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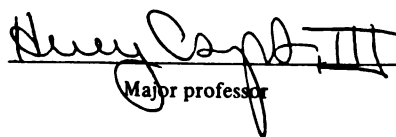
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**WILDLIFE USE OF NATIVE AND
INTRODUCED GRASSLANDS IN MICHIGAN**

By

Christine Hanaburgh

A Thesis

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1995

ABSTRACT

WILDLIFE USE OF NATIVE AND INTRODUCED GRASSLANDS IN MICHIGAN

by

Christine Hanaburgh

Management of wildlife habitats has recently begun to emphasize the use of native plant species. In Michigan, the propagation of introduced grass species has historically been used to achieve many wildlife objectives; however, little is known about the potential benefits of native grasses to wildlife. To determine the value of native grasslands as wildlife habitat in Michigan, wildlife populations and the vegetative characteristics of native grasslands and grasslands dominated by introduced grasses were evaluated.

Relative abundance and diversity of small mammals and invertebrates, and songbird diversity were examined on replicated native grass (*Panicum* spp., *Andropogon scoparius*, *Danthonia spicata*) dominated sites and introduced grass (*Agropyron repens*, *Poa pratensis*) dominated sites in 1993 and 1994 in Allegan County, Michigan. Small mammal populations were also evaluated on native grass dominated coastal plain marshes (wet native sites) in Allegan County. In 1994, planted switchgrass (*Panicum virgatum*) sites in Barry County, Michigan were investigated for small mammal and

invertebrate abundance and diversity.

Plant species composition and structure differed among grassland types, with native sites having the greatest number of unique plant species and more woody vegetation, less live vegetative cover, and drier soils ($P < 0.10$) than introduced sites. Introduced grasslands had the greatest percent ($P < 0.10$) live vegetative cover. Switchgrass sites were characterized by large amounts of dead vegetation, relatively little forb cover, and taller ($P < 0.10$) vegetation than native or introduced grasslands.

A less diverse ($P < 0.10$) songbird community was associated with native grasslands than with introduced sites. Small mammal diversity was greater ($P < 0.10$) on introduced and switchgrass sites than on native sites, while small mammal relative abundance was greatest on wet native sites. Invertebrate abundance was also greater ($P < 0.10$) on introduced than on native grasslands. These results may be attributed to differences in the amounts of herbaceous and woody vegetation, and hiding cover available on each type of grassland, and to the later flowering times observed for grasses dominating native sites.

Although native grasslands may have potential to provide habitat for a diversity of wildlife, results suggest that these grasslands currently may be providing a narrow range of wildlife habitat conditions. It is likely that fire suppression has altered the vegetative structure of these native grasslands and diminished their value to wildlife. Native sites may benefit from periodic prescribed burning to set back succession and increase plant growth, while on introduced, wet native, and switchgrass sites, controlled burning may promote native vegetation while maintaining the structural characteristics necessary for wildlife.

ACKNOWLEDGEMENTS

This project could not have been completed without the support and contributions of many individuals. I would first and foremost like to thank my major advisor, Dr. Rique Campa, for his guidance throughout this project, and for the high standards to which he holds his students. I am also thankful to the other members of my committee, Dr. Scott Winterstein and Dr. Don Beaver, for contributing their time and expertise to this project.

This project was funded by the Michigan Department of Natural Resources, Wildlife Division, and by the Michigan Agricultural Experiment Station. I would like to express appreciation for the information and help in locating study sites given by John Lerg and the staff at the Allegan State Game Area, and Mark Bishop and Bob Humphreys of the Barry State Game Area. Denny Albert of the Michigan Natural Features Inventory was also very helpful during the course of this project. I would like to recognize the field assistance and valuable input of the interns who worked with me, Mike Kurncz, Mark Boerson, Tammy Meier, and Matt Wilsdon. Erin Poston, Rita Bauer, and Robyn Oliver did a wonderful job helping to sort and identify insects.

Finally, I am grateful to my family, particularly my parents and grandparents, for taking pride in my accomplishments and always supporting whatever I have wanted to

do. Most importantly, I owe more than I can say to Jeff, for sharing my interest in my work, helping me out in the field, and for providing me with continual encouragement.

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INTRODUCTION

Native grasslands in Michigan are a unique and diverse habitat type. Historically, native grasslands occurred throughout the southern part of the state, occupying tracts as large as 33,000 ha (Veatch 1928). These areas spanned an ecological continuum from dry sand prairie to wet lakeplain prairie, with distinct plant and wildlife species associated with each type of grassland. Natural disturbance patterns, such as periodic wildfires (Daubenmire 1968), helped perpetuate the unique characteristics of native grasslands, adding another dimension to the ecological profile of these systems.

Today, native grasslands in Michigan have been reduced in size, transformed in both floral and faunal composition, and in many places fragmented into local remnants. The expansion of agriculture has been a primary factor responsible for the loss of some native grasslands and the wildlife abundance and diversity associated with them (Owens and Myres 1973, Farris and Cole 1981). At the same time, the introduction and propagation of European plant species for livestock forage and revegetation (Wilson and Belcher 1989) has altered the vegetative composition of many other grasslands. Because the remaining grasslands comprise only a small percentage of public land, particularly in the Midwest, less attention has been devoted to grassland management than to the management of other habitat types (Ryan 1986). Consequently, conservation of native

grasslands has not been a priority, and many native grasslands have been subjected to management practices that favor or propagate introduced grasses.

Historically, mixtures of introduced grasses, which are considered to be grasses that are not indigenous to Michigan, have been planted because seeds are readily available, germinate better than many native species (Beirne 1995), and have been less expensive than native grass seeds (Kilcher and Looman 1983). Introduced grasses have also been recognized as a valuable source of cover, particularly for some upland game birds (Frank and Woehler 1969), and as a food source for wildlife (Stubbendieck et al. 1986, Church and Pond 1988). However, most research on the benefits of introduced grasses for wildlife has focused on selected wildlife species, rather than on the entire grassland ecosystem.

Recent advances towards ecosystem level management have been accompanied by a greater interest in maintaining the native components of ecosystems and minimizing the propagation of introduced species. As a result, communities dominated by native species are now recognized for their unique habitat qualities and potential to support a diversity of wildlife. Native wildlife have evolved in parallel with native vegetation and, therefore, respond to unique features of native plant communities and the natural disturbance factors that maintain them (Bock et al. 1986). Therefore, maintaining native vegetation should provide habitat conditions for the broadest range of grassland wildlife, compared to habitats dominated by introduced plant species.

Currently, little is known about wildlife use of native grasslands because of the limited use of native grasses, compared with introduced grasses, in managing wildlife

habitat. Wilson and Belcher (1989) examined differences in plant and bird communities of native prairie and introduced Eurasian grass dominated sites in Manitoba. The authors documented that on native mixed-grass sites, dominated by blue grama (*Bouteloua gracilis*), needlegrass (*Stipa spartea*), and little bluestem (*Andropogon scoparius*), plant species richness was nearly double that of the introduced sites, which were dominated by Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*). While the native and introduced sites each had the same number of bird species, bird density was greater on native than on introduced sites. Wilson and Belcher suggested that the lower plant species diversity on Eurasian grasslands resulted in a habitat with nearly uniform height and density which failed to attract birds requiring a more heterogeneous habitat.

Bock et al. (1986) compared plantings of African lovegrasses (*Eragrostis lehmanniana* and *E. curvula*) with native grass dominated sites in Arizona. They found that grasshoppers, the dominant insect group of the area, were 44% less frequent on African lovegrass sites than on native grass sites, and bird species richness was greater on the native than on the introduced sites. Results of their work led them to conclude that greater wildlife diversity is associated with native grasslands because North America's native wildlife species coevolved with the native vegetation and may be less adapted to the habitat attributes provided by nonnative species.

Another potential difference between native and introduced grasslands is the quality and amount of winter cover they provide to wildlife. A preliminary progress report conducted for agricultural lands enrolled 1 and 2 years in the Conservation Reserve Program indicated that fields planted with native grasses maintained slightly better winter

cover for pheasants than those planted with introduced grasses (Hays et al. 1989). In particular, switchgrass (*Panicum virgatum*), a warm season native grass, has been suggested as a good source of winter cover because it retains its leaves throughout the winter and is less susceptible to flattening by snow (Frank and Woehler 1969).

