.0)	(9.5)	(6.8)	(14.4)	(4.5)	(6.5)	(8.4)	(3.2)	(3.0)	(2.0)
Homoptera	7.1	3.1	9.5	3.0	28.7	4.8*	22.7	13.1*	14.3	1.5*	14.7	14.0
	(2.1)	(1.6)	(7.5)	(2.0)	(5.1)	(2.3)	(4.0)	(3.4)	(2.4)	(0.6)	(4.8)	(5.7)
Hymenoptera	0.6	0.4	2.0	0.5	4.7	5.0	3.8	6.5	2.8	0.0	2.0	15.0
	(0.4)	(0.3)	(2.0)	(0.5)	(2.0)	(2.2)	(1.2)	(2.8)	(1.7)	(0.0)	(1.5)	(10.4)
Lepidoptera	0.8	0.0	7.5	0.0	0.0	0.0	1.5	0.1	3.8	0.8	2.3	3.2
	(0.8)	(0.0)	(7.5)	(0.0)	(0.0)	(0.0)	(1.0)	(0.1)	(2.3)	(0.8)	(1.8)	(2.0)

Table 35 (cont'd).

Order	Burn		Wheat		Plow		Control		Mow		Part-control	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
Neuroptera	0.0 (0.0)	2.0 (2.0)	0.0 (0.0)	0.0 (0.0)	1.8 (1.2)	0.2* (0.1)	1.2 (0.9)	1.6 (0.9)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.0 (0.0)
Odonata	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4.3 (4.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.8 (0.8)	1.5 (1.0)
Orthoptera	88.0 (28.0)	6.5* (4.7)	32.5 (32.5)	0.0 (0.0)	39.9 (19.8)	5.4 (2.4)	25.5 (10.5)	0.5* (0.5)	30.5 (1.6)	0.0* (0.0)	41.3 (26.3)	32.0 (15.1)
Plecoptera	1.9 (1.9)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	10.6 (7.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	14.8 (5.8)	0.0* (0.0)
All orders	117.3 (32.4)	29.4* (11.9)	101.0 (27.0)	30.0 (16.0)	180.6 (18.5)	102.3* (14.6)	159.6 (21.3)	176.3 (45.4)	199.5 (113.3)	10.5* (7.0)	157.7 (52.9)	283.2 (54.9)
Number of orders	9	8	8	6	9	8	11	9	9	5	11	9

* Significant ($\alpha = 0.10$; Wilcoxon matched-pairs signed-ranks test) within a treatment between years.



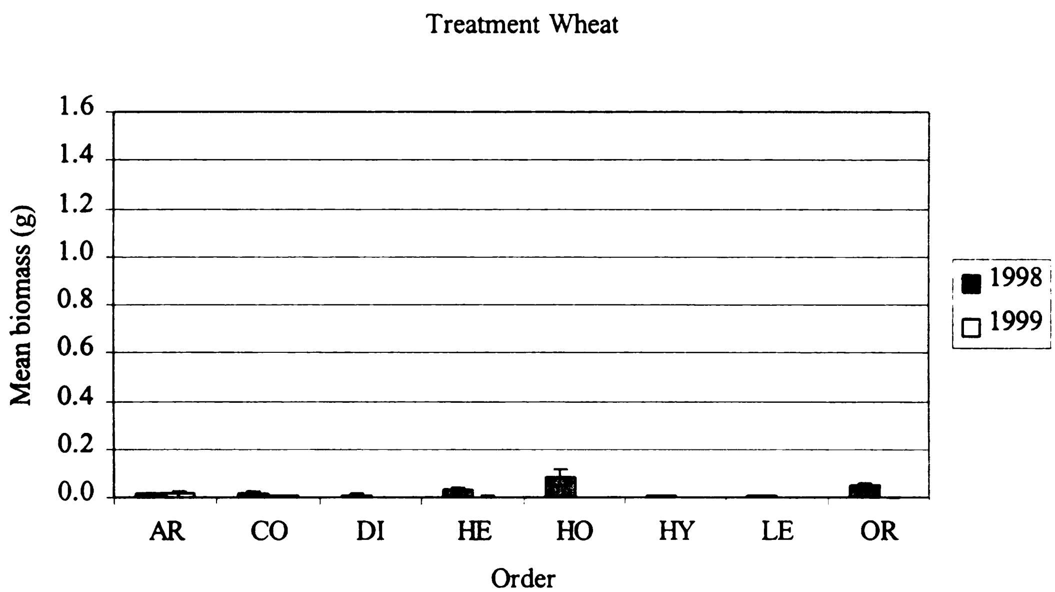
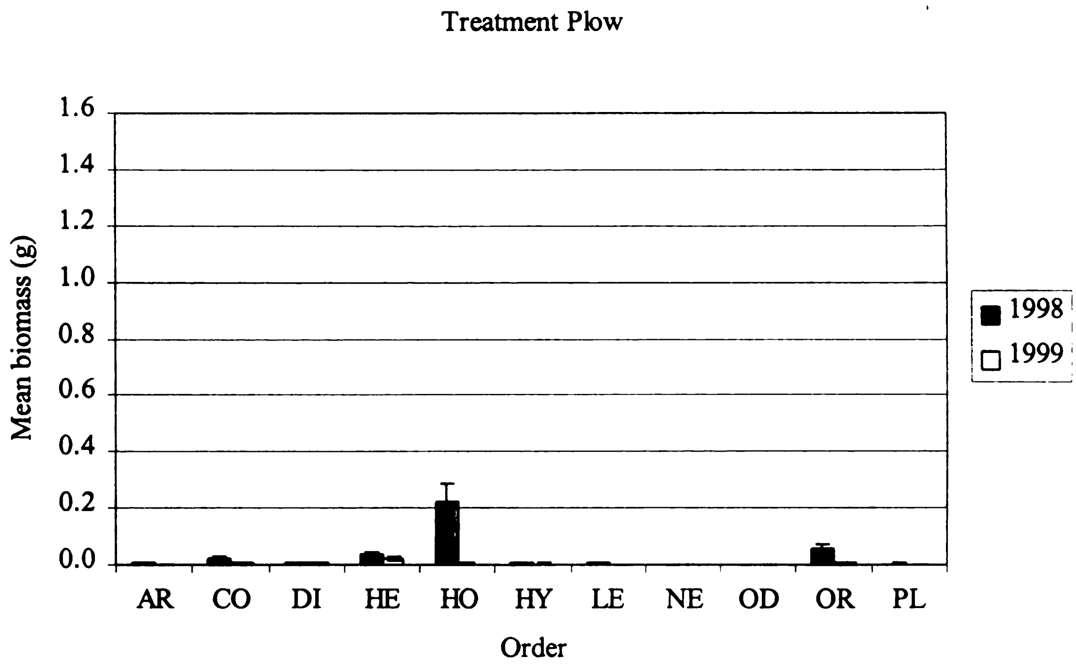


Fig. 2. Mean (SE error bars) insect biomass (g) on grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.
*Abbreviations: AR: Arachnids, CO: Coleoptera, DI: Diptera, EP: Ephemeroptera, HE: Hemiptera, HO: Homoptera, HY: Hymenoptera, LE: Lepidoptera, ME: Mecoptera, NE: Neuroptera, OD: Odonata, OR: Orthoptera, PL: Plecoptera.


Treatment Plow
Mean biomass (g)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
AR
CO
DI
HE
HO
HY
LE
NE
OD
OR
PL
Order
1998
1999

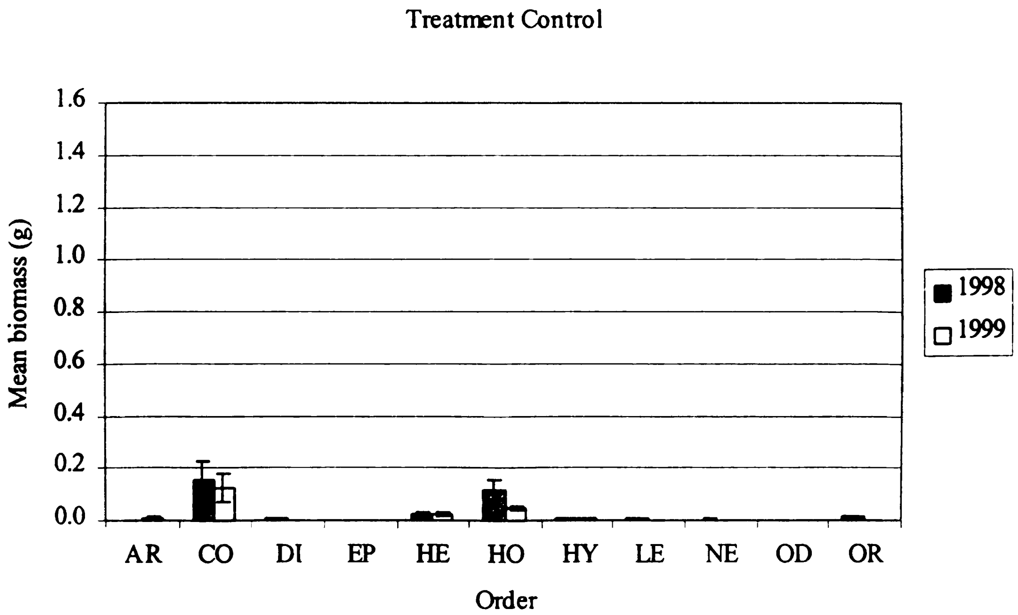
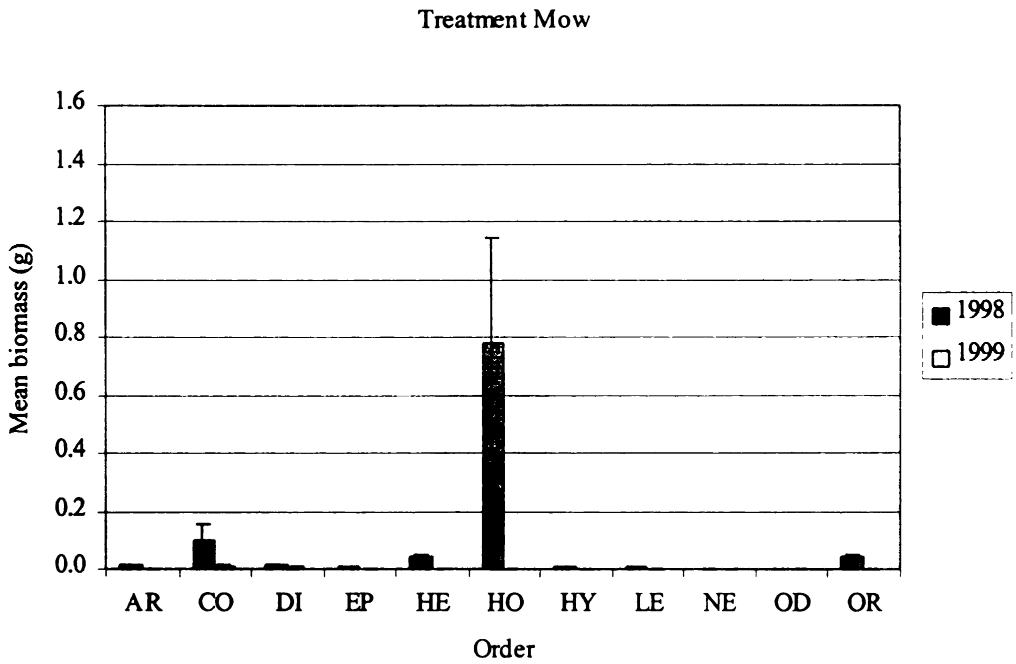

Treatment Control
Mean biomass (g)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
AR
CO
DI
EP
HE
HO
HY
LE
NE
OD
OR
Order
1998
1999

Fig. 2 (cont'd).


Treatment Mow
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Mean biomass (g)
AR
CO
DI
EP
HE
HO
HY
LE
NE
OD
OR
Order
1998
1999

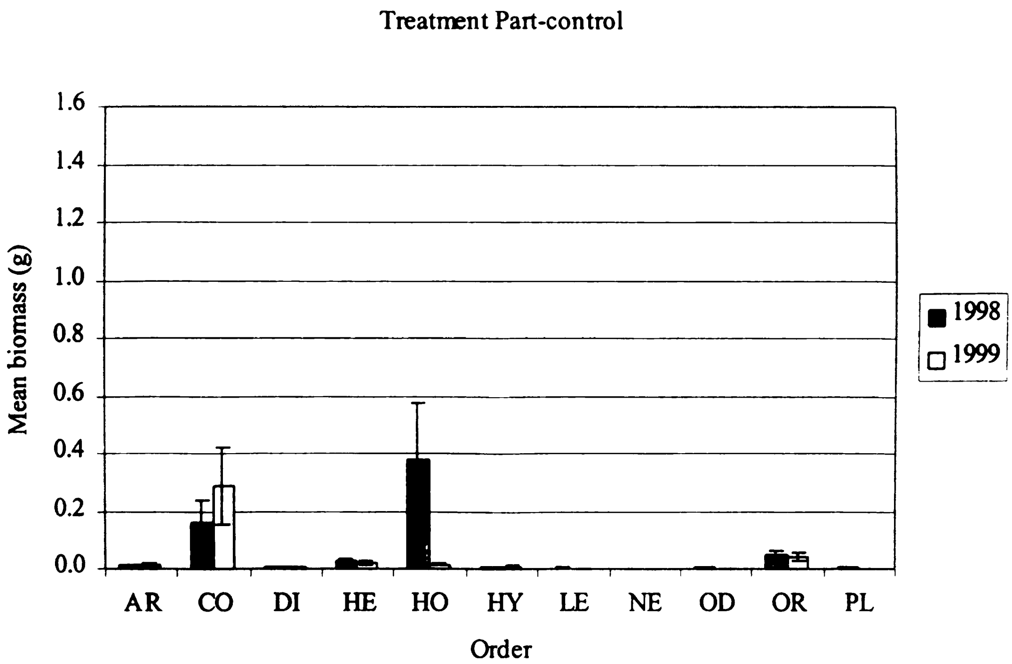

Treatment Part-control
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Mean biomass (g)
AR
CO
DI
HE
HO
HY
LE
NE
OD
OR
PL
Order
1998
1999

Fig. 2 (cont'd).

Arachnids had the greatest biomass on Treatment Wheat, and Coleoptera had the greatest biomass on Treatments Control, Part-control, and Mow (Figure 2). In 1998, Treatment Burn had the greatest insect biomass among all treatments (Figure 3). In 1999, Treatment Part-control had the greatest insect biomass among all treatments. On all treatments, insect biomass decreased between 1998 and 1999. These differences are qualitative only, as no statistical tests were performed.

Lepidoptera

1998

Only the Lepidoptera Family Sphingidae (sphinx or hawk moths) differed ($P \leq 0.10$, $z \geq 2.39$) in mean numbers among fields for 1998 (Table 36). Although a significant difference was detected for this Family among fields using the Kruskal-Wallis one-way analysis-of-variance, the multiple-comparison test did not assist in determining where this difference existed. Fields Burn/Wheat, Plow, and Control each had 7 Lepidoptera Families, while 8 Families were observed on Field Mow/Control in 1998.

The number of Lepidoptera caught did not differ ($P > 0.10$, $z < 2.13$) among months in 1998 (Table 37).

1999

No comparisons were made among treatments in 1999, as treatments received different manipulations. Treatments were evaluated by comparing each field between years.

The number of Lepidoptera caught did not differ ($P > 0.10$, $z < 2.13$) among months in 1999 (Table 38).

Between 1998 and 1999

Field Burn/Wheat had a greater number of the Family Noctuidae ($P = 0.08$; owlet or noctuid moths) in 1998 compared to 1999 (Table 39; Appendix D Figure 1). Field Plow increased in Sphingidae ($P = 0.04$) between 1998 and 1999. Field Control had no differences ($P > 0.10$) in Lepidoptera Families between 1998 and 1999. Field

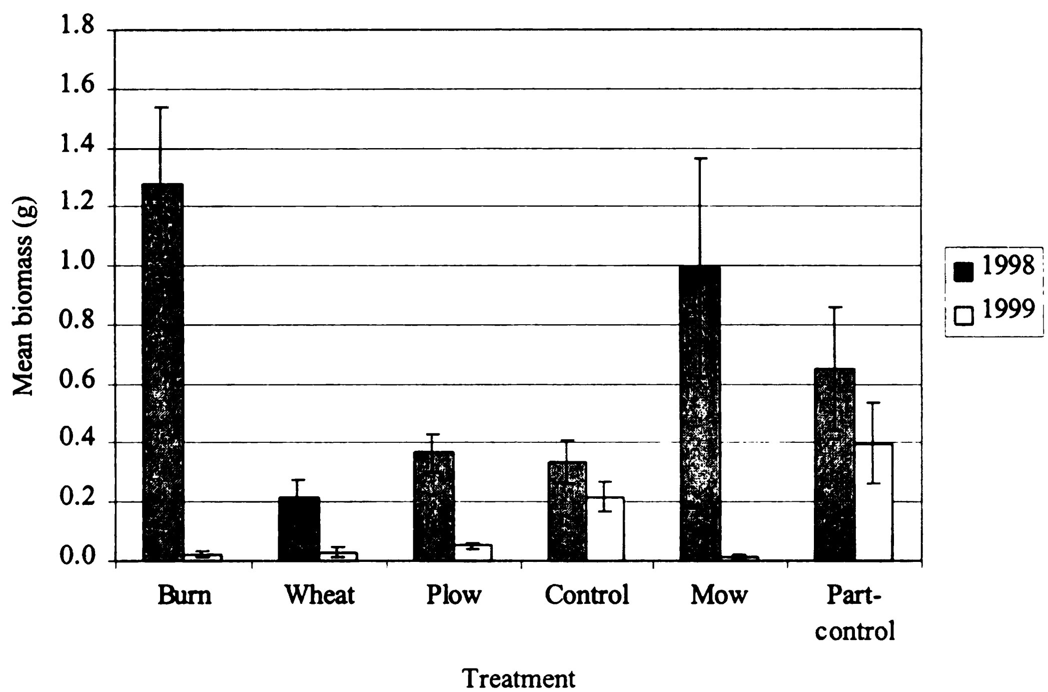


Fig. 3. Overall mean (SE error bars) insect biomass (g) on grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.