The conversion of private grasslands to agricultural crops has isolated publicly owned grasslands as a habitat for many wildlife species. This condition has amplified the need for effective management to preserve native grasslands and the unique habitat conditions they may provide. However, management approaches for perpetuating native grasslands for wildlife in a landscape with many introduced species are poorly defined. An investigation of wildlife use of native and introduced grasslands may provide information on their ecological values for wildlife and help managers plan management practices that may be needed to maintain these ecosystems in Michigan.

OBJECTIVES

The primary objective of this study was to compare songbird, small mammal, and invertebrate use of grasslands dominated by native grasses, grasslands dominated by introduced grasses, and monocultural stands of native grasses. Additional objectives were to compare the vegetative structure and composition of each type of grassland, and to relate wildlife use to specific compositional and structural characteristics of grasslands. Results of this research will be used to provide recommendations for enhancing the diversity of grasslands, and to direct further research on grassland communities in Michigan.

STUDY AREA

In 1993, 3 sites dominated by native grass species, including panic grasses (*Panicum* spp.), little bluestem (*Andropogon scoparius*), and poverty oatgrass (*Danthonia spicata*), 4 sites dominated by the introduced grasses quackgrass (*Agropyron repens*) and Kentucky bluegrass (*Poa pratensis*), and 3 coastal plain marshes were delineated within the Allegan State Game Area (ASGA) in Allegan County, Michigan (Table 1). Coastal plain marshes, hereafter referred to as "wet native sites", are seasonally flooded areas which typically dry out and become dominated by native grasses such as prairie cordgrass (*Spartina pectinata*) and bluejoint (*Calamagrostis canadensis*) during the summer. In 1994, 3 sites of planted switchgrass (*Panicum virgatum*) were also evaluated to quantify wildlife use of relatively pure stands of native grasses that are often maintained for wildlife on state and private lands. Switchgrass sites were located in the Barry State Game Area (BSGA) in Barry County, Michigan (Table 1).

Native, introduced, and wet native sites had not been burned or otherwise actively managed for at least 30 years prior to initiation of this study (J. Garpow, MDNR, pers. commun.). One native site, located in Section 21, T2N, R14W, was burned in May, 1994, so an additional native site, located in the same section and township, and with a similar management history as the other native sites, was sampled in place of the burned

Table 1. Location and sizes of study sites in Allegan and Barry Counties, Michigan, 1993 and 1994.

Type of site	n	Size range (ha)	County	Township/Rang	Section(s)
Native	3	1.0-2.3	Allegan	T2N, R14W	21
				T3N, R14W	22,27
Introduced	4	1.1-2.9	Allegan	T3N, R14W	17,18,19
Wet Native	3	1.0-1.8	Allegan	T3N, R13W	12
				T3N, R14W	13
Switchgrass	3	1.3-2.2	Barry	T3N, R9W	31
				T3N, R10W	14,16

site in 1994. Switchgrass sites were planted 3, 4, and 7 years ago (B. Humphreys, MDNR, pers. commun.). Study sites ranged in size from 1.0 to 2.9 ha.

The ASGA is 20,000 ha in size and is located in southwestern Michigan (Fig. 1). The game area lies about 17 km inland from Lake Michigan, and the majority of the area is drained by the Kalamazoo River watershed.

Allegan County's proximity to Lake Michigan is the chief determinant of the climate in the region. Temperatures in Allegan County average -3.5 C in winter and 20.9 C in summer. Average annual rainfall is 91 cm, 56% of which occurs from April through September, and average snowfall is 202 cm (Knapp 1987).

Soils in the study area are primarily of the Oakville association, which are nearly level to steep, sandy, and well drained soils. These occur on outwash plains, lake plains, dunes, moraines, and beach ridges. Soils of the Morocco-Newton-Oakville association are also found in the region. These are nearly level, sandy soils, ranging from very

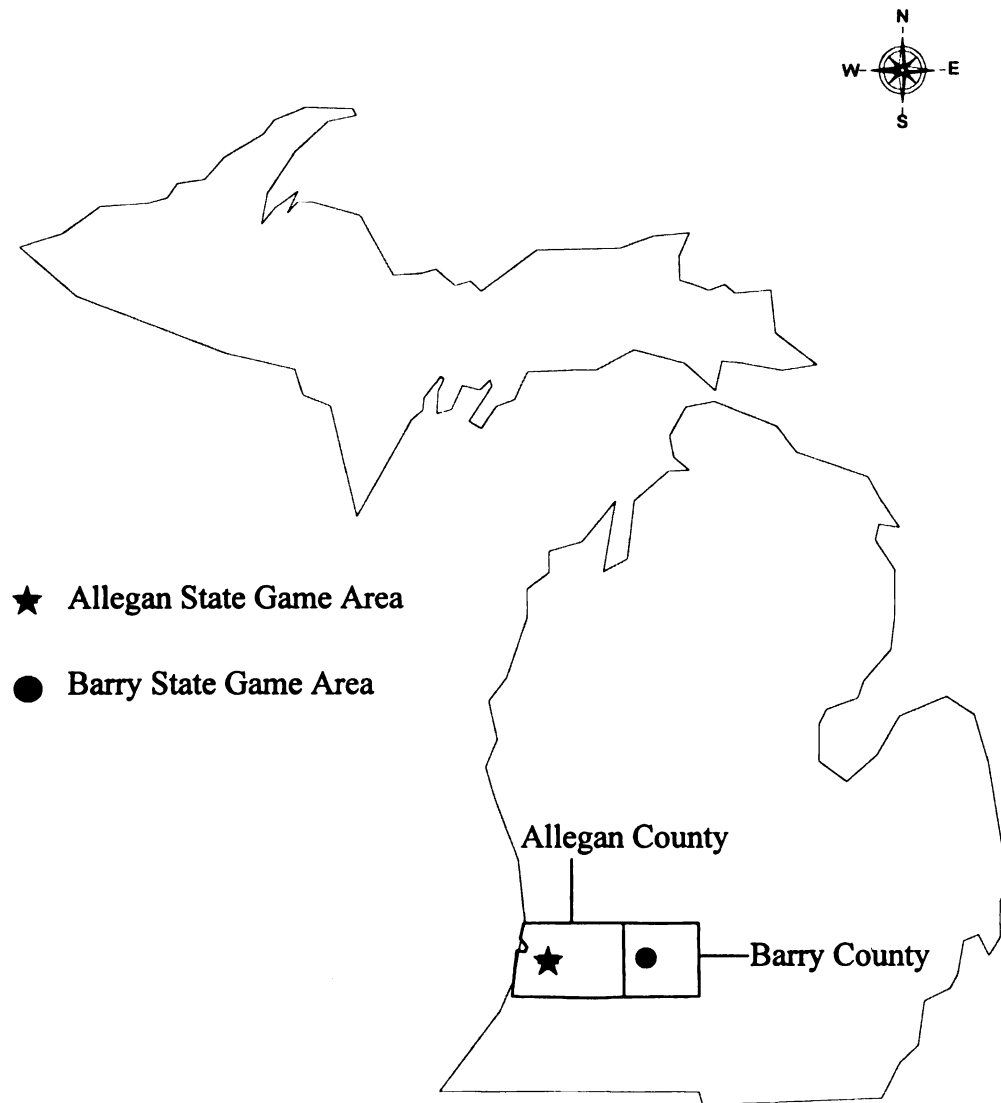


Figure 1. Location of the Allegan State Game Area in Allegan County and the Barry State Game Area in Barry County, Michigan.

poorly drained to well drained, and are found on outwash plains, lake plains, and beach ridges. Soils throughout the area have very low fertility (Knapp 1987).

Oak (*Quercus* spp.)/pine (*Pinus* spp.) forest is the dominant plant community in the ASGA. Other vegetative types include oak forest, southern floodplain forest, southern swamp, emergent marsh, and central hardwood forest. Prior to European settlement, native grasslands were present in the form of oak/pine barrens and dry sand prairie on 20% of what is now the ASGA. Today, oak/pine barrens account for 7% of the land in the ASGA, and only trace amounts of dry sand prairie remain (Mich. Dept. Nat. Resour. 1993). Small regions of coastal plain marsh also exist in the northeast section of the game area.