Table 36. Number of Lepidoptera captured in each Family in grassland fields in RLWRA, Clinton County, Michigan, in summer 1998.

Family	Burn/Wheat	Plow	Control	Mow/Control
Arctiidae	57	36	19	43
Drepanidae	0	0	1	0
Gelechiidae	0	6	2	1
Geometridae	51	28	8	21
Lymantriidae	0	1	0	3
Noctuidae	110	60	55	32
Pterophoridae	1	0	0	0
Pyralidae	86	64	76	69
Sphingidae*	4 Aa	0 A	0 A	8 A
Tortricidae	40	29	32	93
Number of individuals	349	224	193	270
Number of Families	7	7	7	8

* Significant ($\alpha = 0.10$; Kruskal-Wallis one-way analysis-of-variance) among fields.
[a] Among fields within a row, means with the same letter are not significantly different.

Table 37. Mean number of Lepidoptera captured in each month in grassland fields in RLWRA, Clinton County, Michigan, in summer 1998.

	Month		
Field	June	July	August
Burn/Wheat	57	137	155
Plow	55	68	101
Control	40	73	80
Mow/Control	101	111	58
Overall	253	389	394

Table 38. Mean number of Lepidoptera captured in each month in grassland fields in RLWRA, Clinton County, Michigan, in summer 1999.

	Month		
Field	June	July	August
Burn/Wheat	100	22	62
Plow	67	58	66
Control	62	90	53
Mow/Control	61	71	45
Overall	290	241	226

Table 39. Number of Lepidoptera captured in each Family in grassland fields in RLWRA, Clinton County, Michigan, in summer 1998, 1998.

	Burn/Wheat		Plow		Control		Mow/Control	
Family	1998	1999	1998	1999	1998	1999	1998	1999
Arctiidae	57	22	36	13	19	31	43	21
Drepanidae	0	0	0	0	1	0	0	0
Gelechiidae	0	0	6	0	2	0	1	1
Geometridae	51	21	28	15	8	31	21	17
Lasiocampidae	0	0	0	1	0	0	0	2
Limacodidae	0	0	0	1	0	0	0	0
Lymantriidae	0	0	1	2	0	1	3	1
Noctuidae	110	36*	60	88	55	71	32	27
Notodontidae	0	0	0	2	0	0	0	0
Pterophoridae	1	0	0	0	0	0	0	0
Pyralidae	86	78	64	44	76	52	69	82
Saturniidae	0	0	0	0	0	0	0	1
Sphingidae	4	5	0	7*	0	3	8	7
Tortricidae	40	22	29	18	32	16	93	17*
Yponomeutidae	0	0	0	0	0	0	0	1
Number of individuals	349	184	224	191	193	205	270	177
Number of Families	7	6	7	10	7	7	8	11

* Significant ($\alpha = 0.10$; Mann-Whitney U Test) within a field between years.

Mow/Control had a greater number of Tortricidae ($P = 0.05$; tortricid moths) in 1998 compared to 1999. The number of Lepidoptera Families observed in 1998 compared to 1999 was lower in Field Burn/Wheat and greater in Fields Plow and Mow/Control. Field Control had no change in number of Lepidoptera Families between 1998 and 1999. In all fields that received prairie creation techniques, the total number of Lepidoptera caught decreased, though the difference was not significant, from 1998 to 1999 (Appendix D Figure 2).

Sixty-eight species of Lepidoptera were identified on the 6 treatments in 1998, and 78 species were identified in 1999 (Appendix D Table 1). To better understand changes that occurred in the species composition of Lepidoptera on the treatments, it may be beneficial to group species according to the plant types they consume. To determine the food plant category of Lepidoptera, only species of Lepidoptera for which this information was available were included (Covell 1984). No distinction was made between food plants for larvae and for adults. The food plant categories include: forbs, forbs and woody vegetation, forbs and grasses, forbs and vines, grasses, mosses, various vegetation (forbs, grasses, and woody vegetation), and woody vegetation. For groups with more than one type of plant, the particular Lepidoptera species eats plants in either category. In 1998, the most common food category of Lepidoptera caught on Field Burn/Wheat was forbs, followed by forbs and grasses (Table 40; Appendix D Figure 3). In 1999, forbs and grasses was the most common food category, followed by various vegetation (including forbs, grasses, and woody). On Field Plow, forbs was the most common food category in both years, followed by forbs and grasses in 1998 and woody vegetation in 1999. On Field Control, mosses was the most common food category in 1998, followed closely by various vegetation. In 1999, forbs and grasses was the most common food category, followed by woody vegetation. On Field Mow/Control, woody vegetation was the most common food category in 1998, followed by forbs and grasses. In 1999, forbs and grasses was the most common food category, followed by forbs.

Table 40. Number of Lepidoptera in each food category captured in grassland fields in RLWRA, Clinton County, Michigan, in summer 1998, 1999.

	Burn/Wheat		Plow		Control		Mow/Control	
Food category	1998	1999	1998	1999	1998	1999	1998	1999
forbs, woody	2	0	3	0	3	1	2	0
forbs	51	17	47	68	16	13	10	23
forbs, grasses	45	30	19	4	12	33	28	28
forbs, vines	0	0	0	0	0	2	0	1
grasses	7	0	2	2	6	12	8	1
mosses	12	6	14	9	20	16	15	16
various	42	20	18	11	19	21	6	13
woody	26	8	13	17	9	24	30	19

Expenditures

All manipulated treatments received the following management activities: Application of Round-Up® and Plateau®, and planting of prairie grasses and forbs. The costs for these activities were added to each treatment (Table 41). Costs were added for Treatment Burn, which included the total costs for the burn treatment, and Treatment Wheat, which included the costs of the winter wheat planting. These costs are included in Table 41 under "individual costs." The mowing, plowing, disking, and cultipacking costs for Treatment Plow and the mowing costs for Treatment Part-control are summarized under the cost of fuel and equipment. Costs of liming and fertilizing were not included in the table, as the necessity of their application is dependent on the soil characteristics of each individual site. The burn and winter wheat treatments were the most expensive prairie creation techniques, costing approximately \$606 and \$595/ha, respectively, approximately \$100/ha more than the other 2 treatments. Liming and fertilizing added an additional mean of \$72.42/ha to the costs of the prairie creation techniques.

Table 41. Cost ($/ha) of each treatment on grassland fields in RLWRA, Clinton County, Michigan, between August 1998 and May 1999.

	Treatment			
Activity	Burn	Wheat	Plow	Mow
Individual treatment's cost	109.63	98.32	-	-
Cost of Round-Up® and Plateau®, including application	156.49	156.49	156.49	156.49
Cost of fuel and equipment	25.28	25.28	25.28	25.28
Cost of prairie grasses and forbs	314.73	314.73	314.73	314.73
Total cost	606.13	594.82	496.50	496.50

DISCUSSION

Vegetation Structure and Composition

1998

June

In June 1998, before any manipulations had occurred, most treatments were similar to one another in many vegetation characteristics (Table 4). Major significant differences included: Treatment Plow had higher live height, dead height, and dead cover, and less live cover than Treatments Part-control and Mow. Treatment Burn had higher grass cover and dead cover, and less forb cover than the other treatments. Treatment Part-control had greater woody cover than all other treatments, except for Treatment Mow. Treatment Plow had greater litter cover and bare ground than all other treatments, except Treatment Mow.

August

By August, many of these differences had changed (Table 5). Treatment Plow still had higher live height than Treatments Part-control and Mow, but dead height and live cover were not different among these 3 treatments. Treatment Burn still had greater grass cover and less forb cover than all other treatments. Treatment Burn also had less horizontal cover than all treatments except Treatment Mow. Treatment Part-control had greater woody cover than all other treatments, except for Treatments Wheat and Mow. Treatments Wheat and Plow had greater litter cover and bare ground than Treatments Control, Part-control, and Mow. Most of the treatments were similar in both months in 1998. However, some differences did set some treatments apart, especially in terms of grass cover, forb cover and woody cover.

Between Months - 1998 and 1999

Live height changed significantly during the growing season on most treatments in both years (Tables 6 and 7). The only treatments where the change was not significant were Treatment Burn in 1998, where live height decreased slightly, and Treatment Control in 1999. The increase in height during the growing season is likely due to the growth of vegetation between June and August (Brown 1985).

Dead height showed a similar pattern as live height in 1998 (Table 6). All treatments except Treatment Burn showed a significant increase in dead height between June and August 1998, likely due to the growth and subsequent death of vegetation during the growing season. Many plants grow early in the growing season, and die after they bloom (Brown 1985). In 1999, however, this trend is largely reversed (Table 7). On all treatments that received prairie creation techniques, dead height decreased between June and August. The application of herbicides in April and May and the removal of all standing vegetation prior to planting by either mowing, burning, or plowing likely contributed to this trend. Vegetation that was left standing prior to planting in May was dead or dying, and likely decreased in height due to continued wilting during the growing season, or as a result of becoming litter between June and August 1999. Since the amount of bare ground was relatively great in 1999, any litter that may have formed, which by definition is any dead vegetation not considered to be standing dead, was blown away during the growing season, which explains why the litter depth did not increase in that time period.

Horizontal cover showed a similar pattern as live height in 1998 and 1999 (Tables 6 and 7). Horizontal cover increased on all treatments except Treatment Burn in both years, Treatment Control in 1999, and Treatment Part-control in both years. The increase can be explained by the growth of vegetation during the growing season (Brown 1985), similar to live height.

Percent live cover showed opposite trends during the growing season in 1998 compared to 1999 (Tables 6 and 7). While it decreased on most treatments in 1998, it increased on all treatments in 1999. The increase in 1999 is likely due to the planting of vegetation in 1999. As the seeds continued to germinate and grow into seedlings throughout the growing season, the percent live cover increased between June and August. Even though the control treatments also showed increases in live cover in that time period, the changes between June and August are much less pronounced than the changes in the treatments that were manipulated. On Treatments Control and Part-control, live cover increased by 0.72% and 3.59%, respectively between June 1999 and August 1999. On treatments that received prairie creation techniques, however, live cover increased by 8.75%, 30.42%, 41.11%, and 29.00% on Treatments Burn, Wheat, Plow, and Mow, respectively (Table 7), at least doubling the live cover in all cases during the growing season. In 1998, the decrease in percent live cover is likely due to the death of vegetation during the growing season (Brown 1985). This explanation is supported by the complementary changes in percent dead cover.

Percent dead cover changed significantly on all treatments in 1998 and 1999 during the growing season, except in Treatments Plow and Control in 1998 (Tables 6 and 7). While it increased on most treatments in 1998, it decreased on all treatments that received prairie creation techniques in 1999. As mentioned previously, dead height also increased during the 1998 growing season in many treatments, which is likely related to the increase in dead cover in that time period. This would result in an increase in dead height and dead cover between June and August.

Percent grass cover did not change significantly between June and August 1998 (Table 6). In 1999, all treatments except for Treatment Part-control showed an increase in percent grass cover from June to August (Table 7), likely due to the growth and germination of vegetation during the growing season. The increase in grass cover is likely part of the increase in live cover that was discussed previously.

Percent forb cover increased on all treatments that received prairie creation techniques, except Treatment Burn, during the growing season in 1999 (Table 7). This is likely due to the growth of vegetation during the growing season, similar to the increase in grass cover. Treatment Burn had very little percent forb cover in both years, significantly less than the other treatments, and had very high grass cover. Although the percent forb cover increased on Treatment Burn between June and August 1999, the difference was not significant. In 1998, none of the treatments showed a change in the percent forb cover during the growing season, except Treatment Wheat, which decreased significantly (Table 6).

Percent woody cover was low on all treatments in both 1998 and 1999, except on Treatments Part-control and Mow (Tables 6 and 7). Treatment Mow had a greater percentage of shrubs than any other treatment. No changes occurred on any treatment in percent woody cover during the growing seasons of 1998 or 1999.

Percent litter cover and bare ground changed on only 2 treatments during the growing season in 1998, increasing on Treatment Wheat and decreasing on Treatment Mow. The decrease on Treatment Mow was accompanied by an increase in both live cover and dead cover, which resulted in a decrease in the amount of litter cover and bare ground. On Treatment Wheat, live cover decreased during the growing season, while dead cover increased. It is likely that live vegetation died during the growing season, becoming dead standing vegetation. As the increase in dead cover (4.67%) was smaller than the decrease in live cover (17.88%), most of the live cover likely became litter instead of dead standing vegetation, thereby increasing the percent litter cover and bare ground. In 1999, percent bare ground was measured separately from percent litter cover. In 1998, bare ground accounted for a minimal amount of the percent litter cover and bare ground category, and was not considered an important characteristic of the vegetation. The amount of bare ground present in 1998 on all treatments was similar to the control treatments in 1999, in which bare ground accounted for less than 1% of the total cover (Table 7).

Due to the prairie creation techniques, bare ground accounted for approximately 50% or more of total cover on all manipulated treatments in 1999, except Treatment Mow (Table 7). The mowing treatment left stubble with relatively little bare ground compared to the other prairie creation techniques. By August 1999, bare ground decreased significantly on Treatments Wheat, Plow, and Mow, likely as a result of the growth and germination of vegetation.

Percent litter cover decreased on all treatments except Treatments Wheat and Plow during the growing season in 1999. This was accompanied by an increase in the live cover in all treatments in which percent litter decreased. As mentioned previously, the live cover at least doubled on all manipulated treatments, which contributed to the decrease in both litter cover and bare ground.

Litter depth decreased on all treatments between June and August 1998, except on Treatment Mow, where it increased (Table 6). Reasons for the decrease in litter depth during the growing season may be due to decomposition of litter or, more likely, the removal of litter by wind. In 1999, litter depth decreased only on Treatments Control and Mow (Table 7). On Treatments Burn, Wheat, and Plow, the litter depth was negligible in 1999, and although the litter depth decreased on Treatments Burn and Wheat, the changes were not significant.

Between 1998 and 1999

June

All manipulated treatments showed decreases in live height, dead height, horizontal cover, percent live cover, percent grass cover, and litter depth, and an increase in percent litter cover and bare ground between June 1998 and June 1999 (Table 8). These changes were expected, as the prairie creation techniques were designed to kill off the vegetation present before the plantings to decrease competition between undesired species and native prairie species. Percent dead cover increased on Treatments Wheat and Mow between June 1998 and 1999. Vegetation was only mowed on Treatment Mow and the winter wheat cover on Treatment Wheat was not removed in the spring, which left significant amounts of dead vegetation standing on these treatments. Forb cover increased on Treatment Burn between June 1998 and June 1999, which was not expected,

but which can be explained by the low forb cover on Treatment Burn in June 1998, which was less than 1%. Although the forb cover on Treatment Burn accounted for only 2.38% of the total cover in June 1999, lower than all other treatments at that time, the increase between years was significant. Woody cover decreased on Treatment Mow between June 1998 and June 1999 as a result of the mowing treatment.

August

All manipulated treatments showed decreases in live height, dead height, horizontal cover, live cover, grass cover, and litter depth between August 1998 and August 1999, except Treatment Plow, which increased in horizontal cover and live cover in that time period (Table 9). Percent forb cover also increased between August 1998 and 1999 on Treatment Plow. The prairie creation techniques effectively killed off the vegetation present before the plantings, which resulted in the decreases in live and dead height, horizontal cover, live and grass cover, and litter depth. Treatment Plow deviated from these changes, however, as it had the greatest growth of invasive annuals of the manipulated treatments. Although many of the annuals that invaded the sites were native plants, they are aggressive non-prairie annuals that invade newly disturbed sites, and are considered to be undesired species in a prairie creation attempt. These annuals were mostly forbs, which grew considerably between June and August 1999, causing increases in horizontal cover, live cover, and forb cover on Treatment Plow in August 1999 compared to August 1998. The removal of these undesired plants is often one of the most challenging parts of a prairie creation, as they may outcompete the planted prairie plants (Landers et al. 1970, Cottam 1987, Kline and Howell 1987, Anderson 1994, Masters et al. 1996, Wilson and Stubbendieck 1996).

The control treatments did not show the consistent and uniform changes in vegetation characteristics between 1998 and 1999 for both June and August that the manipulated treatments did. These differences are made particularly clear when considering Appendix A Figure 1 to help visualize the differences between the manipulated and the control treatments. For all vegetation characteristics, except possibly percent forb cover and percent woody cover, the manipulated treatments showed wide and consistent fluctuations in the levels of characteristics, which the control treatments did not mimic. As the control treatments were not manipulated, it was not expected that many changes would take place.

Species Composition

All treatments had more forb species than grass species in both 1998 and 1999, except for Treatment Burn (Tables 10 and 11). This is similar to the tallgrass prairie, where grasses dominate the vegetation, but only account for 30% or less of the species present (Reichman 1987). Grasses accounted for 15% or less of the total cover in August 1999 (Table 9) on the manipulated treatments, compared to the percent forb cover, which comprised up to 36% of the total cover on the treatments. The only treatment that had a greater grass than forb cover in August 1999 was Treatment Burn, although the grass cover accounted for approximately 10%. Although the manipulated treatments do not have the appearance of a prairie at this point, prairie plantings generally require at least 3 years to resemble a native tallgrass prairie (Kline and Howell 1987). With continued management of the manipulated treatments, they may, in time, more closely resemble a native tallgrass prairie.

The number of plant species increased on Treatments Burn and Mow and decreased on Treatments Wheat and Plow between 1998 and 1999 (Tables 10 and 11), which can be attributed to the herbiciding of the treatments in the spring. Because of financial constraints, only 8 native tallgrass prairie plants were planted, which did not compensate for the loss of species as a result of the herbiciding. The number of native species, however, increased on Treatments Burn, Plow, and Mow (Tables 12 and 13). Since one of the goals of this study was to establish a native tallgrass prairie on the study sites, it is more important to increase the number of native prairie species and decrease the number of exotic species, than it is to simply increase the overall number of species

(Solecki 1997). The number of exotic species decreased on Treatments Wheat and Plow in both June and August, on Treatment Burn in June, and increased on Treatment Burn in August and Treatment Mow in both June and August between 1998 and 1999.

Creation techniques can be evaluated by the establishment success of planted species. Establishment of tallgrass prairie species has been defined by various authors as ranging from one seedling/m^2 to 20 seedlings/m^2 (Vassar et al. 1981, Masters 1997). The equivalent of at least one seedling/m^2 in this study was that 25% of vegetation plots needed to contain at least one planted species (Table 14), which was met by all manipulated treatments in both months. The number of seedlings/m^2 is likely considerably higher than this, since many of the plots contained more than one species of planted grasses or forbs, and many species had more than one seedling in each plot. The establishment of prairie plants was therefore successful on all treatments. In June, Treatment Wheat had the highest percentage of plots containing at least one planted species, and was therefore considered the most successful treatment in terms of establishment success, followed by Treatment Plow. By August, Treatment Burn was the most successful, followed by Treatment Wheat. The percentage of plots with at least one planted species decreased on Treatment Plow during the growing season, likely due to the growth of invasive annuals.

Individual planted prairie grass and forb species showed varying establishment successes (Table 14). By August, all 3 grass species had become established successfully on Treatments Burn and Wheat. On Treatment Plow, Indian grass had become established in only 11% of plots. On Treatment Mow, none of the planted species had been successfully established individually in June. By August, big bluestem was the only planted species that exceeded 25% of plots on Treatment Mow. None of the forb species were successfully established on any treatment in any month. The only planted forb species that was observed in any vegetation plots was perennial lupine. Forbs were planted at much lower frequencies than grasses, so it was to be expected that forbs would not be in as many vegetation plots compared to grasses. Other studies have also found that forbs tend to have very low establishment successes (Howell and Kline 1994). Sometimes plants fail to germinate if they are planted too deep relative to the diameter of their seeds (V. Stephens, MDNR, pers. commun.). The sizes of forb seeds planted in this study ranged from extremely small (black-eyed susan with 3770 seeds/gram) to relatively large (perennial lupine with 50 seeds/gram; Table 3). All seeds were planted at the same depth. This does not seem to have been a problem in this study, as black-eyed susan, which had the smallest seeds, was one of the most successful forbs planted. Grass seeds, relatively large at approximately 300 seeds/gram, were well established. All 5 forb species were observed in at least one of the manipulated treatments, though most were not found in sampling plots, and black-eyed susan and lance-leaved coreopsis were encountered frequently on Treatments Burn, Wheat, and Plow.

The second requirement for the successful establishment of a native tallgrass prairie on the study sites was a decrease in exotic or non-prairie species. Table 15 lists most of the non-prairie species that commonly are problems in a prairie restoration that were present in the treatments (Solecki 1997). Burning and herbiciding were successful manipulations on Treatment Burn in greatly depressing the incidence of smooth brome. On Treatment Wheat, the winter wheat and herbicides treatments was mostly successful in decreasing the percentage of plots with blue-joint, common ragweed, smooth brome, and wild carrot. The percentage of plots on Treatment Wheat with quack grass decreased by approximately half. Only the annual forb lambs-quarters increased on Treatment Wheat, increasing from being present in no plots in 1998 to almost 20% of plots in 1999. Treatment Plow showed great increases in the percentage of plots with common ragweed, lambs-quarters, and velvet-leaf (Morgan 1997). These species are annual forbs that commonly invade newly disturbed sites. It is likely that the plowing and disking treatments brought previously buried dormant seeds of these species to the surface, causing them to germinate (Morgan 1997). The invasion of undesired species is one of

the greatest challenges of prairie restoration (Kline and Howell 1987, Masters et al. 1996, Morgan 1997). It is possible that the decrease in the percentage of plots with planted species on Treatment Plow between June and August 1999 resulted from the increase in invading annuals that outcompeted the native prairie species. All planted species were perennials, which take longer to germinate and attain their full height than most annuals, as they establish their underground parts first (Reichman 1987). Quack grass, blue-joint, and smooth brome decreased slightly between 1998 and 1999 on Treatment Plow, while wild carrot showed a substantial decrease in the percentage of vegetation plots it was present in. Treatment Mow showed small increases in the percentage of plots with lambs-quarters, quack grass, smooth brome, and wild carrot. Although the changes were not substantial, it is worrisome that quack grass was present in 83% of plots in 1999. This is an aggressive grass that is not desirable in a prairie restoration.

The soil of creation sites is an important factor that has to be taken into consideration when attempting a prairie restoration or creation. The establishment success of many plants varies with the quality of the soil, and Gibson et al. (1993) found soil type to be the most important discriminator of plant communities. Generally, dry and sandy soils are considered low quality and sandy-loam to loamy soils are considered high quality soils for vegetation growth (U.S.D.A. 1978, Beirne 1995). The soils on the study sites in this study were dominated by high- to moderate-quality soils (U.S.D.A. 1978). Prairie remnants in Michigan are usually found on sandy, poor-quality soils (Hauser 1953), and Beirne (1995) found that native grasses dominated poor-quality forest openings, while introduced grasses tended to dominate high-quality forest openings in the Hiawatha National Forest in Michigan. Beirne (1995) also found that several native grasses, among them several prairie grasses, tended to have better germination rates in poor-quality compared to high-quality soils in greenhouse trials, while the trend was reversed for introduced grasses. It is therefore possible that private landowners who emulate the prairie creation techniques examined in this study will get different results,

especially regarding establishment success of planted species and invasion of invasive non-prairie species, based on the soil of their sites.

The effective size of a prairie restoration or creation, the actual area that is of benefit to native tallgrass prairie plants and animals, may be more or less than the actual size, depending on the surrounding vegetation (Kline and Howell 1987, Kline 1997). If the surrounding areas are wooded, the effective size of the grassland area is smaller than the actual size. Trees and shrubs on the boundaries, especially along south and west sides, can reduce the amount of sunshine and wind the affected area gets, important considerations in a prairie creation, as most species in a prairie are shade intolerant (Kline 1997). If the surrounding areas are old fields or plowed fields, on the other hand, the effective size of the restoration can be increased (Kline 1997). Many grassland birds have area requirements of at least 10 to 30 ha (Johnson and Temple 1986, Herkert 1994a, Vickery et al. 1994, Johnson et al. 1998). Even though the size of a prairie creation may be smaller than the minimum area requirements of many grassland birds, the occurrence of old fields in adjacent areas may be sufficient to allow the presence of these birds, as they are structurally similar to the prairie creation. The presence of woodlots and other woody vegetation bordering the restoration may be a source of brown-headed cowbirds, which are considered parasitic birds of many grassland birds and may decrease their reproductive success (Johnson and Temple 1986). The effective size of Field Burn/Wheat was probably greater than the actual size, since it was surrounded by old fields and an agricultural field on 3 sides. Field Plow, however, was surrounded by woodlots on 2.5 sides, with an old field bordering it on 0.5 sides, and shrubland on one side. The woodlots were on the northern, western, and part of the southern side. This may negatively affect the effective size of the restoration. Field Control was surrounded by an agricultural field on the northern and western sides, a residential area on the eastern side, and a woodlot on the southern side. Just north of the agricultural fields, however, was a field planted to a monoculture of switchgrass, a native tallgrass prairie grass. This

site may be a source of switchgrass seeds. The woodlot on the southern edge, however, may decrease the effective size considerably. Field Mow/Control was surrounded by forest on all sides. Field Mow/Control is, therefore, not likely to become a successful prairie creation. It is very small to begin with, consisting of only 2 ha, and has, most likely, an even smaller effective size.

Small Mammal Relative Abundance

In 1998, the fields differed considerably in small mammals species composition (Table 16). Field Control had more meadow voles and more overall mammals than Fields Burn/Wheat and Plow. Field Burn/Wheat had more Peromyscus and more thirteen-lined ground squirrels than Fields Control and Mow/Control, on which these 2 species were absent in 1998. The reasons for these differences are not clear, as the fields were relatively similar to one another in regards to vegetation composition in 1998, before any manipulations occurred. As thirteen-lined ground squirrels seem to be more abundant on shrub-dominated sites (Higgins and Stapp 1997), it was expected that Field Mow/Control would have the greatest abundance of thirteen-lined ground squirrels, as it had the greatest woody cover among fields in 1998 (Tables 4 and 5). Field Burn/Wheat is bordered by an old field on the northern side, which may explain the relatively high abundance of thirteen-lined ground squirrels on this site. Meadow voles generally prefer moist to wet meadows and marshes (Baker 1983). They were, however, absent from one of the wetter fields, Field Burn/Wheat, and were the most abundant on Field Control, which was relatively dry.

Peromyscus include the species deer mice and white-footed mice, which generally prefer open habitats and wooded habitats, respectively (Burt and Grossenheider 1980, Baker 1983, Reichman 1987), so it was expected that at least one of these species would be encountered on every field, yet they were absent from Fields Control and Mow/Control in 1998.

Between 1998 and 1999, small mammals changed considerably in both abundance and species composition on all fields (Table 19). On the manipulated fields, the abundance of Peromyscus increased, the change being significant on Fields Burn/Wheat and Mow/Control. Even though the increase in Peromyscus was not significant on Field Plow, Peromyscus was the only small mammal species captured on this field in 1999, while it was one of 6 species captured in 1998. The number of meadow voles captured decreased on all fields, the amount being significant only on Fields Control and Mow/Control. These changes were similar to a study by Lemen and Clausen (1984), who found that the abundance of deer mice increased following burning and mowing of a tallgrass prairie. Meadow voles showed the opposite trend, decreasing in abundance after removal of the vegetation by burning and mowing. Both species returned to pre-treatment abundances as the aboveground biomass of the vegetation returned to pre-treatment levels.

Even though deer mice and white-footed mice could not be distinguished between during this study, it is likely that a majority of Peromyscus captured on the study sites were deer mice, as they are known to inhabit open lands (Burt and Grossenheider 1980, Baker 1983, Reichman 1987), as opposed to white-footed mice, which generally prefer wooded areas (Burt and Grossenheider 1980, Baker 1983, Reichman 1987).

Masked shrews were present on all fields in 1998, but disappeared from the fields that received prairie creation techniques in 1999 (Table 19). Masked shrews are ubiquitous, and can be found in all terrestrial habitats in Michigan (Baker 1983) and Manitoba (Wrigley et al. 1979), except possibly newly plowed fields (Baker 1983). This exception may explain why masked shrews were not present on any of the manipulated areas in 1999. Shrews are insectivores, and may consume several times their own weight each day. The immense reduction in the biomass of insects on manipulated fields from 1998 to 1999 (Figures 2 and 3) may have reduced the prey base for masked shrews enough to cause them to disappear from these fields. As the above-ground vegetation

grows back in future years, and the insect biomass recovers to pre-treatment levels, it is expected that masked shrew levels will recover.

Shorttail shrews also decreased considerably on the manipulated fields between 1998 and 1999 (Table 19). Wrigley et al. (1979) found shorttail shrews in many kinds of habitats, and concluded that vegetation type and cover were not dominating factors controlling its local distribution. The shorttail shrew is dependent on the presence of larger prey items, including beetles, snails, and earthworms, compared to the masked shrew (Wrigley et al. 1979). The decrease in insect biomass, particularly that of Coleoptera on the manipulated treatments, may explain the decrease in shorttail shrew numbers on the fields.

Meadow voles showed a great fluctuation in population levels between 1998 and 1999 on Field Control (Table 19). Populations of meadow voles fluctuate widely from year to year, with highs at 3- to 5- year intervals (Burt and Grossenheider 1980, Ostfeld and Canham 1993). This may explain the change in meadow vole populations on Field Control. As this field was not manipulated and few changes in vegetation characteristics took place between 1998 and 1999, this is likely the most plausible explanation for the large changes in the meadow vole population on Field Control in that time period.

Thirteen-lined ground squirrels were the only species captured on the fields that have a distribution centered on the grasslands of the Great Plains (Benedict et al. 1996). The abundance of thirteen-lined ground squirrels decreased significantly on Field Plow after the implementation of prairie creation techniques, and decreased on Field Burn/Wheat, although the difference was not significant (Table 19). Higgins and Stapp (1997) report that prey abundance may be an important indicator of the presence of thirteen-lined ground squirrels. This species eats primarily insects and seeds (Burt and Grossenheider 1980, Baker 1983), and the Orders Coleoptera and Orthoptera may be especially important parts of its diet (Flake 1973, Higgins and Stapp 1997). On Fields Burn/Wheat and Plow, the abundance of insects decreased considerably (Figures 2 and

3), especially the Orders Coleoptera and Orthoptera, between 1998 and 1999. This may be one of the main reasons for the decrease of thirteen-lined ground squirrels.

The differences in small mammal species composition on manipulated treatments become even clearer when considering each treatment, not only entire fields (Table 20). These results could not be analyzed statistically, since the information was qualitative only. Table 19 showed that 4 small mammal species were captured on Field Mow/Control in 1999. When separating the control and the manipulated treatments of Field Mow/Control, however, one can see that the only species captured on Treatment Mow was Peromyscus, while Treatment Part-control had more species. This confirms the pattern seen on the other manipulated treatments, that Peromyscus is the dominant species captured on areas of the study sites that received prairie creation techniques.

It is likely that the changes in small mammal species composition are results of the removal of the majority of standing vegetation and the resulting decrease in insect biomass on the treatments, which does not assist in determining the success of the prairie creation techniques. The dominant small mammals on tallgrass prairies are voles, mice, and members of the squirrel family (Grant and Birney 1979), and all small mammals caught on the study sites also occur on the tallgrass prairie (Risser et al. 1981). It seems, therefore, that the small mammal species composition on the study sites was more similar to that of a tallgrass prairie in 1998 than in 1999. However, deer mice are the most abundant small mammal on Konza Prairie in Kansas (Reichman 1987), similar to the study sites in 1999, indicating that the study sites may be approaching the small mammals species composition of native tallgrass prairies. Although the results from this study are preliminary, it is often assumed that the creation of prairie habitat will be followed by the natural recruitment of animals (Kline and Howell 1987). This clearly has not happened on the study sites, at least in regards to the small mammal species composition. It will take at least several more years until the vegetation resembles that of

a tallgrass prairie (Kline and Howell 1987), and may take at least that long to recruit the small mammal species composition of a native prairie.

Avian Relative Abundance and Productivity

Study Sites

Of the avian species observed on the 4 fields, only bobolinks and savannah sparrows are considered to be true grassland/prairie species (Ehrlich et al. 1988, Herkert 1994a; Table 24). Bobolinks were seen only on Field Burn/Wheat in 1998, and savannah sparrows were seen only on Field Control in 1998. It is unlikely that these species would nest in the study sites, as they have been found to select areas of at least 40 ha (Herkert 1994a, b). The most common bird species observed on the fields in both years were American crows, American goldfinches, common yellowthroats, field sparrows, red-winged blackbirds, and song sparrows. Most of these species are generally found in forest edge habitat. Field sparrows are characteristic of mid-grass/shrub habitats, and American goldfinches are characteristic of late successional prairie and forest edges (Ryan 1990). Field sparrows, common yellowthroats, song sparrows, and red-winged blackbirds generally prefer smaller grassland areas, and are considered to be edge species (Herkert 1994a, b; Meier et al. 1997; Vickery et al. 1994). The bird species composition was, therefore, heavily influenced by adjacent habitats consisting of forests and shrublands. Birds that commonly nest in forests were also observed during census counts, and include the following species: hairy woodpecker (*Picoides villosus*), tufted titmouse (*Paris bicolor*), and blue jay (*Cyanocitta cristata*; Ehrlich et al. 1988). These species likely use the study sites as foraging habitat only, not as breeding habitat.