Barry County lies east of Allegan County (Fig. 1). The climate is similar to that of Allegan County, with average temperatures ranging from -4.1 C in winter to 20.8 C in summer. Annual rainfall in Barry County averages 79 cm, of which 60% falls from April through September. Average annual snowfall is 132 cm (Thoen 1990).

Coloma-Boyer and Coloma-Boyer-Spinks are the most common soil associations in the BSGA. The soils of the Coloma-Boyer association are nearly level to gently sloping, excessively drained and well drained, sandy, and are found on outwash plains. Coloma-Boyer-Spinks soils are similar, but are classified as moderately sloping to steep, and occur on outwash plains and moraines (Thoen 1990).

METHODS

A scientific collecting permit and an endangered species permit were obtained through the Michigan Department of Natural Resources, Wildlife Division, prior to all vegetative, small mammal, and invertebrate sampling. In addition, all small mammal trapping and handling procedures were previously reviewed and approved by Michigan State University's All University Committee on Animal Use and Care (AUF # 09/92-224-01).

Vegetative Structure and Composition

Vegetative sampling was conducted in May and July, 1993 and 1994, on native and introduced sites, and switchgrass sites were sampled in May and July 1994. Wet native sites remained flooded during the May and July vegetative sampling periods, except for 1 site that dried out before the others and was sampled in May and July, 1994. To evaluate vegetative characteristics prior to spring growth, native and introduced sites were also sampled between March and April of 1994.

A 50 x 50 cm sampling frame (Daubenmire 1959) was used to measure the percent canopy cover of grasses, forbs, litter, and woody vegetation, live and dead vegetation, and percent bare ground. Species composition was assessed within the sampling frames, and absolute species frequencies are reported as the percent of plots

sampled in which the species was present. Litter depth and the height of live and dead vegetation were also recorded on each site. Vertical cover was measured using the line intercept method (Canfield 1941). Percent vertical cover was recorded within strata of 0-30 cm, 31 cm-2 m, and >2 m. These strata were used because of their relationship to the cover requirements of small mammals and ground nesting birds, and to reflect differences in structural characteristics observed on the grasslands. The density of woody stems in each stratum was recorded within a 3 m x 20 m belt transect. All sampling occurred at randomly selected points located at least 10 m from the edges of study sites.

Horizontal cover was quantified to assess relative differences in hiding cover among grassland communities. Measurements were made with a 30 cm x 2 m profile board (Nudds 1977) and were taken in May, June, and July of both years, and in March and April, 1994. At each point, the board was placed upright in the vegetation and read from a predetermined direction at a distance of 15 m. Percent cover within strata of 0-30 cm, 31 cm-1 m, and 1-2 m was visually estimated and classified within categories of 0%, 1-25%, 26-50%, 51-75%, and 76-100% cover.

Soil Moisture

Soil moisture was evaluated because it may directly influence vegetative characteristics of a site (Stubbendieck 1987), and ultimately wildlife populations. Soil moisture was measured monthly from May-July using a soil moisture meter (Forestry Suppliers, Inc., Jackson, Miss.), read on a scale of 0-10, with 0 indicating dry and 10 completely saturated. Measurements were taken between 1000 (EST) and 1300 (EST), and sampling was not done when it had rained within the last 24 hours.

Avian Species Composition and Diversity

Bird populations were censused on native and introduced sites from May through July of both years of the study. Thirty minute point counts, modified from the method described by Whitcomb et al. (1981), were used, with 1 census point located at the center of each study site. The 30 minute time period was established by conducting several preliminary counts, lasting from 6 to 40 minutes, during which the number of species observed was plotted against the amount of time spent censusing. From the preliminary counts, 30 minutes was determined to be the minimum length of time in which a representative number of species could be observed, and beyond which few new species were observed.

At each census station, species, gender, distance from the field edge, and the radial distance at which birds were detected were recorded. Observers also noted the behavioral activity, such as singing, feeding, or moving, in which a bird was engaged when first observed during the census period. Censusing began at sunrise and was completed within a maximum of 3 hours (Robbins 1981a). Data were not collected on exceptionally windy, rainy, or foggy days (Robbins 1981b). Observers and order in which sites were censused were rotated among sites to minimize observer bias. Each site was monitored a minimum of 4 times in May, 5 times in June, and 4 times in July.

Bird censusing was also conducted in January and February, 1994 to evaluate avian use of sites in winter. The same methods used during summer were also used in winter, with the exception that censuses were conducted between 1000 (EST) and 1500 (EST). Census data were not collected while it was snowing. Each site was censused 4

times throughout the winter census period.

In 1994, all sites were searched monthly from May-July for active bird nests to quantify avian breeding activities on study sites. Nests were located by carefully walking back and forth across grasslands, while looking at vegetation, until the entire area had been covered. When a bird was flushed, or a nest was otherwise detected, the contents of the nest were recorded, the area around the nest was flagged, and nests were revisited every 3-4 days until the birds fledged or the nest became inactive. Nests located during other field sampling activities were monitored in the same way as nests located during nest searching.

Small Mammal Abundance and Diversity

Relative abundance of small mammals on native, introduced, and switchgrass sites was quantified by live-trapping (large Sherman live traps, H. B. Sherman Co., Tallahassee, Fla.) for 5 consecutive nights each month from May-September. Wet native sites were only trapped in August and September, with the exception of 1 site that was dry enough to trap from May-September of 1994.

Traps were baited with a mixture of whole oats, lard, and anise extract. Traps were set 15 m apart in a 5 x 6 grid centered on each site, with 2 traps per station. One switchgrass site was particularly long and narrow, making it necessary to modify the trapping grid to fit the field. Two grids were placed on the field, each with 3 trap lines on the field and 2 lines in the vegetation adjacent to the field, to determine if small mammal populations of the grassland were distinctly different from the adjacent habitat, since the site was so narrow.

In 1994, assessment trap lines were established on native, introduced, and wet native sites to examine small mammal use outside of the grid and in areas adjacent to each site. Assessment lines were not used on switchgrass sites because of their long and narrow dimensions. Assessment lines extended from the midpoint of each of the 4 edges of the grid to a minimum of 45 m beyond the edge of the field, unless a road or a body of water was encountered. Traps were spaced 15 m apart along each assessment line, with 1 trap located at each station. All traps were checked each morning, and captured animals were ear-tagged and released after recording species, gender, tag number, and location of capture.

Invertebrate Abundance and Diversity

Invertebrates were collected monthly from May-August, 1993 and from May-July, 1994 using the sweepnet technique (Ruesink and Haynes 1973) to determine diversity and relative abundance associated with each grassland type. Between 10 and 15 randomly located samples, each consisting of 10 sweeps, were collected from the herbaceous layer of each site. Collected insects were dried at 60 C for 48 hours, identified to Order, and weighed.

Herptile Diversity

Herptile species were recorded as observed while conducting all other sampling.

Data Analysis

The Shannon-Weaver diversity index (Shannon and Weaver 1949) was used to calculate vegetative and small mammal species diversities, and diversity of invertebrate taxa within each monthly sampling period. Bird species diversity for each site was

determined by calculating the Shannon-Weaver index for each daily observation period, and then averaging the Shannon-Weaver values across each month to produce a mean diversity index for May, June, and July for each site. The mean diversity indices calculated for each site within a month were used to compute standard errors for each grassland type within each monthly sampling period.

Comparisons of all vegetative characteristics, soil moisture, and avian, mammalian, invertebrate, and vegetative diversities within months between native and introduced sites in 1993 were made using the Mann-Whitney U test (Siegel 1956). The Kruskal-Wallis one-way analysis of variance (Siegel 1956) was used to compare among native, introduced, wet native, and switchgrass sites, within months, in 1994. Significant differences ($P < 0.10$) detected with the Kruskal-Wallis test were further analyzed with the Kruskal-Wallis multiple comparison statistic (Siegel 1988) to determine which pairs of site types were different ($P < 0.10$). The Mann-Whitney U test was also applied to 1994 data for native and introduced sites, within months, to maintain consistency with 1993 comparisons between native and introduced sites.

Comparisons of vegetative characteristics and plant species diversities between May and July within each site type were examined using a paired t-test (Ott 1988). Differences in avian, mammalian, and invertebrate diversity among months on each type of grassland were made with the Kruskal-Wallis one-way analysis of variance (Siegel 1956).