On manipulated areas, the relative abundance of overall birds decreased significantly between 1998 and 1999 (Table 24). This is likely the result of the loss of most of the aboveground vegetation biomass, reducing both cover and food for most birds. As the aboveground vegetation biomass increases in future years, it is likely that

the bird abundance will increase again. Another possible reason for the decrease in the relative abundance of overall birds is the decrease in insect biomass on the fields (Figures 2 and 3). This may have reduced the amount of food available to insectivorous birds, similar to insectivorous small mammals discussed previously.

Areas Adjacent to Study Sites

As mentioned previously, only 20 bird species were observed in the fields in 1998 and 1999, compared to 42 bird species in adjacent areas. The increase in the number of species in adjacent areas compared to the treatment areas is likely due to the increased variety of habitat in adjacent areas. Surrounding areas included residential areas, forest, shrubland, agricultural areas, and grasslands. Avian species composition in adjacent areas may also explain the large number of forest edge/forest species observed during census counts of treatment fields. Many of these species likely use the study sites as foraging sites, not as breeding areas.

Productivity

More nests were found in 1998 compared to 1999 (Tables 26 and 27), likely due to the loss of cover and nesting materials after manipulations. No standing vegetation was available for males to perch on to establish breeding territories in early spring on the manipulated treatments, a necessary vegetation characteristic for many grassland species (Robel et al. 1998). The number of nests decreased greatly on Field Control as well, which did not receive prairie creation techniques. Most of the birds nesting on Field Control in 1998 were red-winged blackbirds, and they were the only species that nested on Field Control in 1999. Why the productivity decreased is not clear, especially when considering that the relative abundance of red-winged blackbirds had increased between 1998 and 1999 on Field Control, though this increase was not significant.

Insect Abundance

Insect sweepnetting

In 1998, before any manipulations occurred, the biomass of many insect Orders was lower in August than in June and/or July on many treatments (Table 31). The exceptions to this pattern were Orthoptera on Treatment Burn, and Coleoptera on Treatments Plow and Part-control, which had a lower biomass in June than in August, and Plecoptera on Treatment Part-control, which had a lower biomass in June and July than in August. By 1999, most treatments and Orders had their lowest biomass in June compared to July and August (Table 32). This is likely due to low amount of live cover in June. During the growing season, live cover and live height increased again on the manipulated treatments due to the growth of vegetation, and more habitat became available to insects. Only the control treatments exhibited similar patterns in the changes of insect biomass during the growing season as in 1998.

Many insect Orders decreased significantly between 1998 and 1999 on the manipulated treatments (Tables 33, 34, and 35). By August, however, the Orders Coleoptera and Diptera showed an increase in biomass between 1998 and 1999 on Treatments Burn and Plow, respectively. The causes of the increase in Coleoptera on Treatment Burn are not clear, as it was expected that all insect Orders would decrease as a result of the removal of the vegetation. Many insect Orders require horizontal as well as vertical heterogeneity to accommodate all growing stages of many insects (Panzer 1988), and removing cover and foraging materials for insects was expected to decrease the biomass of insects on the manipulated treatments. The increase in Diptera on Treatment Plow can be explained easier. By August 1999, live height and live vegetation cover had increased to August 1998 levels, and more forage and cover was available to insects. Other Orders, however, had not increased to pre-treatment levels. It may take some time before the biomass of insects increases to pre-treatment levels, even though the vegetation height and cover may increase. Few insects are present on the manipulated

treatments currently, and more insects need to re-colonize the areas before their biomass can increase again. Native tallgrass prairies are often described as literally "buzzing" with insects (Taron 1997), although restorations or creations usually do not approach either the insect diversity or biomass of the prairie remnants (Taron 1997). The decrease in insect biomass on prairie restorations and creations may be related to the poorer vegetation species diversity of most restorations/creations, or simply their younger age. It may take years for some rarer prairie insects to be recruited into a new tallgrass restoration or creation.

Homoptera were the most common insect Order on all treatments in June 1998 (Table 33). In July 1998, Homoptera were the most common insect Order on all treatments except Treatments Control and Part-control, on which Coleoptera was the most common Order (Table 34). Coleoptera were also the most common Order on all treatments in August 1998 except for Treatments Burn and Wheat, on which Orthoptera were the most common Order (Table 35). These results are similar to other studies in grasslands, which found that Homoptera are characteristic of grasslands (Curry 1994). Orthoptera are also known to be very common on grasslands (Risser et al. 1981, Curry 1994), and are described as one of the most visible insect Orders on Konza Prairie in Kansas (Reichman 1987). The Order Coleoptera is the largest insect Order regarding number of species and overall abundance (Borror and White 1970, Curry 1994), which may explain its dominance on many treatments in July and August 1998.

In 1999, dominant Orders of insects changed considerably. In June, Coleoptera were dominant on Treatments Wheat and Plow (Table 33). Orthoptera were dominant on Treatment Burn. Homoptera, Hemiptera, and Diptera were dominant on Treatments Control, Part-control, and Mow, respectively. In July, Coleoptera were dominant on Treatments Plow, Control, Part-control, and Mow (Table 34). Hemiptera and Arachnids were dominant on Treatments Burn and Wheat, respectively. In August, Hemiptera were dominant on Treatments Burn and Plow, Coleoptera were dominant on Treatments

Wheat, Control, and Part-control, and both Diptera and Hemiptera were dominant on Treatment Mow (Table 35). The dominant insect Orders had changed considerably on all manipulated treatments between 1998 and 1999, while the dominant Orders stayed mostly the same on the control treatments. This is likely due to the changes in vegetation cover between 1998 and 1999 (Tables 8 and 9). Homoptera and Orthoptera, 2 very prominent Orders in 1998, had decreased considerably in biomass by 1999, likely due to the decrease in percent grass cover on the manipulated treatments. These Orders are common on grasslands, but are often dependent on areas in which grasses make up a large percentage of the total cover (Curry 1994).

Over the entire year, Homoptera had the greatest biomass of all Orders on all Treatments except Treatment Control in 1998, in which Coleoptera had the greatest biomass (Figure 2). By 1999, Coleoptera had the highest biomass on Treatments Control, Part-control, and Mow, Hemiptera had the greatest biomass on Treatments Burn and Plow, and Arachnids had the greatest biomass on Treatment Wheat. The vegetation cover had changed considerably between 1998 and 1999, decreasing greatly in live height and percent live cover, and increasing in bare ground. These changes resulted in a decreased vertical heterogeneity, which is known to negatively affect the diversity and abundance of many insects (Panzer 1988).

Lepidoptera

Only the Lepidoptera Family Sphingidae showed a significant difference in mean numbers among fields for 1998 (Table 36). The primary food of members of this family is woody plants. Field Mow/Control, which had the greatest abundance of Sphingidae, is surrounded on all sides by woodlots, which may explain why they were found there.

Between 1998 and 1999, the number of Lepidoptera captured decreased on Fields Burn/Wheat, Plow, and Mow/Control, although these differences were not significant (Table 39). These changes are likely due to the decrease in live vegetation cover in that time period, which decreased the amount of food available to moths, as well as the cover

available as hiding places while Lepidoptera rest during the day (Covell 1984). As the vegetation returns to pre-treatment levels, the number of Lepidoptera captured may increase again, although the species composition will likely change as a result of changes in the species composition of the vegetation of the fields.

It may be easier to evaluate changes in the Lepidoptera species composition by placing Lepidoptera species into several food categories characterized by the major vegetation they consume as larvae and adults (Table 40). Lepidoptera species were placed into the appropriate food plant categories in accordance to the plants they consumed the most (Covell 1984). In some cases, this information was available for the caterpillars of the respective species only, while in other cases, both caterpillar and adult foods are included. Some species of Lepidoptera only feed as caterpillars, and do not have a digestive system as adults, concentrating solely on reproduction (Covell 1984). For these species, the food plant category may be misleading, as only adults are caught in the light traps. The caterpillars of these species could be feeding on plants in entirely different areas, and not on the study sites themselves, in which case the food plant category listed would be meaningless in attempting to determine the food plants of species observed on the fields. For some Lepidoptera species, individual species of plants that are preferably consumed (Covell 1984) were grouped into the larger categories of forbs, grasses, vines, woody vegetation, or any combination of these categories. For other Lepidoptera species, it was not known what vegetation species or type of vegetation they consumed, and these species were omitted from this analysis.

On Field Burn/Wheat, the food categories forbs, forbs and grasses, and various vegetation dominated the Lepidoptera composition in both 1998 and 1999. The woody vegetation category was also well represented, likely due to the woody vegetation in the surrounding areas. On Field Plow, the food category forbs showed a marked increase between 1998 and 1999, likely due to the increased forb cover as a result of the annual forbs that had invaded this field. The other food categories, except for woody vegetation,

decreased on Treatment Plow between 1998 and 1999, which may be the result of the decrease in type of vegetation heterogeneity on Field Plow in that time period, which robbed Lepidoptera other than those specializing in forbs of their preferred food plants. Field Mow/Control did not show any great differences in the composition of food categories between the 2 years. The woody vegetation and forb and grasses vegetation categories were predominant in 1998 on Field Mow/Control. In 1999, more Lepidoptera were in the forb and the forb and grasses categories on Field Mow/Control, though the woody category was still well represented, which was expected, as this field was surrounded by a woodlot. On Field Control, most food categories were well distributed. In 1999, the forb and grass category had increased considerably and was the most dominant food category on Field Control.

Expenditures

The winter wheat and burn treatments, though the most successful prairie creation techniques in regards to planted species establishment, were also the most expensive techniques. The burn and winter wheat treatments added approximately $100 and $110 per ha, respectively, to the total cost of the mowing and the plowing and disking treatments. This can add up to quite a bit of added cost when considering large prairie creation attempts. However, considering that the costs of the prairie seeds and the herbicide applications added up to almost $500 per ha, the added cost is small compared to the added benefit. Both the better establishment of the tallgrass prairie species and the lesser amount of aggressive undesired vegetation species made the burn and winter wheat treatments considerably more effective.

CONCLUSIONS

When considering solely the changes in vegetation characteristics and vegetation species composition, the burn and winter wheat treatments (Treatments Burn and Wheat) were the most successful in establishing planted prairie species and reducing the amount of undesirable exotic and non-prairie species. Although the plowing and disking treatment (Treatment Plow) had the highest establishment success of planted prairie species in June 1999, undesired and aggressive annuals proliferated on this site, and seemed to have outcompeted many planted species by August.

When considering the wildlife changes on the manipulated treatments, no conclusions can be made yet on which prairie creation technique was the most successful. The abundance of small mammals and avian species generally decreased considerably on the manipulated treatments, likely as a result of the removal of vegetation and a reduction in the biomass of insects on the treatments. The removal of most of the vegetation from the manipulated treatments resulted in a reduction in available food plants and cover for many wildlife species. The biomass of insects decreased considerably as a result of the decrease in live vegetation height and live cover, which robbed insectivorous small mammals and birds of a valuable food source.

The small mammal species composition was very similar on all manipulated treatments, with Peromyscus dominating the sites. Even though deer mice are also the most abundant small mammal on Konza Prairie in Kansas (Reichman 1987), the small mammal composition in native tallgrass prairies is very diverse, with dominant small mammal groups including voles, mice, and members of the squirrel family. It may take several more years until the manipulated treatments resemble a native tallgrass prairie in regards to the vegetation composition, and it may take at least that long to recruit the small mammal species of a prairie.

The avian species composition on all study sites was dominated by forest edge species, which likely used the study sites as foraging sites only, not for reproduction. Only 2 grassland species, the bobolink and the savannah sparrow, were observed on the study sites in 1998, and none were observed in 1999. The areas of the study sites are smaller than the minimum area requirements of many grassland birds. As the areas surrounding the study sites include a wide variety of habitats, including woodlots, shrublands, residential areas, agricultural areas, and old fields, it may be difficult to successfully recruit many grassland birds in future years.

A limitation of this study was that we only had sites available to us that had not contained prairie patches historically. Generally, it is preferable to perform prairie restorations on sites that were originally tallgrass prairies, than to perform prairie creations on sites that never contained prairie patches. However, it is necessary to develop effective prairie restoration and creation techniques to be able to restore tallgrass prairies more efficiently, and this project provided a unique opportunity to explore several different prairie creation techniques in the range of the prairie peninsula, and will continue to provide insight into the ecology of prairie creation as long as the project is continued. However, germination rates of planted species and the invasion of undesired non-prairie species may vary greatly with the soil.

The proximity of the study sites to forests and shrublands, and their small size, may pose limitations on their usefulness to native tallgrass prairie species. It is likely that maintenance activities will have to be continued, possibly on a yearly basis, to reduce the invasion of exotic species and woody vegetation on these sites in the future. However, these limitations do not reduce the value of this project in providing landowners with information on how to best create or restore tallgrass prairie plots on their properties. As the project continues and more information is gathered on the continued progress of the prairie creations, landowners will more easily be able to compare the cost of each

treatment and weigh it against its success over a period of several years in creating a native tallgrass prairie.

RECOMMENDATIONS

This project may provide valuable insights into the effects of the applied prairie creation techniques if continued on a long-term basis. As prairie creation attempts take at least 3 years to resemble a native tallgrass prairie, the project should be continued for at least that long to fully analyze the success of each technique. Maintenance activities need to be continued for at least another 2 to 3 years to reduce the amounts of undesired vegetation species present on the sites. It is generally accepted that burning and/or mowing are important manipulations in a prairie creation, as the accumulation of litter may reduce the productivity of grasslands. Although the mowing treatment was the least successful prairie creation technique regarding the establishment success of planted prairie species, mowing is a popular and efficient means to provide an effective disturbance regime to a tallgrass prairie restoration or creation, as it mimics the effects of fire in some ways (Steinauer and Collins 1996). Fire has been an important disturbance in the history of the tallgrass prairie and the prairie peninsula, and it is possible to influence the species composition of a prairie by burning at different times of the year and at different frequencies (Mitchell et al. 1996, Steinauer and Collins 1996, Davison and Kindscher 1999). Although the mow treatment was not as successful in establishing the planted grasses and forbs as the other treatments, it is possible that by mowing early in the growing season the growth of undesired non-prairie cool-season grasses will be discouraged, while the growth of planted warm-season grasses will be encouraged (Mitchell et al. 1996)

It will be necessary to apply herbicides at least once more to reduce the amounts of undesired non-prairie species on the sites. Quack grass is present on all manipulated treatments and may outcompete many planted species. As both Round-Up® and Plateau® are generally not very successful in eradicating quack grass, it may be necessary to apply the herbicide Fusilade II®, which is known to kill quack grass. Although Canada thistle is not currently very prevalent on the manipulated treatments, it is notorious for its ability to persist in a prairie creation attempt, and may need to be treated with additional applications of Round-Up® before it has the opportunity to spread on the prairie creation sites.

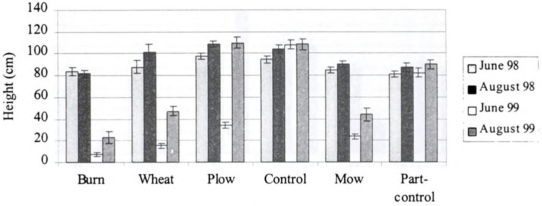
It is recommended that the sites will be mowed in April 2000. In late April, the manipulated treatments should be sprayed with the herbicide Fusilade II® to reduce the amount of quack grass on the treatments. In early May, when forbs are actively growing, the sites should be sprayed with the herbicide Plateau® to reduce the amount of undesired forbs on the sites. Any Canada thistle that is present on the sites should be sprayed with Plateau® using a backpack sprayer, as necessary.

The small size of the prairie creation sites may be a problem in successfully restoring native prairie plants and animals. If possible, areas surrounding the manipulated treatments should also receive prairie creation manipulations, thereby adding to the areas of the prairie creation sites. If this is not possible, it would be preferable to remove the woodlots along the boundaries of the manipulated treatments, and replace them with either prairies or grasslands. This would increase the effective sizes of the prairie creations, and would likely aid in recruiting native tallgrass prairie wildlife.

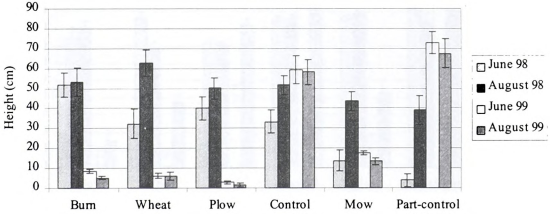
APPENDICES

APPENDIX A

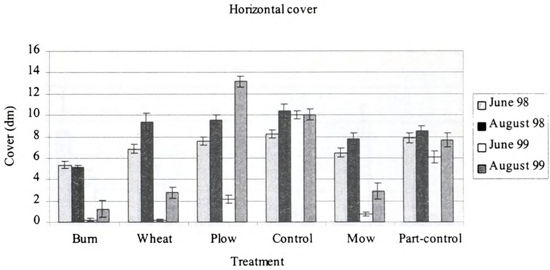
Live height

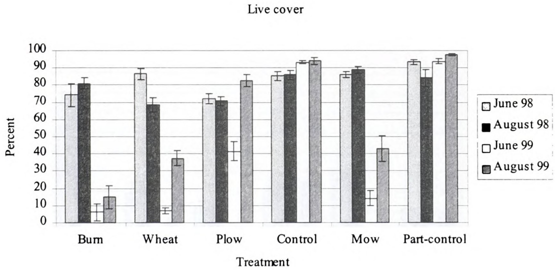


Dead height



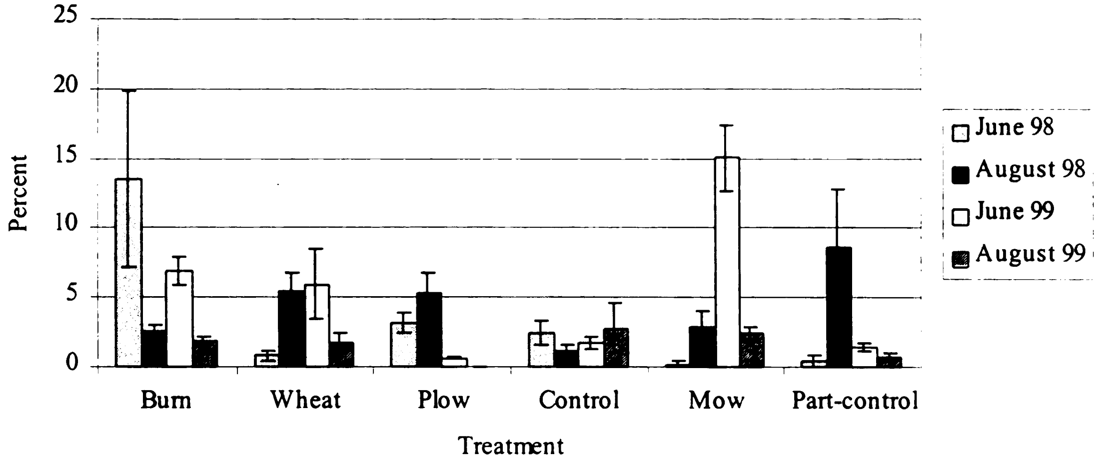
Appendix A. Fig. 1. Graphic representation of mean (SE error bars) vegetation characteristics of grassland treatments in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.



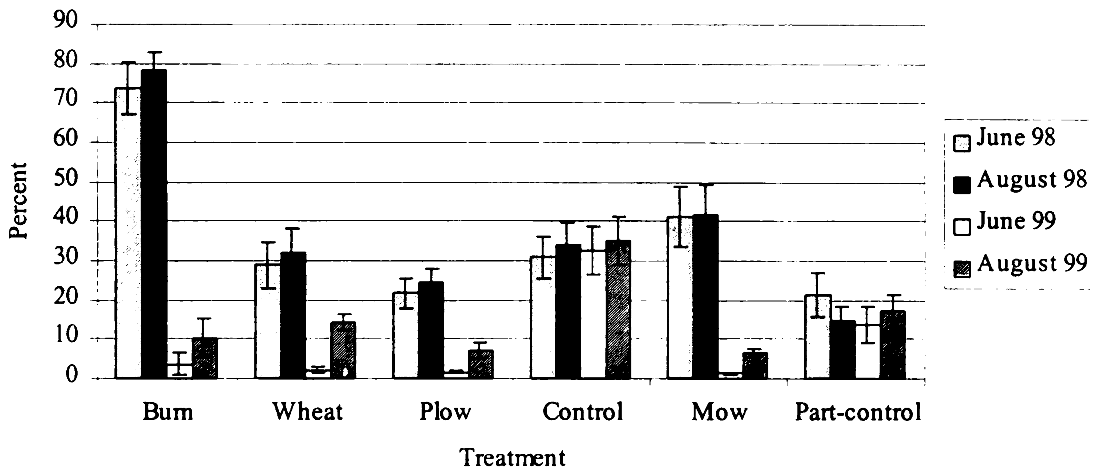


Appendix A. Fig. 1 (cont'd).

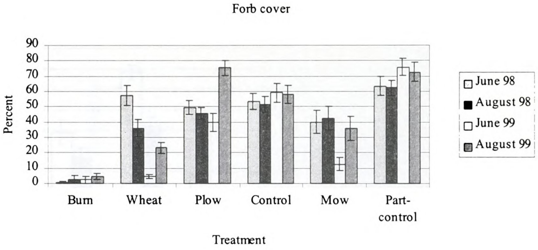
Dead cover

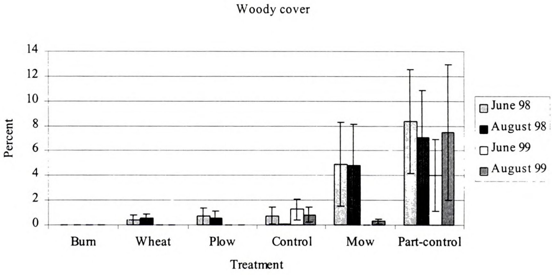


Grass cover



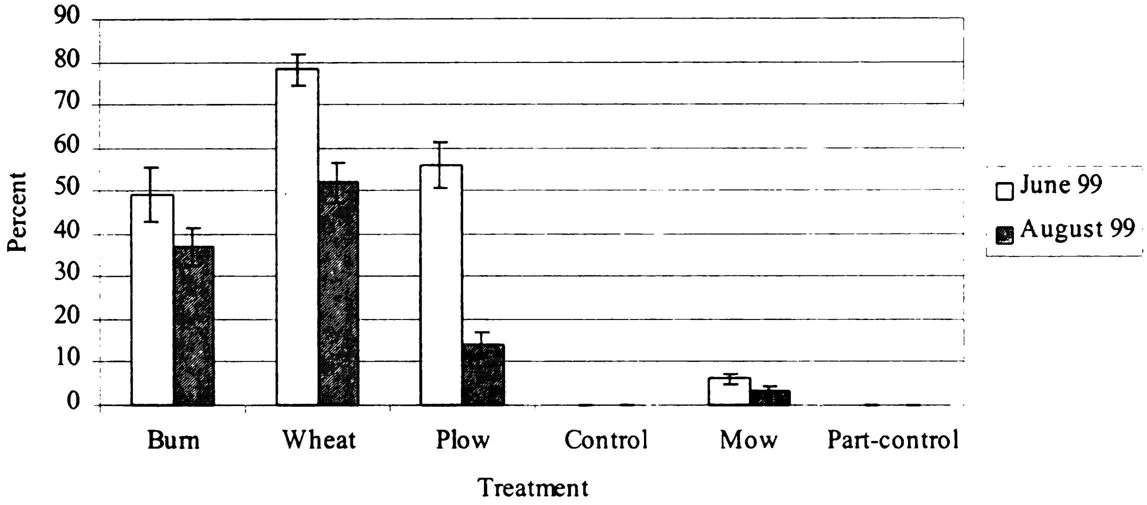
Appendix A. Fig. 1 (cont'd).



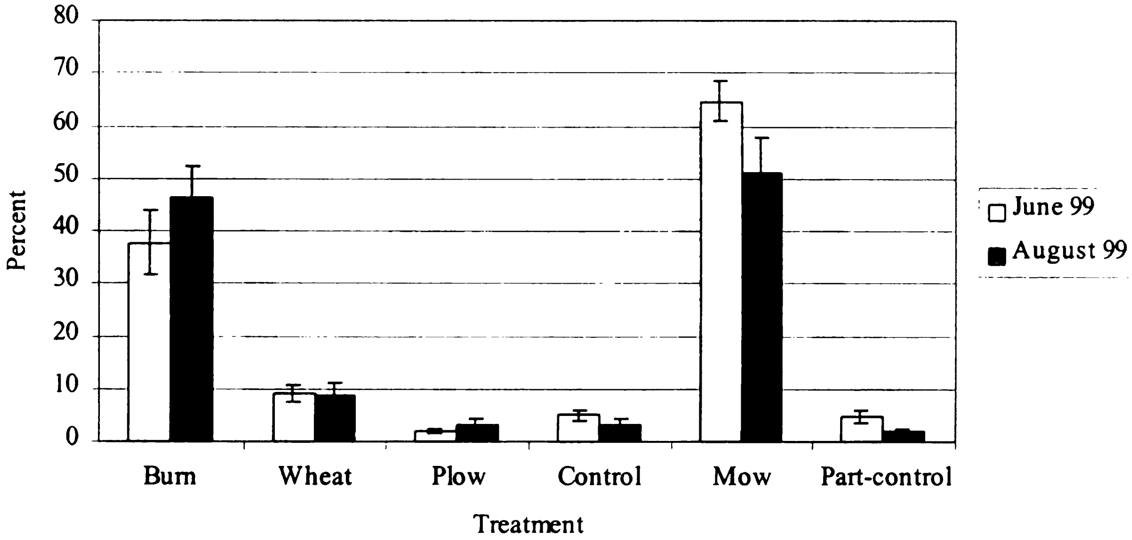


Appendix A. Fig. 1 (cont'd).

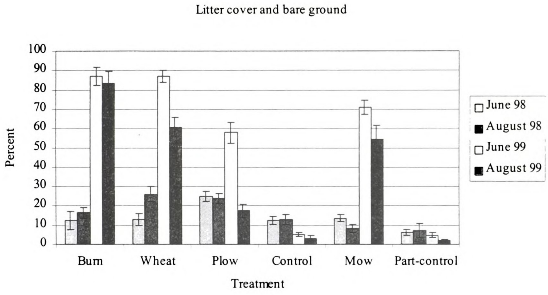
Bare ground

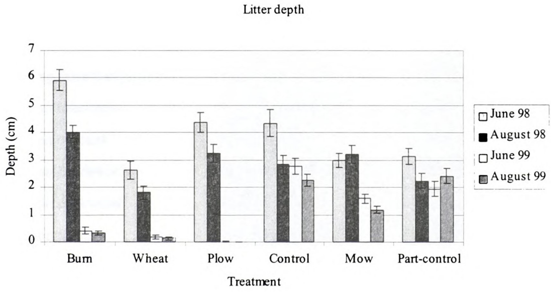


Litter cover



Appendix A. Fig. 1 (cont'd).





Appendix A. Fig. 1 (cont'd).

Appendix A. Table 1. Vegetation species present in grassland areas in RLWRA in Clinton County, Michigan, from June to August 1998 and 1999.

Common Name	Scientific Name	Family
Alsike clover [C]	*Trifolium hybridum*	Fabaceae
Arrow-leaved violet [B]	*Viola sagittata*	Violaceae
Aster sp. [B]	*Aster sp.*	Asteraceae
Autumn-olive [B]	*Elaeagnus umbellata*	Eleagnaceae
Big bluestem [B]	*Andropogon gerardii*	Poaceae
Black raspberry	*Rubus occidentalis*	Rosaceae
Blue-joint [C]	*Calamagrostis canadensis*	Poaceae
Bull thistle [C]	*Cirsium vulgare*	Asteraceae
Bush-clover [A]	*Lespedeza violacea*	Fabaceae
Bush-clover sp. [C]	*Lespedeza sp.*	Fabaceae
Canada thistle [C]	*Cirsium arvense*	Asteraceae
Climbing false buckwheat [B]	*Polygonum scandens*	Polygonaceae
Common blackberry [A]	*Rubus allegheniensis*	Rosaceae
Common burdock [C]	*Arctium minus*	Asteraceae
Common dandelion [C]	*Taraxacum officinale*	Asteraceae
Common milkweed [A]	*Asclepias syriaca*	Asclepiadaceae
Common mullein [C]	*Verbascum thapsus*	Scrophulariaceae
Common plantain [A]	*Plantago major*	Plantaginaceae
Common ragweed [C]	*Ambrosia artemisiifolia*	Asteraceae
Common sow thistle [C]	*Sonchus oleraceus*	Asteraceae
Curly dock [A]	*Rumex crispus*	Polygonaceae
Daisy fleabane [A]	*Erigeron annuus*	Asteraceae
Elm sp. [C]	*Ulmus sp.*	Ulmaceae
Fall panicum [A]	*Panicum dichotomiflorum*	Poaceae

Appendix A. Table 1 (cont'd).

Common Name	Scientific Name	Family
Field bindweed	*Convolvulus arvensis*	Convolvulaceae
Field sow-thistle [B]	*Sonchus arvensis*	Asteraceae
Fringed loosestrife [A]	*Lysimachia ciliata*	Primulaceae
Goldenrod sp. [C]	*Solidago sp.*	Asteraceae
Grape sp. [C]	*Vitis sp.*	Vitaceae
Hairy vetch [C]	*Vicia villosa*	Fabaceae
Hawkweed sp. [C]	*Hieracium sp.*	Asteraceae
Hawthorn [A]	*Crataegus sp.*	Rosaceae
Hoary alyssum [C]	*Berteroa incana*	Brassicaceae
Horsetail [C]	*Equisetum arvense*	Equisetaceae
Horseweed [A]	*Conyza canadensis*	Asteraceae
Indian grass [B]	*Sorghastrum nutans*	Poaceae
Lambs-quarters [B]	*Chenopodium album*	Chenopodiaceae
Little bluestem [B]	*Andropogon scoparius*	Poaceae
Low hop clover [B]	*Trifolium campestre*	Fabaceae
Maple sp. [A]	*Acer sp.*	Aceraceae
Milkweed sp. [C]	*Asclepias sp.*	Asclepiadaceae
Mountain watercress [A]	*Cardamine rotundifolia*	Brassicaceae
Mullein sp. [A]	*Verbascum sp.*	Scrophulariaceae
Night-flowering catchfly [B]	*Silene noctiflora*	Caryophyllaceae
Nightshade [A]	*Solanum dulcamara*	Solanaceae
Nodding thistle [A]	*Carduus nutans*	Asteraceae
Northern dewberry [A]	*Rubus flagellaris*	Rosaceae
Path rush [C]	*Juncus tenuis*	Juncaceae

Appendix A. Table 1 (cont'd).

Common Name	Scientific Name	Family
Poison-ivy [B]	*Toxicodendron radicans*	Anacardiaceae
Poke milkweed [A]	*Asclepias exaltata*	Asclepiadaceae
Quack grass [C]	*Agropyron repens*	Poaceae
Red clover [C]	*Trifolium pratense*	Fabaceae
Red-osier dogwood [C]	*Cornus stolonifera*	Cornaceae
Reed canary grass [C]	*Phalaris arundinaceae*	Poaceae
Rose sp. [A]	*Rosa sp.*	Rosaceae
Rough-fruited cinquefoil [C]	*Potentilla recta*	Rosaceae
Short-toothed mountain mint [B]	*Pycnanthemum muticum*	Lamiaceae
Shrubby St. John's-wort [A]	*Hypericum prolificum*	Clusiaceae
Slender bush-clover [A]	*Lespedeza virginica*	Fabaceae
Smartweed sp. [C]	*Polygonum sp.*	Polygonaceae
Smooth brome [C]	*Bromus inermis*	Poaceae
Sow thistle sp. [A]	*Sonchus sp.*	Asteraceae
Spotted St. John's-wort [A]	*Hypericum punctatum*	Clusiaceae
Stinging nettle [A]	*Urtica dioica*	Apiaceae
Sweet cicely [A]	*Osmorhiza claytonii*	Apiaceae
Switch grass [B]	*Panicum virgatum*	Poaceae
Thistle sp. [C]	*Cirsium sp.*	Asteraceae
Timothy grass [C]	*Phleum pratense*	Poaceae
Velvet-leaf [B]	*Abutilon theophrasti*	Malvaceae
Violet sp. [A]	*Viola sp.*	Violaceae
Virginia creeper [A]	*Parthenocissus quinquefolia*	Vitaceae
White avens [A]	*Geum canadense*	Rosaceae

Appendix A. Table 1 (cont'd).