Principal components analysis (PCA) (Morrison 1990) was used to reduce the large number of vegetative variables to weighted sums of a few variables that could

describe the variation among grasslands. Differences detected at $P < 0.10$ are reported as significant.

RESULTS

Plant Species Composition and Diversity

Absolute frequencies of plant species on each site indicate that grasses of the genus *Panicum* (Panic grass spp.) were the dominant grasses on native sites during the May sampling period in 1993 and 1994 (Tables 2 and 3). Panic grasses remained the most frequently observed grasses in July (Tables 4 and 5), although little bluestem, poverty oatgrass, and purple needlegrass (*Aristida purpurascens*) also occurred at relatively high frequencies. On introduced sites, quackgrass was the dominant grass in May and July (Tables 2-5). Kentucky bluegrass also occurred at a high frequency in May of both years, compared to other grasses on introduced sites, but tended to become less prevalent in July. Little bluestem, a native grass, increased in frequency on introduced sites in July. Switchgrass was the dominant grass on planted switchgrass fields for all sampling periods (Tables 3 and 5). Although high water levels restricted vegetation sampling on wet native sites, prairie cordgrass and bluejoint appeared visually to be the dominant grasses on these sites.

A total of 93 herbaceous species and 7 woody species were identified on native, introduced, and switchgrass sites (Appendix A). Species reported in Appendix A for each type of site include those which were recorded during vegetation sampling and

Table 2. Mean absolute frequencies (standard errors) of vegetative species sampled on native and introduced grasslands in Allegan County, Michigan, May, 1993.

Species	Species frequency of grassland types	
	Native	Introduced
Big bluestem	8.3 (8.3)	0.0 (0.0)
Little bluestem	13.9 (7.3)	5.5 (3.4)
Panic grass spp.	51.5 (1.5)	12.4 (6.3)
Poverty oatgrass	2.8 (2.8)	10.9 (8.5)
Kentucky bluegrass	11.6 (5.8)	29.3 (13.3)
Quackgrass	0.0 (0.0)	66.9 (13.0)
Bastard toadflax	16.7 (16.7)	0.0 (0.0)
Butterflyweed	2.8 (2.8)	0.0 (0.0)
Corn speedwell	0.0 (0.0)	10.1 (4.4)
Dwarf dandelion	11.4 (2.7)	0.0 (0.0)
Field hawkweed	33.8 (9.2)	48.1 (7.4)
Field peppergrass	0.0 (0.0)	1.8 (1.8)
Greenbrier	2.8 (2.8)	0.0 (0.0)
Hoary alyssum	0.0 (0.0)	17.2 (6.4)
Horsemint	3.0 (3.0)	0.0 (0.0)
Lance-leaved coreopsis	0.0 (0.0)	1.9 (1.9)
Lichen	25.8 (0.8)	1.8 (1.8)
Long-headed thimbleweed	2.8 (2.8)	0.0 (0.0)
Moss	14.1 (2.5)	21.0 (2.0)
Northern dewberry	34.6 (17.7)	45.8 (13.6)
Pasture rose	0.0 (0.0)	5.9 (3.7)
Pennsylvania sedge	48.0 (14.1)	16.2 (7.9)
Rough blazing star	5.8 (2.9)	0.0 (0.0)
Rough-fruited cinquefoil	0.0 (0.0)	6.6 (2.4)
Sheep sorrel	37.6 (18.8)	46.3 (11.1)
Smooth Solomon's seal	0.0 (0.0)	1.9 (1.9)
Spotted knapweed	3.0 (3.0)	58.5 (10.7)
Tall Wormwood	2.8 (2.8)	0.0 (0.0)
Western ragweed	0.0 (0.0)	1.4 (1.4)
Wild lupine	2.8 (2.8)	2.1 (2.1)
Wild strawberry	3.0 (3.0)	2.8 (2.8)
Yarrow	0.0 (0.0)	1.9 (1.9)
Black cherry	0.0 (0.0)	3.5 (2.1)
Red oak	2.8 (2.8)	0.0 (0.0)
White oak	3.0 (3.0)	0.0 (0.0)

Table 3. Mean absolute frequencies (standard errors) of vegetative species sampled on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, May, 1994.

Species	Species frequency of grassland types		
	Native	Introduced	Switchgrass
Big bluestem	0.0 (0.0)	2.3 (1.3)	0.0 (0.0)
Junegrass	9.5 (9.5)	0.0 (0.0)	0.0 (0.0)
Little bluestem	36.5 (24.6)	13.7 (12.2)	0.0 (0.0)
Panic grass spp. ^a	50.8 (12.4)	7.0 (2.3)	1.6 (1.6)
Commons panic grass	27.0 (7.9)	2.4 (2.4)	0.0 (0.0)
Few-flowered panic grass	3.2 (3.2)	3.5 (2.3)	0.0 (0.0)
Panicum capillare	1.6 (1.6)	0.0 (0.0)	1.6 (1.6)
Starved panic grass	28.6 (14.5)	1.1 (1.1)	0.0 (0.0)
Poverty oatgrass	34.9 (13.0)	4.5 (4.5)	0.0 (0.0)
Switchgrass	0.0 (0.0)	0.0 (0.0)	81.0 (9.9)
Canada bluegrass	14.3 (8.2)	10.3 (6.0)	0.0 (0.0)
Downy chess	0.0 (0.0)	0.0 (0.0)	1.6 (1.6)
Kentucky bluegrass	9.5 (5.5)	33.7 (12.8)	0.0 (0.0)
Quackgrass	6.3 (6.3)	65.4 (14.5)	30.2 (15.1)
Rye	0.0 (0.0)	0.0 (0.0)	9.5 (9.5)
Bastard toadflax	3.2 (3.2)	2.4 (2.4)	0.0 (0.0)
Blue toadflax	3.2 (1.6)	0.0 (0.0)	0.0 (0.0)
Cleavers	0.0 (0.0)	1.1 (1.1)	0.0 (0.0)
Common cinquefoil	0.0 (0.0)	0.0 (0.0)	1.6 (1.6)
Common mullein	0.0 (0.0)	1.2 (1.2)	1.6 (1.6)
Common St. Johnswort	0.0 (0.0)	2.3 (2.3)	4.8 (2.7)
Corn speedwell	0.0 (0.0)	11.6 (4.7)	15.9 (13.6)
Cylindric blazing star	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Dwarf dandelion	9.5 (7.3)	0.0 (0.0)	0.0 (0.0)
Field hawkweed	54.0 (13.0)	42.6 (12.0)	0.0 (0.0)
Field pansy	0.0 (0.0)	0.0 (0.0)	14.3 (12.0)
Field peppergrass	0.0 (0.0)	4.7 (1.9)	0.0 (0.0)
Flowering spurge	15.9 (11.4)	7.0 (4.0)	0.0 (0.0)
Frostweed	0.0 (0.0)	3.5 (2.3)	0.0 (0.0)
Goat's rue	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Hairy bushclover	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Hairy hawkweed	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Hairy vetch	1.6 (1.6)	1.2 (1.2)	1.6 (1.6)
Hoary alyssum	0.0 (0.0)	15.1 (3.4)	15.9 (7.9)
Hoary puccoon	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Horsemint	4.8 (2.7)	10.6 (4.6)	4.8 (4.8)
Horse nettle	4.8 (2.7)	0.0 (0.0)	3.2 (1.6)

Table 3 (Cont).

Species	Species frequency of grassland types		
	Native	Introduced	Switchgrass
Horseweed	0.0 (0.0)	0.0 (0.0)	55.6 (17.5)
Hyssop	0.0 (0.0)	0.0 (0.0)	6.3 (6.3)
Lance-leaved coreopsis	6.3 (3.2)	12.8 (7.4)	0.0 (0.0)
Lichen	41.3 (23.4)	23.2 (3.6)	0.0 (0.0)
Long-headed thimbleweed	0.0 (0.0)	1.1 (1.1)	0.0 (0.0)
Moss	71.4 (13.7)	4.5 (3.2)	28.6 (17.2)
Northern dewberry	61.9 (28.6)	53.5 (5.9)	19.0 (9.9)
Ohio spiderwort	0.0 (0.0)	9.4 (6.5)	0.0 (0.0)
Orange hawkweed	4.8 (2.7)	0.0 (0.0)	0.0 (0.0)
Pasture rose	3.2 (1.6)	6.9 (5.4)	0.0 (0.0)
Pennsylvania sedge	34.9 (11.4)	21.0 (12.9)	0.0 (0.0)
Prickly pear	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Racemed milkwort	3.2 (3.2)	0.0 (0.0)	0.0 (0.0)
Rough blazing star	3.2 (3.2)	0.0 (0.0)	0.0 (0.0)
Rough-fruited cinquefoil	1.6 (1.6)	6.9 (2.2)	1.6 (1.6)
Sheep sorrel	73.0 (9.7)	37.1 (7.1)	14.3 (0.0)
Slender knotweed	0.0 (0.0)	14.0 (5.9)	0.0 (0.0)
Smooth tick-trefoil	4.8 (2.7)	0.0 (0.0)	0.0 (0.0)
Spotted knapweed	3.2 (3.2)	80.2 (2.2)	9.5 (9.5)
Sweet everlasting	0.0 (0.0)	1.1 (1.1)	9.5 (2.7)
Tall wormwood	3.2 (1.6)	2.4 (2.4)	0.0 (0.0)
Thyme-leaved sandwort	0.0 (0.0)	1.1 (1.1)	15.9 (9.7)
Tower mustard	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Venus' looking glass	0.0 (0.0)	0.0 (0.0)	28.6 (19.2)
Wandlike bushclover	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Western ragweed	0.0 (0.0)	8.2 (5.6)	0.0 (0.0)
Wild bergamot	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Wild lettuce	0.0 (0.0)	0.0 (0.0)	12.7 (6.9)
Wild lupine	14.3 (14.3)	3.4 (3.4)	0.0 (0.0)
Winged sumac	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Yarrow	0.0 (0.0)	0.0 (0.0)	6.3 (6.3)
Yellow wood sorrel	0.0 (0.0)	0.0 (0.0)	7.9 (7.9)
Black cherry	1.6 (1.6)	4.5 (3.2)	0.0 (0.0)
Late low blueberry	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Red Oak	3.2 (3.2)	1.1 (1.1)	0.0 (0.0)
Sassafras	1.6 (1.6)	1.2 (1.2)	0.0 (0.0)
White oak	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)

*excluding switchgrass

Table 4. Mean absolute frequencies (standard errors) of vegetative species sampled on native and introduced grasslands in Allegan County, Michigan, July, 1993.

Species	Species frequency of grassland types	
	Native	Introduced
Big bluestem	11.1 (11.1)	7.1 (4.6)
Black oatgrass	1.6 (1.6)	0.0 (0.0)
Junegrass	4.8 (4.8)	0.0 (0.0)
Little bluestem	34.9 (28.1)	14.3 (11.3)
Panic grass spp.	58.7 (11.4)	9.3 (3.7)
Poverty oatgrass	44.4 (14.1)	8.3 (4.9)
Ticklegrass	12.7 (8.4)	0.0 (0.0)
Canada bluegrass	6.3 (4.2)	2.3 (1.3)
Kentucky bluegrass	0.0 (0.0)	5.9 (1.2)
Quackgrass	3.2 (3.2)	58.8 (11.9)
Smooth brome	0.0 (0.0)	3.5 (1.2)
Unidentified grass	1.6 (1.6)	3.5 (1.2)
Bouncing bet	3.2 (3.2)	0.0 (0.0)
Bracken Fern	1.6 (1.6)	0.0 (0.0)
Butterflyweed	0.0 (0.0)	1.2 (1.2)
Clammy ground cherry	1.6 (1.6)	0.0 (0.0)
Common St. Johnswort	0.0 (0.0)	6.0 (4.5)
Dwarf dandelion	1.6 (1.6)	0.0 (0.0)
Field hawkweed	38.1 (17.2)	36.3 (7.7)
Flowering spurge	12.7 (12.7)	15.5 (6.0)
Frostweed	3.2 (3.2)	0.0 (0.0)
Gray goldenrod	4.8 (4.8)	0.0 (0.0)
Hairy bedstraw	1.6 (1.6)	0.0 (0.0)
Hairy bushclover	3.2 (3.2)	0.0 (0.0)
Hairy hawkweed	1.6 (1.6)	0.0 (0.0)
Hoary alyssum	0.0 (0.0)	24.8 (14.2)
Horse nettle	1.6 (1.6)	0.0 (0.0)
Horsemint	0.0 (0.0)	7.1 (4.1)
Lance-leaved coreopsis	3.2 (1.6)	13.1 (4.5)
Lichen	36.5 (13.6)	0.0 (0.0)
Moss	44.4 (22.1)	12.8 (3.8)
Northern dewberry	60.3 (25.4)	66.0 (8.3)
Ohio spiderwort	0.0 (0.0)	3.5 (2.3)
Orange hawkweed	1.6 (1.6)	0.0 (0.0)
Pasture rose	14.3 (7.3)	3.6 (3.6)
Pennsylvania sedge	60.3 (17.9)	26.1 (14.1)

Table 4 (Cont).

Species	Species frequency of grassland types	
	Native	Introduced
Racemed milkwort	6.3 (6.3)	0.0 (0.0)
Rough blazing star	4.8 (2.7)	0.0 (0.0)
Rough-fruited cinquefoil	1.6 (1.6)	8.2 (3.5)
Sheep sorrel	31.7 (15.9)	17.6 (7.0)
Slender knotweed	0.0 (0.0)	15.4 (5.0)
Smooth tick trefoil	6.3 (3.2)	0.0 (0.0)
Spotted knapweed	4.8 (4.8)	78.8 (7.4)
Tall wormwood	0.0 (0.0)	3.6 (2.3)
Western ragweed	0.0 (0.0)	15.2 (8.8)
Whorled milkweed	1.6 (1.6)	0.0 (0.0)
Wild peppergrass	0.0 (0.0)	1.2 (1.2)
Winged sumac	12.7 (10.4)	1.2 (1.2)
Yarrow	0.0 (0.0)	1.2 (1.2)
Yellow goatsbeard	1.6 (1.6)	0.0 (0.0)
Black cherry	1.6 (1.6)	1.2 (1.2)
Red oak	3.2 (1.6)	0.0 (0.0)
Sassafras	3.2 (3.2)	6.0 (2.3)
White oak	1.6 (1.6)	1.2 (1.2)

Table 5. Mean absolute frequencies (standard errors) of vegetative species sampled on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, July, 1994.

Species	Species frequency of grassland types		
	Native	Introduced	Switchgrass
Big bluestem	1.6 (1.6)	3.6 (2.3)	0.0 (0.0)
Junegrass	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Little bluestem	36.5 (31.9)	28.6 (16.5)	0.0 (0.0)
Panic grass spp. ^a	68.3 (10.4)	16.7 (4.6)	6.4 (1.5)
Commons panic grass	49.2 (3.2)	10.7 (6.3)	0.0 (0.0)
Few-flowered panic grass	11.1 (11.1)	2.4 (2.4)	0.0 (0.0)
Panicum capillare	3.2 (3.2)	2.4 (1.4)	0.0 (0.0)
Starved panic grass	30.2 (11.1)	3.6 (2.3)	0.0 (0.0)
Unidentified panic grass	9.5 (7.3)	0.0 (0.0)	6.4 (1.5)
Poverty oatgrass	31.7 (14.1)	7.1 (3.1)	0.0 (0.0)
Purple needlegrass	38.1 (12.6)	0.0 (0.0)	0.0 (0.0)
Switchgrass	0.0 (0.0)	0.0 (0.0)	93.6 (4.2)
Ticklegrass	3.2 (3.2)	0.0 (0.0)	1.7 (1.7)
Canada bluegrass	6.3 (3.2)	7.1 (7.1)	0.0 (0.0)
Kentucky bluegrass	7.9 (4.2)	21.4 (10.6)	0.0 (0.0)
Quackgrass	0.0 (0.0)	50.0 (14.4)	34.0 (9.9)
Smooth brome	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Bastard toadflax	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Black-eyed Susan	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Bracken fern	3.2 (3.2)	6.0 (6.0)	0.0 (0.0)
Bull thistle	0.0 (0.0)	0.0 (0.0)	1.6 (1.6)
Butterflyweed	3.2 (3.2)	0.0 (0.0)	0.0 (0.0)
Clammy ground cherry	1.6 (1.6)	1.2 (1.2)	0.0 (0.0)
Common St. Johnswort	1.6 (1.6)	0.0 (0.0)	12.8 (7.9)
Cow vetch	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Cylindric blazing star	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Deptford pink	0.0 (0.0)	0.0 (0.0)	1.7 (1.7)
Dwarf dandelion	4.8 (4.8)	0.0 (0.0)	0.0 (0.0)
Field hawkweed	39.7 (12.4)	36.9 (14.5)	7.9 (4.2)
Field pansy	0.0 (0.0)	2.4 (1.4)	11.7 (11.7)
Flowering spurge	20.6 (16.1)	25.0 (9.8)	0.0 (0.0)
Frostweed	7.9 (5.7)	0.0 (0.0)	0.0 (0.0)
Goldenrod spp.	3.2 (3.2)	0.0 (0.0)	0.0 (0.0)
Hairy bushclover	9.5 (2.7)	0.0 (0.0)	0.0 (0.0)
Hairy hawkweed	7.9 (7.9)	0.0 (0.0)	0.0 (0.0)
Hairy vetch	0.0 (0.0)	0.0 (0.0)	1.7 (1.7)

Table 5 (Cont).