Common Name	Scientific Name	Family
White campion	*Silene pratensis*	Caryophyllaceae
White clover [A]	*Trifolium repens*	Fabaceae
White sweet-clover [C]	*Melilotus alba*	Fabaceae
Wild carrot [C]	*Daucus carota*	Apiaceae
Wild lupine [B]	*Lupinus perennis*	Fabaceae
Wild red raspberry [C]	*Rubus strogosus*	Rosaceae
Wild strawberry [C]	*Fragaria virginiana*	Rosaceae
Wood sorrel sp. [C]	*Oxalis sp.*	Oxalidaceae
Yellow avens [C]	*Geum aleppicum*	Rosaceae
Yellow foxtail [B]	*Setaria glauca*	Poaceae
Yellow rocket [A]	*Barbarea vulgaris*	Brassicaceae
Yellow sweet-clover [A]	*Melilotus officinalis*	Fabaceae

[A] Observed in 1998 only
[B] Observed in 1999 only
[C] Observed in 1998 and 1999

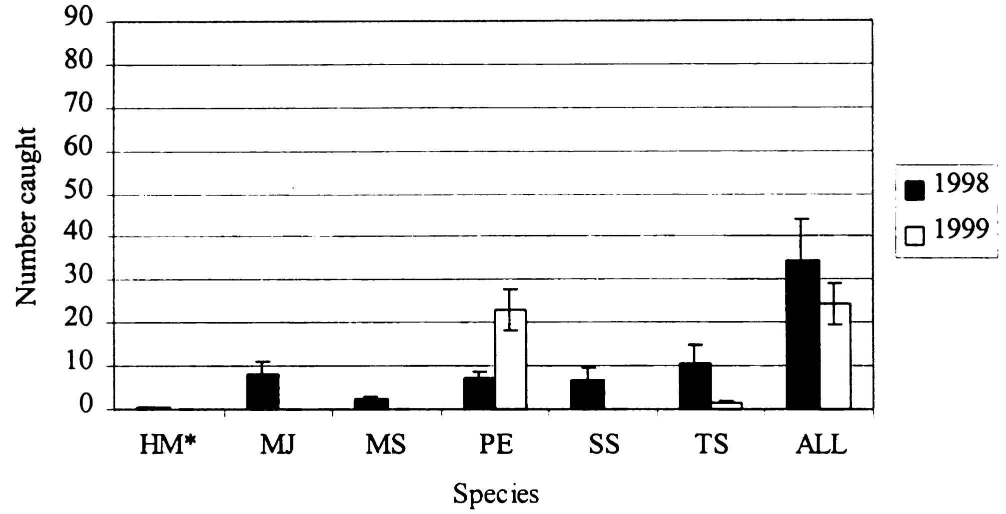
APPENDIX B

Appendix B. Table 1. Small mammal species live-trapped in grassland areas in RLWRA in Clinton County, Michigan, from May to August 1998 and 1999.

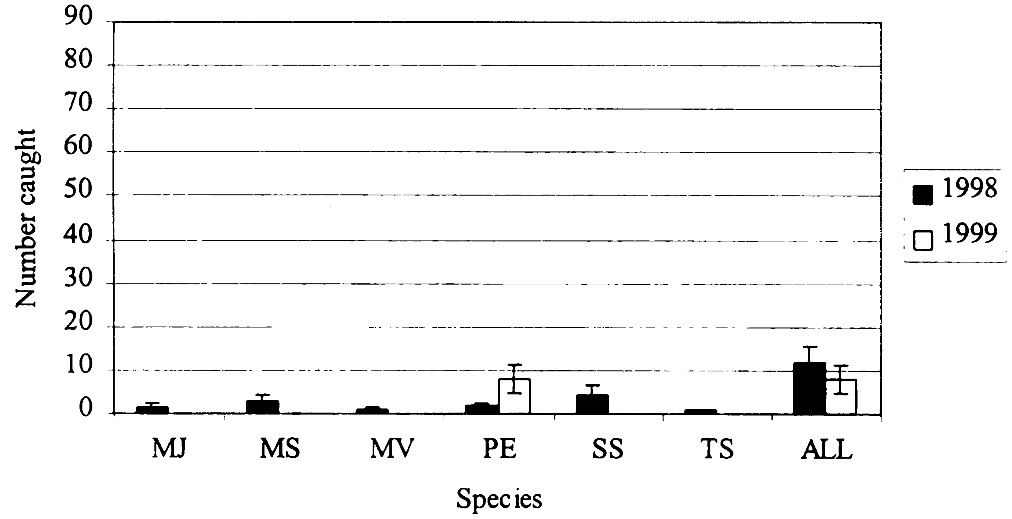
Common Name	Scientific Name
House mouse [A]	*Mus musculus*
Longtail weasel [B]	*Mustela frenata*
Least weasel [A]	*Mustela rixosa*
Meadow jumping mouse [C]	*Zapus hudsonius*
Masked shrew [C]	*Sorex cinereus*
Meadow vole [C]	*Microtus pennsylvanicus*
Peromyscus [C]	*Peromyscus sp.*
Shorttail shrew [C]	*Blarina brevicauda*
Thirteen-lined ground squirrel [C]	*Citellus columbianus*

[A] Observed in 1998 only
[B] Observed in 1999 only
[C] Observed in 1998 and 1999

Field Burn/Wheat



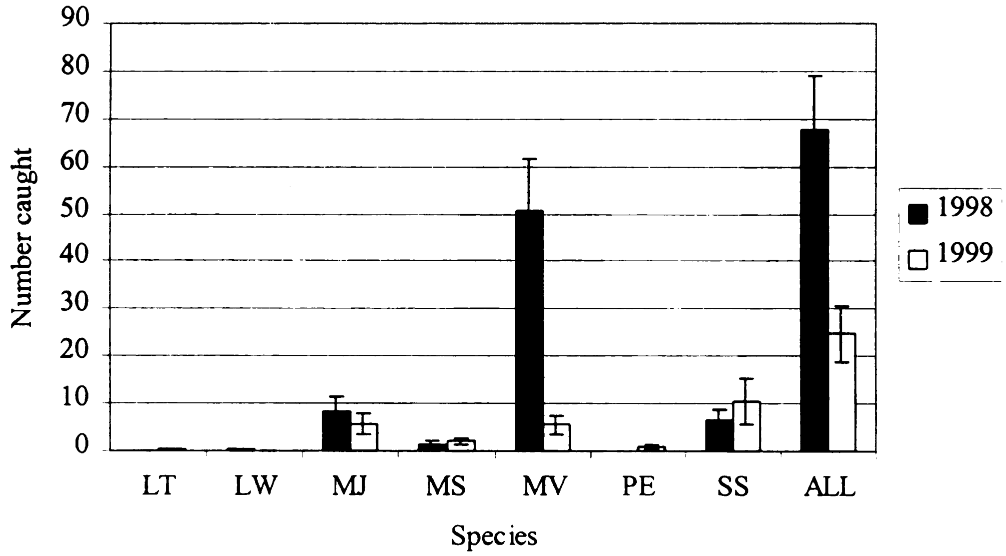
Field Plow



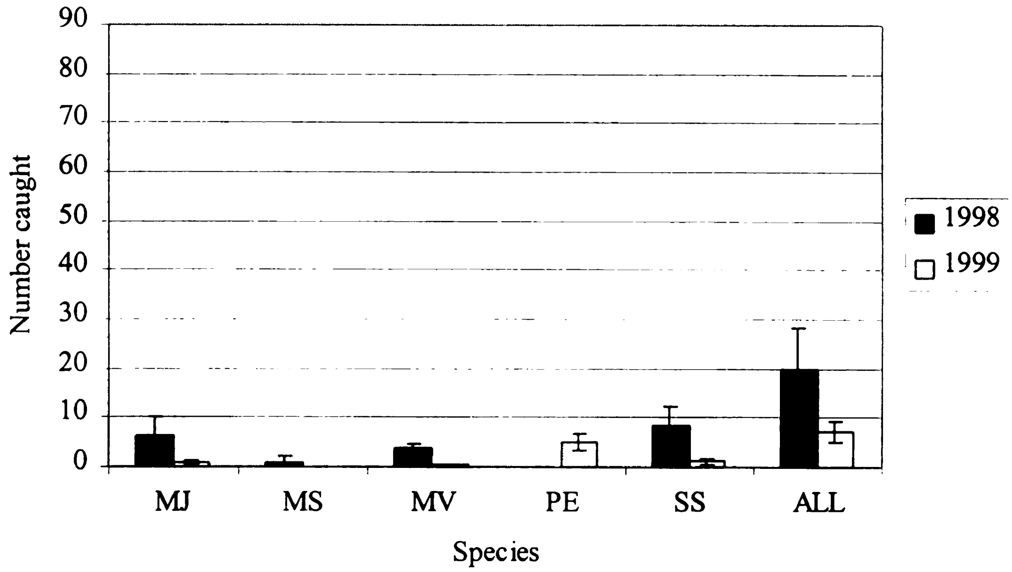
Appendix B. Fig. 1. Graphic representation of mean (SE error bars) abundance of small mammals captured on grassland fields in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.

*Abbreviations: HM: house mouse, LW: least weasel, LT: long-tailed weasel, MJ: meadow jumping mouse, MS: masked shrew, MV: meadow vole, PE: Peromyscus, SS: shorttail shrew, TS: thirteen-lined ground squirrel.

Field Control



Field Mow/Control



Appendix B. Fig. 1 (cont'd).

APPENDIX C

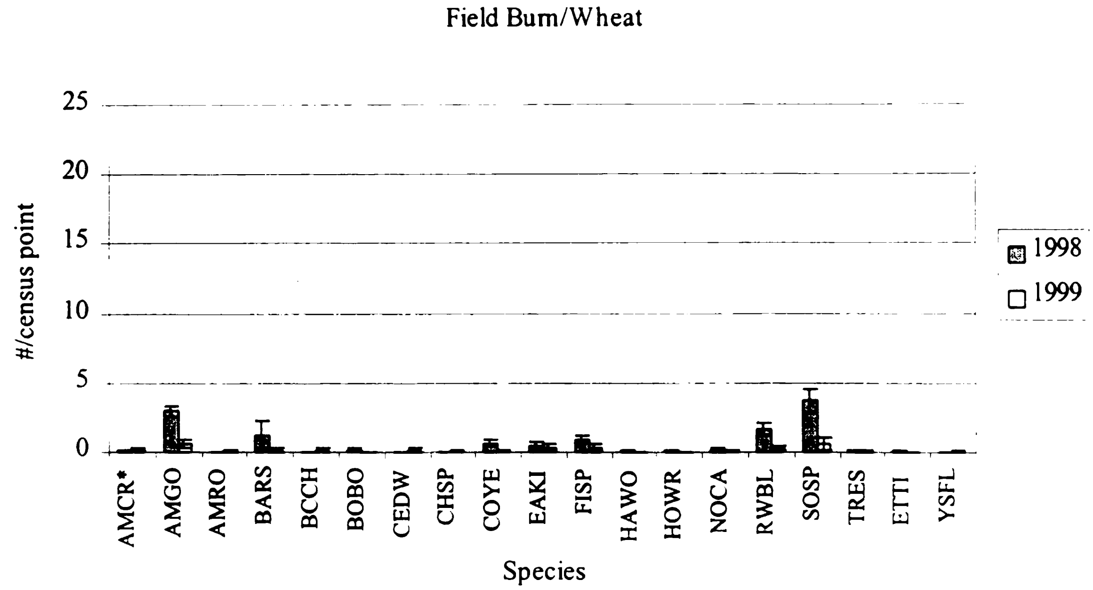
Appendix C. Table 1. Bird species observed during census counts in fields in RLWRA, Clinton County, Michigan, from May to August 1998 and 1999.

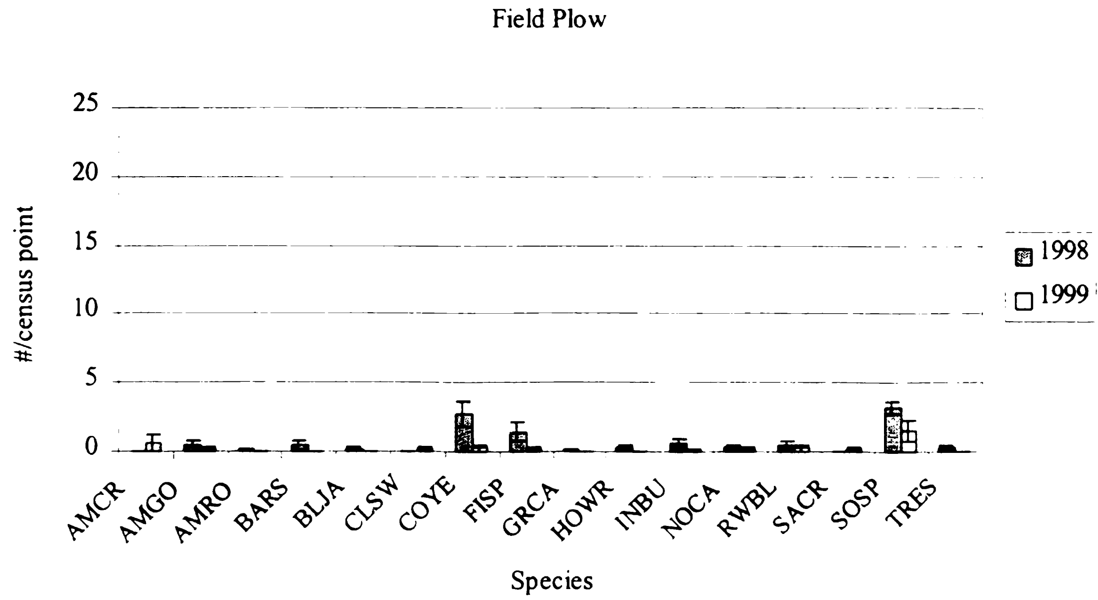
Common Name	Scientific Name
American crow [C]	*Corvus brachyrhynchos*
American goldfinch [C]	*Carduelis tristis*
American robin [C]	*Turdus migratorius*
Barn swallow [C]	*Hirundo rustica*
Black-capped chickadee [B]	*Parus atricapillus*
Blue jay [C]	*Cyanocitta cristata*
Bobolink [A]	*Dolichonyx oryzivorus*
Cedar waxwing [C]	*Bombycilla cedrorum*
Chipping sparrow [B]	*Spizella passerina*
Cliff swallow [B]	*Petrochelidon pyrrhonata*
Common yellowthroat [C]	*Geothlypis trichas*
Eastern kingbird [C]	*Tyrannus tyrannus*
Field sparrow [C]	*Spizella pusilla*
Gray catbird [A]	*Dumetella carolinensis*
Hairy woodpecker [A]	*Picoides villosus*
House wren [A]	*Troglodytes aedon*
Indigo bunting [C]	*Passerina cyanea*
Northern cardinal [C]	*Cardinalis cardinalis*
Red-winged blackbird [C]	*Agelaius phoeniceus*
Sandhill crane [B]	*Grus canadensis*
Savanna sparrow [A]	*Passerculus sandwichensis*
Song sparrow [C]	*Melospiza melodia*
Tree swallow [C]	*Iridoprocne bicolor*

Appendix C. Table 1 (cont'd).

Common Name	Scientific Name
Tufted titmouse [A]	*Parus bicolor*
Yellow-shafted flicker [B]	*Colaptes auratus*

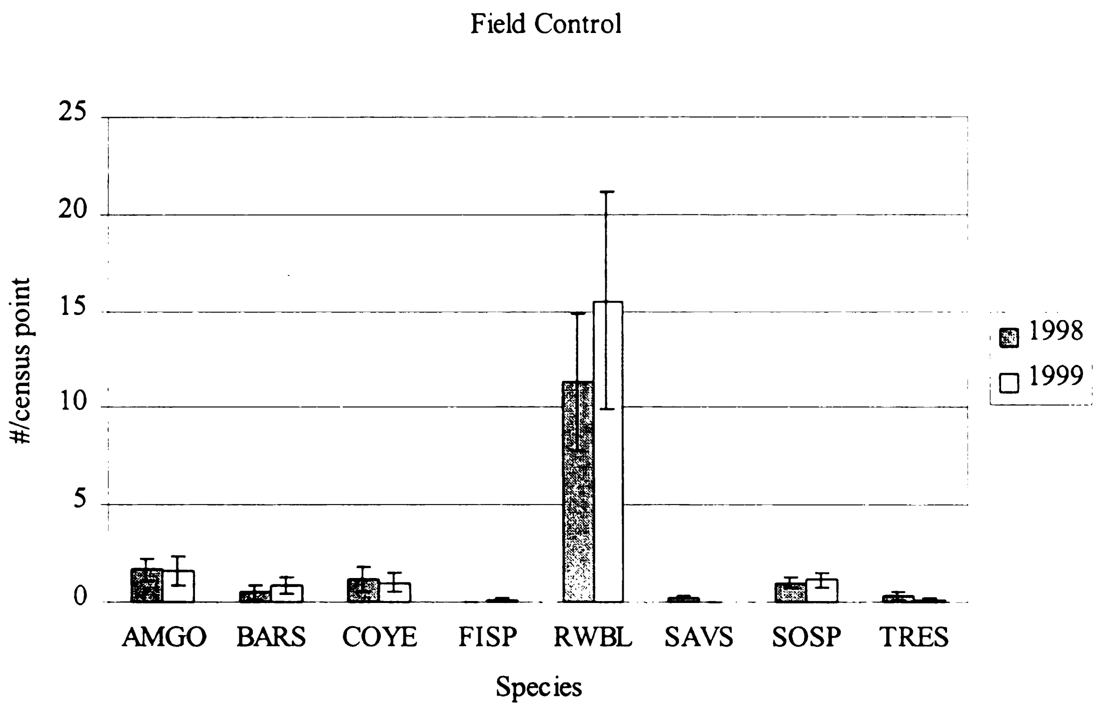
[A] Observed in 1998 only
[B] Observed in 1999 only
[C] Observed in 1998 and 1999

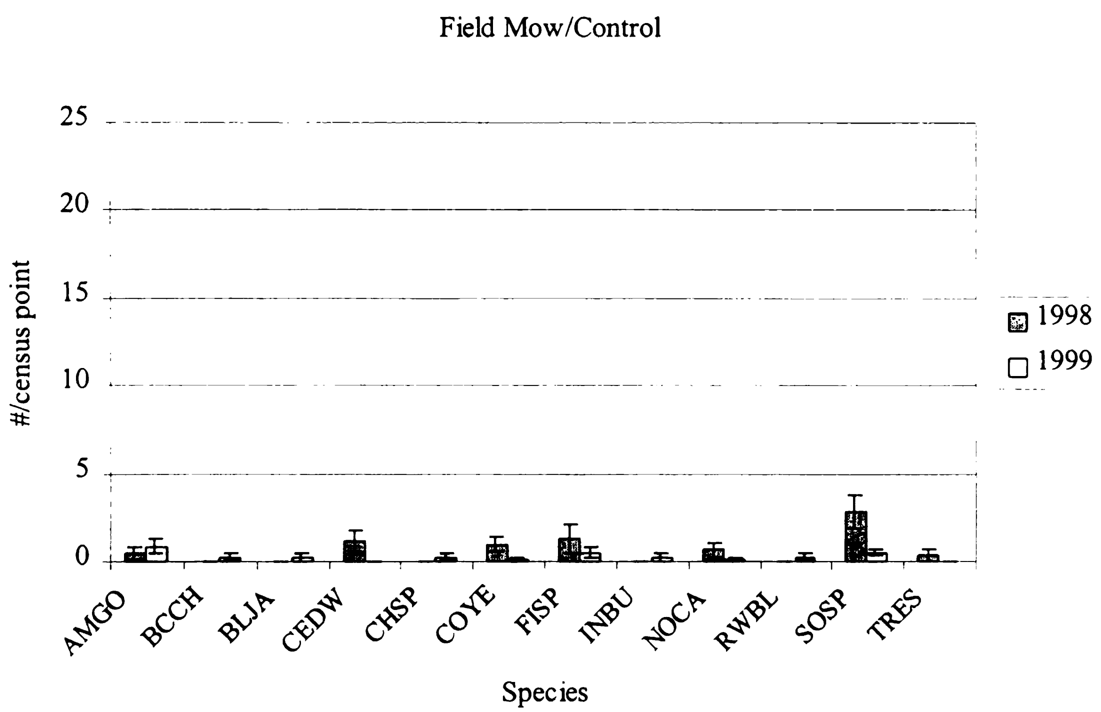




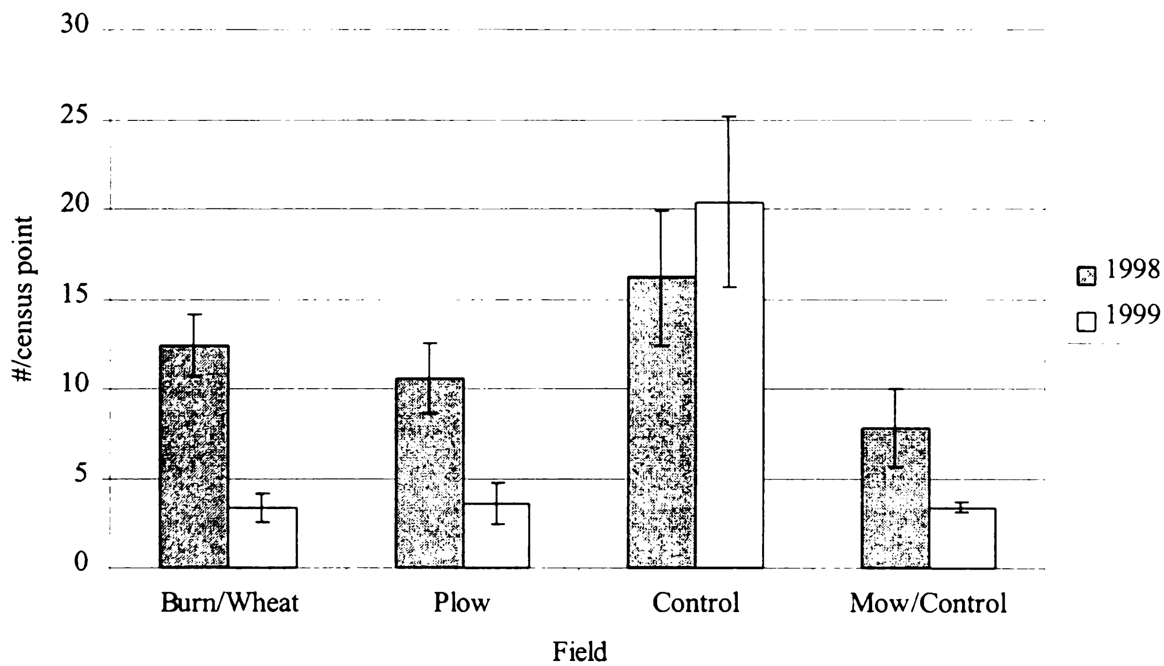
Appendix C. Fig. 1. Graphic representation of mean (SE error bars) relative abundance (birds/census point) of birds observed on grassland fields in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.

*Abbreviations: AMCR: American crow, AMGO: American goldfinch, AMRO: American robin, BARS: barn swallow, BCCH: black-capped chickadee, BLJA: blue jay, BOBO: bobolink, CEDW: cedar waxwing, CHSP: chipping sparrow, CLSW: cliff swallow, COYE: common yellowthroat, EAKI: eastern kingbird, FISP: field sparrow, GRCA: gray catbird, HAWO: hairy woodpecker, HOWR: house wren, INBU: indigo bunting, NOCA: northern cardinal, RWBL: red-winged blackbird, SACR: sandhill crane, SAVS: savannah sparrow, SOSP: song sparrow, TRES: tree swallow, ETTI: tufted titmouse, YSFL: yellow-shafted flicker.





Appendix C. Fig. 1 (cont'd).



Appendix C. Fig. 2. Graphic representation of mean (SE error bars) overall relative abundance (birds/census point) of birds observed on grassland fields in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.

Appendix C. Table 2. Bird species observed during census counts in adjacent areas in RLWRA, Clinton County, Michigan, from May to August 1998 and 1999.

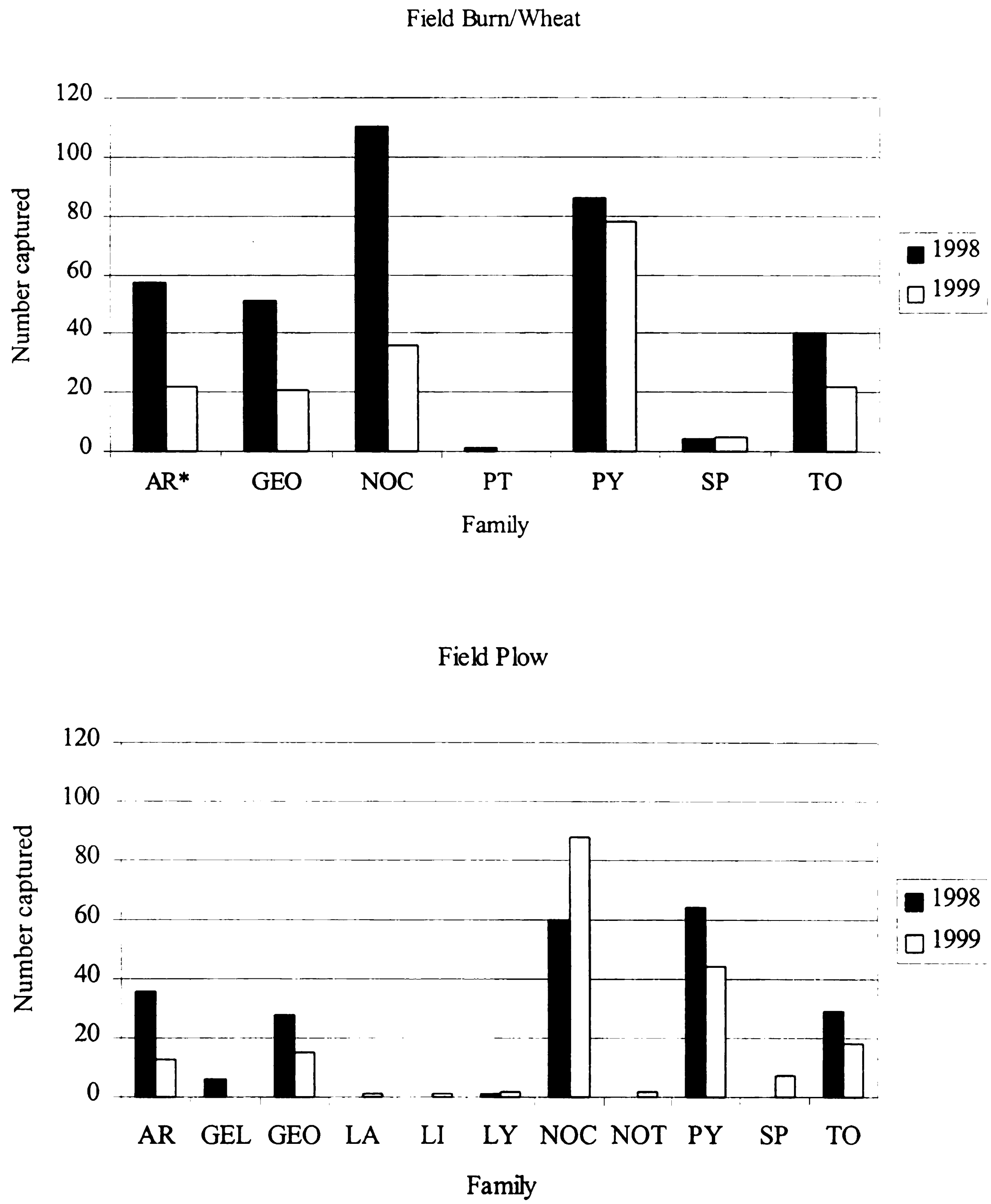
Common Name	Scientific Name
American crow [C]	*Corvus brachyrhynchos*
American goldfinch [C]	*Carduelis tristis*
American robin [C]	*Turdus migratorius*
Bank swallow [A]	*Riparia riparia*
Barn swallow [C]	*Hirundo rustica*
Black-capped chickadee [C]	*Parus atricapillus*
Blue jay [C]	*Cyanocitta cristata*
Bobolink [A]	*Dolichonyx oryzivorus*
Brown thrasher [C]	*Toxostoma rufum*
Brown-headed cowbird [C]	*Molothrus ater*
Canada goose [B]	*Branta canadensis*
Cedar waxwing [C]	*Bombycilla cedrorum*
Chimney swift [A]	*Chaetura pelagica*
Chipping sparrow [B]	*Spizella passerina*
Common yellowthroat [C]	*Geothlypis trichas*
Downy woodpecker [B]	*Picoides pubescens*
Eastern kingbird [C]	*Tyrannus tyrannus*
Eastern pewee [C]	*Contopus virens*
Field sparrow [C]	*Spizella pusilla*
Gray catbird [C]	*Dumetella carolinensis*
House wren [A]	*Troglodytes aedon*
Indigo bunting [C]	*Passerina cyanea*
Killdeer [C]	*Charadrius vociferus*
Mallard [C]	*Anas platyrhynchos*

Appendix C. Table 2 (cont'd).

Common Name	Scientific Name
Marsh wren [B]	*Cistothorus palustris*
Mourning dove [C]	*Zenaida macroura*
Northern cardinal [C]	*Cardinalis cardinalis*
Red-tailed hawk [C]	*Buteo jamaicensis*
Red-winged blackbird [C]	*Agelaius phoeniceus*
Ring-necked pheasant [A]	*Phasianus colchicus*
Rock dove [C]	*Columbus livia*
Rufous-sided towhee [C]	*Pipilo erythrophthalmus*
Sandhill crane [C]	*Grus canadensis*
Savanna sparrow [A]	*Passerculus sandwichensis*
Song sparrow [C]	*Melospiza melodia*
Tree swallow [C]	*Iridoprocne bicolor*
Tufted titmouse [C]	*Parus bicolor*
Veery [B]	*Catharus fuscescens*
White-breasted nuthatch [B]	*Sitta carolinensis*
Wood thrush [B]	*Hylocichla mustelina*
Yellow Warbler [C]	*Dendroica petechia*
Yellow-shafted flicker [B]	*Colaptes auratus*

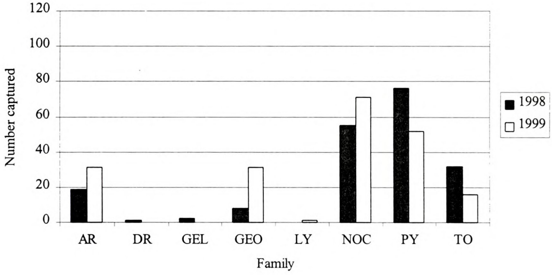
[A] Observed in 1998 only
[B] Observed in 1999 only
[C] Observed in 1998 and 1999

APPENDIX D

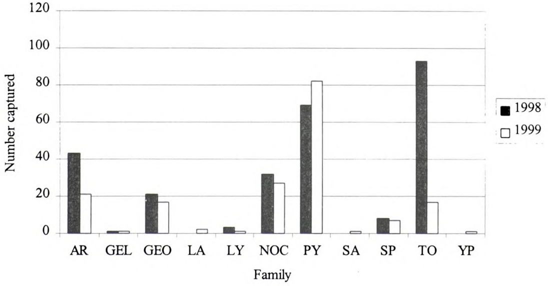


Appendix D. Fig. 1. Graphic representation of number of Lepidoptera captured on grassland fields in RLWRA, Clinton County, Michigan, in summer 1998 and 1999. *Abbreviations: AR: Arctiidae, DR: Drepanidae, GEL: Gelechiidae, GEO: Geometridae, LA: Lasiocampidae, LI: Limacodidae, LY: Lymantriidae, NOC: Noctuidae, NOT: Notodontidae, PT: Pterophoridae, PY: Pyralidae, SA: Saturniidae, SP: Sphingidae, TO: Tortricidae, YP: Yponomeutidae.

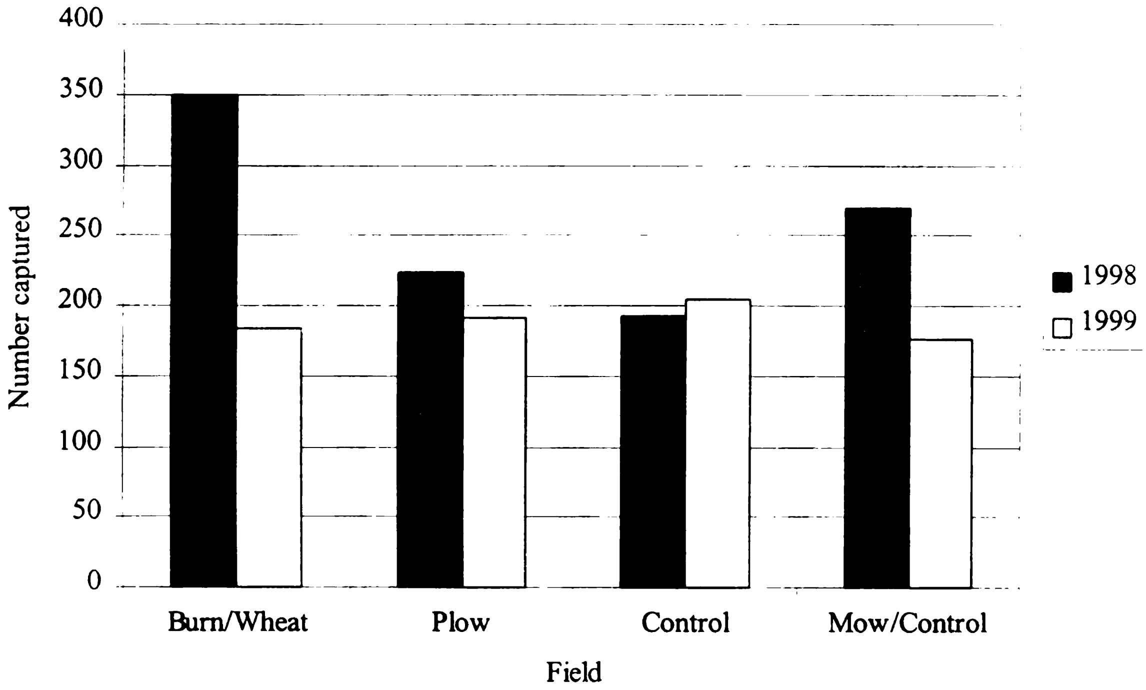
Field Control



Field Mow/Control



Appendix D. Fig. 1 (cont'd).



Appendix D. Fig. 2. Graphic representation of number of overall Lepidoptera captured on grassland fields in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.

Appendix D. Table 1. Lepidoptera species captured in grassland areas in RLWRA in Clinton County, Michigan, from June to August 1998 and 1999.