Species	Species frequency of grassland types		
	Native	Introduced	Switchgrass
Hoary alyssum	0.0 (0.0)	21.4 (6.3)	12.9 (7.0)
Horsemint	6.3 (6.3)	17.9 (7.1)	6.7 (6.7)
Horse nettle	0.0 (0.0)	1.2 (1.2)	22.7 (11.6)
Horseweed	0.0 (0.0)	0.0 (0.0)	61.5 (6.9)
Hyssop	0.0 (0.0)	0.0 (0.0)	13.3 (13.3)
Lance-leaved coreopsis	4.8 (2.7)	20.2 (10.0)	0.0 (0.0)
Lichen	79.4 (4.2)	19.0 (6.1)	0.0 (0.0)
Long-bearded hawkweed	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Milkweed	1.6 (1.6)	0.0 (0.0)	6.4 (1.5)
Moss	85.7 (4.8)	15.5 (7.9)	23.8 (12.0)
Northern dewberry	74.6 (20.8)	57.1 (2.7)	30.2 (23.4)
Ohio spiderwort	0.0 (0.0)	3.6 (2.3)	0.0 (0.0)
Pasture rose	0.0 (0.0)	9.5 (5.1)	0.0 (0.0)
Pennsylvania sedge	30.2 (11.1)	17.9 (9.0)	0.0 (0.0)
Prickly pear	3.2 (3.2)	0.0 (0.0)	0.0 (0.0)
Queen Anne's lace	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Racemed milkwort	7.9 (4.2)	0.0 (0.0)	0.0 (0.0)
Round-headed bush clover	1.6 (1.6)	4.8 (3.4)	0.0 (0.0)
Rough blazing star	6.3 (4.2)	0.0 (0.0)	0.0 (0.0)
Rough-fruited cinquefoil	0.0 (0.0)	7.1 (2.4)	1.7 (1.7)
Sheep sorrel	68.3 (16.8)	33.3 (9.7)	25.8 (9.6)
Slender knotweed	0.0 (0.0)	17.9 (9.8)	0.0 (0.0)
Smooth tick-trefoil	4.8 (4.8)	0.0 (0.0)	0.0 (0.0)
Spotted knapweed	3.2 (3.2)	81.0 (3.9)	15.9 (13.6)
Spreading dogbane	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Sweet everlasting	1.6 (1.6)	1.2 (1.2)	11.1 (5.7)
Tall wormwood	4.8 (2.7)	4.8 (3.4)	0.0 (0.0)
Tower mustard	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Venus' looking glass	0.0 (0.0)	0.0 (0.0)	6.4 (1.5)
Western ragweed	0.0 (0.0)	17.9 (12.4)	0.0 (0.0)
Wild bergamot	0.0 (0.0)	1.2 (1.2)	0.0 (0.0)
Wild lettuce	0.0 (0.0)	0.0 (0.0)	6.3 (6.3)
Wild lupine	12.7 (10.4)	1.2 (1.2)	0.0 (0.0)
Wild peppergrass	0.0 (0.0)	1.2 (1.2)	5.0 (5.0)
Wild strawberry	0.0 (0.0)	0.0 (0.0)	1.6 (1.6)
Winged sumac	6.3 (6.3)	0.0 (0.0)	0.0 (0.0)
Yarrow	0.0 (0.0)	1.2 (1.2)	6.7 (6.7)
Yellow goatsbeard	0.0 (0.0)	0.0 (0.0)	1.6 (1.6)

Table 5 (Cont).

Species	Species frequency of grassland types		
	Native	Introduced	Switchgrass
Yellow wood sorrel	0.0 (0.0)	0.0 (0.0)	4.8 (2.7)
American birch	1.6 (1.6)	0.0 (0.0)	0.0 (0.0)
Black cherry	3.2 (3.2)	2.4 (1.4)	0.0 (0.0)
Red Oak	4.8 (2.7)	0.0 (0.0)	0.0 (0.0)
Sassafras	0.0 (0.0)	9.5 (4.3)	0.0 (0.0)

*excluding switchgrass

species that did not necessarily occur at any sampling points, but were observed on sites. On native sites, 62 herbaceous species were identified, of which 24 species, or 39%, were found only on native sites (Fig. 2). Fifty-seven herbaceous species were found on introduced sites, including 13 species (23%) which were unique to introduced sites. On switchgrass sites, 33 species were identified, 11 of which (33%) were not found on native or introduced sites (Fig. 2).

Of the 18 grass species encountered among native, introduced, and switchgrass sites, 12 were native grass species and 6 were introduced grass species. Fifty-two of the 75 forb species are native to Michigan (Gleason and Cronquist 1991), 21 are considered introduced, and 2 were only identified to genus, so their origins could not be determined. Native grass dominated sites had 46 (74%) native herbaceous species, while introduced grass dominated sites had 38 (67%) native species, and switchgrass sites had 13 (39%) native herbaceous plant species (Fig. 2).

In 1993, no differences ($P > 0.10$) in plant species diversity were detected between native and introduced sites for May or July (Table 6). Similar results were documented in 1994 among native, introduced, and switchgrass sites, although switchgrass sites tended to have lower plant species diversity than native or introduced grass dominated sites (Table 6).

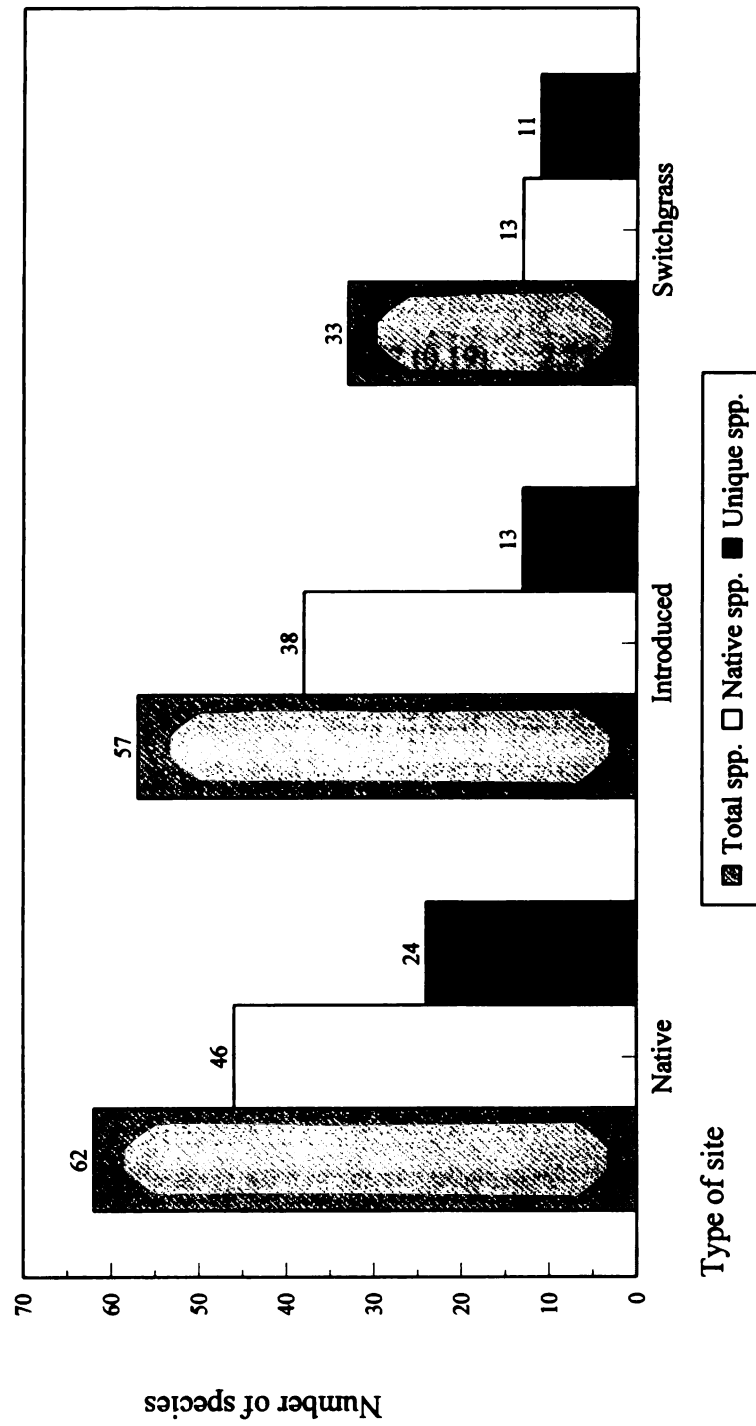


Figure 2. Total number of herbaceous species identified, including native species and species unique to each type of site, on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, 1993 and 1994.

Table 6. Mean Shannon-Weaver diversity indices (standard errors) for plant species on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, May and July, 1993 and 1994.

Year	Grassland types			Probability level ^a	
	Sampling period	Native	Introduced		Switchgrass
1993					
	May	2.18 (0.06)	2.25 (0.24)	ND ^b	0.724
	July	2.50 (0.08)	2.53 (0.21)	ND	1.000
1994					
	May	2.65 (0.10)	2.62 (0.19)	2.27 (0.27)	0.316
	July	2.81 (0.14)	2.74 (0.18)	2.47 (0.10)	0.118

^aMann-Whitney U test (1993 data) and Kruskal-Wallis one-way analysis of variance (1994 data) (Siegel 1956).

^bND = No data collected in 1993.

Vegetative Structure and Soil Moisture

Comparisons of vegetative structure and soil moisture among grassland types

Measurements of vertical cover on native and introduced sites during green-up in March and April showed that native sites had significantly shorter live vegetation and more bare ground than introduced sites (Table 7). No other variables measured during this time period were statistically different between grassland types.

Several significant differences in vegetative characteristics were detected among native, introduced, and planted switchgrass sites within the May and July sampling periods. In May for at least 1 of the 2 years of the study, percent canopy cover of total live vegetation, grasses, and forbs, vertical cover in the 0-30 cm stratum, maximum height of live vegetation, and litter depth were greater on introduced sites than on native sites (Tables 8 and 9). Canopy coverage of dead vegetation was significantly greater on native sites than on introduced sites in May, 1993, with a similar trend shown in 1994 (Tables 8 and 9). Native sites tended to have more bare ground than introduced or switchgrass sites, but this trend was not statistically significant.

Comparisons among native, introduced, and switchgrass sites in May, 1994 (Table 9) indicated that grass canopy cover and the maximum height of live and dead vegetation were significantly greater on switchgrass sites than on native sites. Forb canopy cover, vertical cover from 0-30 cm, and vertical cover >2 m were significantly less on switchgrass sites than on introduced sites (Table 9). Although native sites appeared to have the greatest mean percent vertical cover >2 m, a large variance was associated with this value, and it was not found to be statistically different from the other

Table 7. Means (standard errors) of vegetative characteristics on native and introduced grasslands in Allegan County, Michigan, March-April, 1994.

Variable	Grassland types		Probability level ^a
	Native	Introduced	
Max. live vegetation height (cm)	4.0 (1.4)	10.1 (0.9)	0.034
Max. dead vegetation height (cm)	19.2 (2.9)	19.1 (0.3)	0.480
% Total dead canopy	85.1 (3.3)	90.9 (3.7)	0.480
% Dead canopy	48.7 (4.6)	45.2 (9.7)	0.724
% Litter cover	43.1 (8.2)	52.1 (10.9)	0.724
% Live canopy	7.1 (1.7)	8.9 (1.6)	0.480
% Grass canopy	2.6 (0.4)	2.4 (1.0)	0.593
% Forb canopy	4.1 (1.9)	7.0 (1.2)	0.289
% Woody canopy	0.8 (0.5)	0.1 (0.1)	0.172
% Bare ground	11.0 (2.2)	4.1 (1.6)	0.077
Litter depth (cm)	1.1 (0.3)	1.6 (0.3)	0.480

^aMann-Whitney U test (Siegel 1956).

Table 8. Means (standard errors) of vegetative and soil moisture characteristics on native and introduced grasslands in Allegan County, Michigan, May, 1993.

Variable	Grassland types		Probability level ^a
	Native	Introduced	
Max. live vegetation height (cm)	17.3 (0.5)	25.7 (3.1)	0.077
Max. dead vegetation height (cm)	27.2 (2.1)	25.4 (4.6)	0.596
% Total dead canopy	66.4 (3.4)	45.1 (6.2)	0.034
% Dead canopy	34.1 (4.2)	14.8 (3.5)	0.034
% Litter cover	34.6 (2.9)	31.5 (5.9)	0.724
% Live canopy	16.7 (1.5)	42.2 (3.4)	0.034
% Grass canopy	8.2 (0.1)	12.8 (2.8)	0.034
% Forb canopy	9.0 (2.1)	31.0 (2.6)	0.034
% Woody canopy	0.4 (0.2)	0.1 (0.1)	0.289
% Bare ground	15.7 (4.7)	8.8 (3.1)	0.157
% Live vertical cover			
0-30 cm	11.0 (0.6)	22.4 (1.1)	0.034
31 cm-2 m	2.0 (0.7)	2.7 (1.3)	0.724
>2 m	5.8 (1.5)	5.4 (2.1)	0.724
Litter depth (cm)	1.1 (0.3)	1.6 (0.3)	0.157
Soil moisture index	0.3 (0.1)	1.0 (0.2)	0.034
(0=Dry, 10=Saturated)			

^aMann-Whitney U test (Siegel 1956).

Table 9. Means (standard errors) of vegetative and soil moisture characteristics on native, introduced, and wet native grasslands in Allegan County and switchgrass sites in Barry County, Michigan, May, 1994.

	Grassland types			Probability level ^b
	Native	Introduced	Switchgrass	Wet Native ^a
Max. live vegetation height (cm)	18.9A ^c (2.3)	27.1AB (3.5)	44.9B (2.7)	37.0
Max. dead vegetation height (cm)	20.1A (1.7)	21.6AB (1.8)	74.7B (6.2)	16.7
% Total dead canopy	60.7AB (1.8)	57.8A (4.3)	76.0B (2.8)	73.8
% Dead canopy	35.3A (4.5)	32.3A (7.7)	46.8A (3.6)	65.2
% Litter cover	24.7A (3.4)	24.9A (5.0)	29.4A (0.6)	8.8
% Live canopy	23.8A (1.0)	35.8B (2.3)	24.6AB (0.4)	21.0
% Grass canopy	7.9A (0.4)	9.1AB (0.8)	12.6B (1.1)	11.4
% Forb canopy	17.4AB (0.7)	27.3A (2.1)	12.8B (0.6)	5.5
% Woody canopy	0.6A (0.2)	1.6A (1.2)	0.0A (0.0)	4.8
% Bare ground	14.6A (2.4)	9.0A (2.6)	5.8A (3.3)	11.2
% Live vertical cover				
0-30 cm	12.0AB (1.2)	18.4A (1.2)	11.8B (0.9)	8.1
31 cm-2 m	2.0A (0.4)	1.0A (0.4)	1.0A (0.2)	0.5
>2 m	4.7AB (2.4)	4.0A (1.1)	0.0B (0.0)	0.0
Litter depth (cm)	0.9A (0.2)	1.8B (0.2)	1.5AB (0.3)	1.2
Soil moisture	0.0A (0.0)	0.0A (0.0)	0.1A (0.1)	0.0
(0=Dry, 10=Saturated)				

^aOnly 1 site sampled.