Common Name	Scientific Name	Family
Agreeable tiger moth [C]	*Spilosoma congrua*	Arctiidae
Ailanthus webworm moth [B]	*Atteva punctella*	Yponomeutidae
American ear moth [A]	*Amphipoea americana*	Noctuidae
Apple sphinx [A]	*Sphinx gordius*	Sphingidae
Arched hooktip [A]	*Drepana arcuata*	Drepanidae
Archips purpurana [A]	*Archips purpurana*	Tortricidae
Arcigera flower moth [A]	*Schinia arcigera*	Noctuidae
Arge moth [B]	*Grammia arge*	Arctiidae
Armyworm moth [B]	*Pseudaletia unipuncta*	Noctuidae
Banded tussock moth [C]	*Halysidota tessellaris*	Arctiidae
Beautiful wood-nymph [B]	*Eudryas grata*	Noctuidae
Bent-line carpet [B]	*Orthonama centrostrigaria*	Geometridae
Big poplar sphinx [B]	*Pachysphinx modesta*	Sphingidae
Blinded sphinx [C]	*Paonias excaecatus*	Sphingidae
Bridled arches [B]	*Lacinipolia lorea*	Noctuidae
Bristly cutworm moth [C]	*Lacinipolia renigera*	Noctuidae
Carter's sphinx [B]	*Protambulyx carteri*	Sphingidae
Celery looper moth [B]	*Anagrapha falcifera*	Noctuidae
Choristoneura fractivittana [A]	*Choristoneura fractivittana*	Tortricidae
Clover hayworm moth [B]	*Hypsopygia costalis*	Pyralidae
Clover looper moth [A]	*Caenurgina crassiuscula*	Noctuidae
Common gray [A]	*Anavitrinella pampinaria*	Geometridae
Common looper moth [B]	*Autographa precationis*	Noctuidae
Common spragueia [A]	*Spragueia leo*	Noctuidae

Appendix D. Table 1 (cont'd).

Common Name	Scientific Name	Family
Crambus agitatellus [C]	*Crambus agitatellus*	Pyralidae
Crambus laqueatellus [C]	*Crambus laqueatellus*	Pyralidae
Dasychira sp. [A]	*Dasychira sp.*	Lymantriidae
Dingy cutworm moth [C]	*Feltia jaculifera*	Noctuidae
Eastern tent caterpillar moth [B]	*Malacosoma americanum*	Lasiocampidae
Emmelina monodactyla [A]	*Emmelina monodactyla*	Pterophoridae
False crocus geometer [C]	*Xanthotype urticaria*	Geometridae
Filbertworm moth [A]	*Melissopus latiferreanus*	Tortricidae
Flame-shouldered dart [A]	*Ochropleura plecta*	Noctuidae
Forage looper moth [B]	*Caenurgina erechtea*	Noctuidae
Frosted tan wave [B]	*Scopula cacuminaria*	Geometridae
Fruit-tree leafroller moth [C]	*Archips argyrospila*	Tortricidae
Grand arches [B]	*Lacanobia grandis*	Noctuidae
Grape leaffolder moth [B]	*Desmia funeralis*	Pyralidae
Gray half-spot [A]	*Nedra ramosula*	Noctuidae
Great ash sphinx [B]	*Sphinx chersis*	Sphingidae
Greater black-letter dart [A]	*Xestia dolosa*	Noctuidae
Gypsy moth [C]	*Lymantria dispar*	Lymantriidae
Henry's marsh moth [B]	*Simyra henrici*	Noctuidae
Honest pero [B]	*Pero honestaria*	Geometridae
Huebner's pero [C]	*Pero hubneraria*	Geometridae
Ipsilon dart [A]	*Agrotis ipsilon*	Noctuidae
Isabella tiger moth [B]	*Pyrrharctia isabella*	Arctiidae
Johnson's Euchlaena [B]	*Euchlaena johnsonaria*	Geometridae

Appendix D. Table 1 (cont'd).

Common Name	Scientific Name	Family
Juniper geometer [B]	*Patalene olyzonaria puber*	Geometridae
Large lace-border [C]	*Scopula limboundata*	Geometridae
Large looper moth [A]	*Autographa ampla*	Noctuidae
Large maple spanworm moth [A]	*Prochoerodes transversata*	Geometridae
Laurel sphinx [A]	*Sphinx kalmiae*	Sphingidae
Least-marked euchlaena [B]	*Euchlaena irraria*	Geometridae
Little virgin moth [B]	*Grammia virguncula*	Arctiidae
Locust underwing [A]	*Euparthenos nubilis*	Noctuidae
Major sallow [B]	*Feralia major*	Noctuidae
Many-lined wainscot [C]	*Leucania multilinea*	Noctuidae
Master's dart [A]	*Feltia herilis*	Noctuidae
Melanolophia sp. [B]	*Melanolophia sp.*	Geometridae
Milkweed tussock moth [B]	*Euchaetes egle*	Arctiidae
Mottled bomolocha [A]	*Bomolocha palparia*	Noctuidae
Nais tiger moth [A]	*Apantesis nais*	Arctiidae
Nomophila nearctica [B]	*Nomophila nearctica*	Pyralidae
Nondescript dagger moth [A]	*Acronicta spinigera*	Noctuidae
Northern burdock borer moth [C]	*Papaipema arctivorens*	Noctuidae
Oblique-banded leafroller moth [C]	*Choristoneura rosaceana*	Tortricidae
Olive-shaded bird-dropping moth [C]	*Tarachidia candefacta*	Noctuidae
Painted lichen moth [C]	*Hypoprepia fucosa*	Arctiidae
Pale beauty [C]	*Campaea perlata*	Geometridae
Pearly wood-nymph [C]	*Eudryas unio*	Noctuidae
Pepper-and-salt geometer [B]	*Biston betularia cognataria*	Geometridae

Appendix D. Table 1 (cont'd).

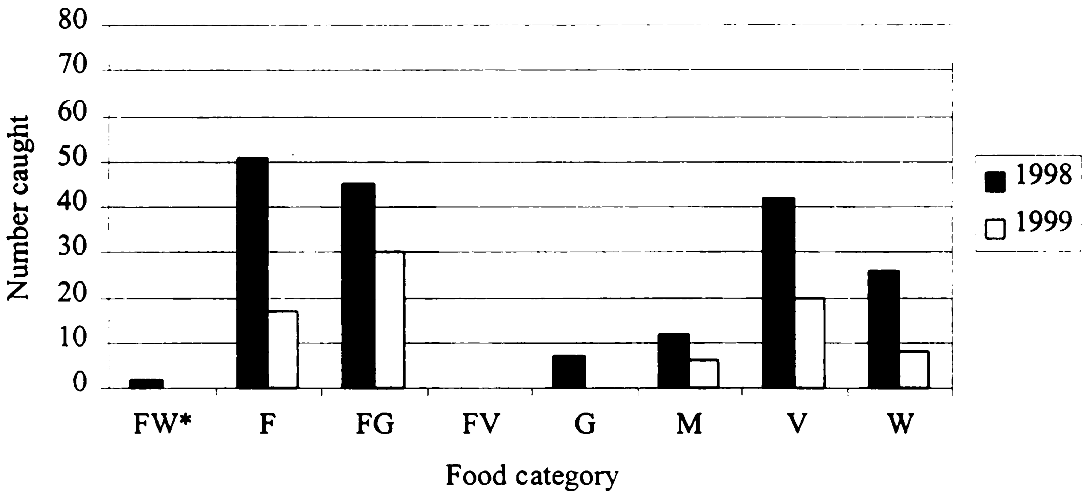
Common Name	Scientific Name	Family
Pickerelweed borer moth [B]	*Bellura densa*	Noctuidae
Pink-legged tiger moth [B]	*Spilosoma latipennis*	Arctiidae
Platynota flavedana [A]	*Platynota flavedana*	Tortricidae
Primrose moth [A]	*Schinia florida*	Noctuidae
Ragweed flower moth [B]	*Schinia rivulosa*	Noctuidae
Red twin-spot [B]	*Xanthorhoe ferrugata*	Geometridae
Red-headed inchworm moth [C]	*Semiothisa bisignata*	Geometridae
Redbanded leafroller moth [C]	*Argyrotaenia velutinana*	Tortricidae
Salt marsh moth [B]	*Estigmene acrea*	Arctiidae
Scirpus wainscot [B]	*Leucania scirpicola*	Noctuidae
Sharp-angled carpet [A]	*Euphyia unangulata*	Geometridae
Signate quaker [B]	*Tricholita signata*	Noctuidae
Slant-lined owlet [B]	*Macrochilo absorptalis*	Noctuidae
Small bird-dropping moth [C]	*Tarachidia erastrioides*	Noctuidae
Small-eyed sphinx [B]	*Paonias myops*	Sphingidae
Soft-lined wave [A]	*Scopula inductata*	Geometridae
Sparganothis fruitworm moth [A]	*Sparganothis sulfureana*	Tortricidae
Sparganothis reticulatana [C]	*Sparganothis reticulatana*	Tortricidae
Speckled cutworm moth [A]	*Lacanobia subjuncta*	Noctuidae
Spiny oak-slug moth [B]	*Euclea delphinii*	Limacodidae
Spiny oakworm moth [B]	*Anisota stigma*	Saturniidae
Spotted fireworm moth [A]	*Choristoneura parallela*	Tortricidae
Straight-lined wave [A]	*Lobocleta plemyraria*	Geometridae
Subgothic dart [A]	*Feltia subgothica*	Noctuidae

Appendix D. Table 1 (cont'd).

Common Name	Scientific Name	Family
Tawny holomelina [C]	*Holomelina opella*	Arctiidae
The nutmeg [B]	*Discestra trifoli*	Noctuidae
Three-lined leafroller moth [B]	*Pandemis limitata*	Tortricidae
Trichotaphe flavocostella [C]	*Trichotaphe flavocostella*	Gelechiidae
Twin-spotted sphinx [C]	*Smerinthus jamaicensis*	Sphingidae
Ultronia underwing [A]	*Catocala ultronia*	Noctuidae
Veiled ear moth [B]	*Amphipoea velata*	Noctuidae
Virgin tiger moth [C]	*Grammia virgo*	Arctiidae
Virginia ctenucha [C]	*Ctenucha virginica*	Arctiidae
Waved sphinx [B]	*Ceratomia undulosa*	Sphingidae
Wavy-lined zanclognatha [B]	*Zanclognatha ochreipennis*	Noctuidae
Wheat head armyworm moth [C]	*Faronta diffusa*	Noctuidae
White slant-line [C]	*Tetracis cachexiata*	Geometridae
White-dotted prominent [B]	*Nadata gibbosa*	Notodontidae
White-marked tussock moth [A]	*Orgyia leucostigma*	Lymantriidae
Wonderful underwing [A]	*Catocala mira*	Noctuidae
Yellow bear moth [C]	*Spilosoma virginica*	Arctiidae
Yellow slant-line [B]	*Tetracis crocallata*	Geometridae
Yellow-headed cutworm moth [A]	*Apamea amputatrix*	Noctuidae

[A] Observed in 1998 only
[B] Observed in 1999 only
[C] Observed in 1998 and 1999

Field Burn/Wheat



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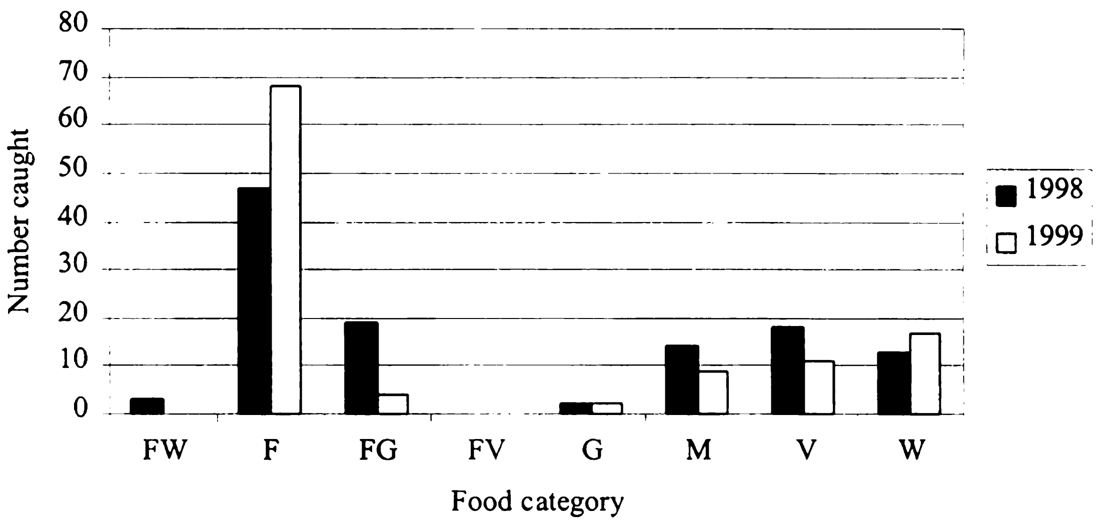
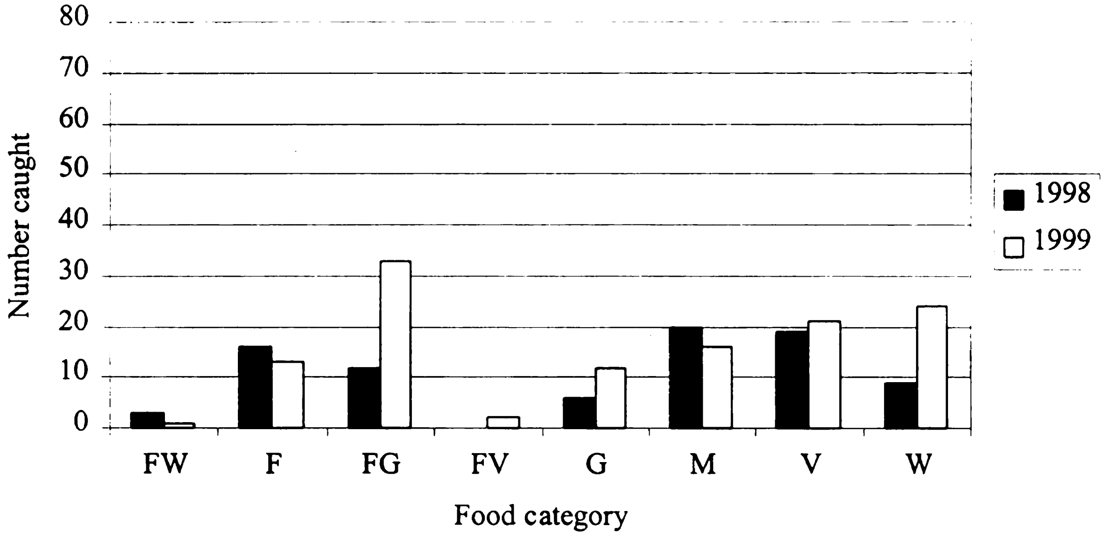


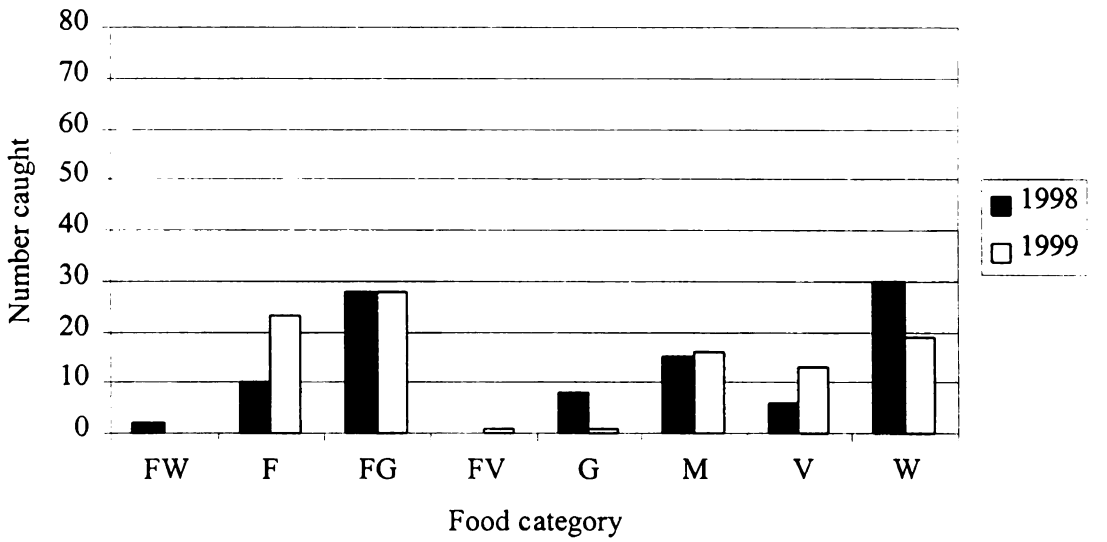
Appendix D. Fig. 3. Graphic representation of number of Lepidoptera captured in each food category on grassland fields in RLWRA, Clinton County, Michigan, in summer 1998 and 1999.

*Abbreviations: FW: forbs and woody vegetation, F: forbs, FG: forbs and grasses, FV: forbs and vines, G: grasses, M: mosses, V: vines, W: woody vegetation.

Field Control



Field Mow/Control



Appendix D. Fig. 3 (cont'd).

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