^bKruskal-Wallis one-way analysis of variance (Siegel 1956).

^cMeans on the same line with the same letter are not significantly different ($P>0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

^dSignificant difference ($P<0.10$) detected between native and introduced sites using the Mann-Whitney U test (Siegel 1956).

types of study sites.

Similar differences between native and introduced sites observed in May were also apparent during July (Tables 10 and 11). Native sites were still characterized by less live canopy cover, forb cover, and vertical cover at 0-30 cm than introduced grass dominated sites in July of both years. In addition, the maximum height of dead vegetation was shorter on native sites than on introduced sites in July of 1993 (Table 10). Native sites also tended to have more woody canopy cover and vertical cover >2 m than introduced sites in July, but these differences were not statistically significant (Tables 10 and 11).

When the Kruskal-Wallis test was applied to data from all 3 grassland types in July, 1994, switchgrass sites had taller live and dead vegetation, and more soil moisture than native sites. Although not statistically significant, switchgrass sites had the greatest percent grass canopy cover of the 3 types of grasslands. Switchgrass sites were also characterized by less vertical cover >2 m, and less litter cover than native sites. Forb and woody canopy cover, and vertical cover from 0-30 cm on switchgrass sites were less than on introduced sites, while vertical cover from 31 cm-2 m and total dead canopy cover were greater than on introduced sites (Table 11). Although the Kruskal-Wallis test showed a significant difference in live canopy cover among site types, no differences between pairs of site types were detected with the multiple comparison test.

All 3 types of study sites had very dry soils. The highest soil moisture index for an individual site was 1.02. Soil moisture on native sites was significantly lower than on introduced sites for May and July of 1993 and for July, 1994 (Tables 8-11). Native sites

Table 10. Means (standard errors) of vegetative and soil moisture characteristics on native and introduced grasslands in Allegan County, Michigan, July, 1993.

Variable	Grassland types		Probability level ^a
	Native	Introduced	
Max. live vegetation height (cm)	34.7 (2.0)	51.4 (4.2)	0.034
Max. dead vegetation height (cm)	28.4 (2.5)	26.9 (0.7)	0.480
% Total dead canopy	44.8 (6.1)	39.4 (5.1)	0.289
% Dead canopy	13.3 (0.2)	11.5 (1.6)	0.285
% Litter cover	32.8 (6.5)	30.6 (4.4)	1.000
% Live canopy	44.4 (6.5)	56.7 (2.8)	0.077
% Grass canopy	19.4 (7.4)	14.3 (3.0)	0.480
% Forb canopy	22.3 (2.0)	42.8 (3.7)	0.034
% Woody canopy	9.8 (3.2)	3.1 (1.6)	0.480
% Bare ground	9.8 (3.2)	7.4 (2.8)	0.289
% Live vertical cover			
0-30 cm	27.8 (3.0)	41.4 (2.5)	0.034
31 cm-2 m	4.0 (1.6)	6.8 (1.5)	0.289
>2 m	4.5 (2.2)	3.7 (2.2)	0.724
Litter depth (cm)	1.5 (0.3)	1.9 (0.5)	0.724
Soil moisture index	0.3 (0.1)	0.6 (<0.1)	0.034
(0=Dry, 10=saturated)			

^aMann-Whitney U test (Siegel 1956).

Table 11. Means (standard errors) of vegetative and soil moisture characteristics on native, introduced, and wet native grasslands in Allegan County and switchgrass sites in Barry County, Michigan, July, 1994.

Variable	Grassland types			Probability level ^b
	Native	Introduced	Switchgrass	Wet Native ^a
Max. live vegetation height (cm)	35.1A ^c (4.9)	44.4AB (2.6)	97.8B (4.2)	82.8
Max. dead vegetation height (cm)	21.5A (3.2)	25.6AB (2.0)	75.5B (3.5)	33.6
% Total dead canopy	55.6AB (3.4)	46.8A (2.8)	67.2B (7.1)	72.5
% Dead canopy	23.9AB (5.0)	17.6A (2.7)	51.4B (4.8)	48.5
% Litter cover	31.0A (2.4)	27.5AB (5.4)	15.5B (2.6)	24.0
% Live canopy	41.2A (2.2)	56.1A (3.7)	42.4A (6.5)	36.3
% Grass canopy	11.7A (3.8)	14.5A (5.1)	19.8A (3.5)	28.0
% Forb canopy	28.9AB (3.9)	40.1A (3.9)	23.2B (7.7)	8.8
% Woody canopy	4.9AB (2.6)	4.0A (1.1)	0.0B (0.0)	0.0
% Bare ground	9.8A (1.1)	7.3A (1.5)	7.8A (4.7)	6.0
% Live vertical cover				
0-30 cm	25.7AB (4.5)	35.1A (2.1)	17.1B (2.8)	16.9
31 cm-2 m	5.1AB (1.4)	3.7A (0.7)	14.7B (1.3)	6.6
>2 m	9.0A (3.9)	6.7AB (0.7)	0.0B (0.0)	0.0
Litter depth (cm)	0.7A (0.3)	1.1A (0.3)	1.3A (0.3)	1.0
Soil moisture	0.0A (0.0)	0.2AB (0.1)	0.7B (0.3)	0.6
(0=Dry, 10=Saturated)				

^aOnly 1 site sampled.

^bKruskal-Wallis one-way analysis of variance (Siegel 1956).

^cMeans on the same line with the same letter are not significantly different ($P>0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

^dSignificant difference ($P<0.10$) detected between native and introduced sites using the Mann-Whitney U test (Siegel 1956).

also had significantly drier soils than switchgrass sites in July of 1994.

Profile board measurements indicated that horizontal cover at ground level (0-30 cm) was greater ($P < 0.10$) on introduced sites than on native sites, and switchgrass sites also had significantly greater cover than native sites (Table 12). In the middle stratum (31 cm-1 m), native sites had significantly more horizontal cover than introduced sites, and when all 3 types of sites were compared, switchgrass sites had greater cover than native sites. In the upper stratum (1m-2 m), native sites also had consistently more horizontal cover than introduced sites, with significant differences occurring in June and July, 1994.

The trends observed for profile board measurements were also observed for densities of woody stems in similar strata. Native sites had a significantly greater density of trees > 2 m in height than introduced sites (Table 13). Although introduced sites appear to have more trees at the 2 lowest strata than native sites, tree densities varied among introduced sites and no significant differences were detected between native and introduced sites at these strata. Switchgrass sites had very few trees at any stratum, and stem densities were significantly lower on switchgrass sites than on introduced sites in the 2 lowest strata, and lower than on native sites in the upper stratum.

Comparisons of vegetative structure and soil moisture between sampling periods

From May to July of 1993, several differences were evident within both native and introduced grass dominated sites (Tables 8 and 10). Maximum height of live vegetation, live canopy cover, forb canopy cover, and vertical cover at 0-30 cm increased

Table 12. Significant differences ($P < 0.10$) in horizontal cover among native (N) and introduced (I) grasslands in Allegan County and switchgrass (S) sites in Barry County, Michigan, May-July, 1993 and 1994.

Year	Stratum		
	0-30 cm	31 cm-1 m	1 m-2 m
1993			
May	$I > N^*$	$I > N$	$N > I$
June	$I > N^*$	$N > I$	$N > I$
July	$I > N^*$	$I > N$	$N > I$
1994			
March	$I > N$	$N > I$	$N > I$
May	$S^A > I^{AB} > N^B$	$S^A > N^{AB} > I^B$	$S^A > N^A > I^A$
June	$S^A > I^{AB} > N^{B*}$	$S^A > N^{AB} > I^{B*}$	$N^A > I^A > S^{A*}$
July	$S^A > I^{AB} > N^B$	$S^A > N^{AB} > I^{B*}$	$N^A > S^{AB} > I^{B*}$

*Significant difference ($P < 0.10$) between native and introduced sites using the Mann-Whitney U test (Siegel 1956).

*Grassland types designated by the same capital letter within a stratum are not significantly different ($P < 0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

Table 13. Mean densities (standard errors) of woody stems in 3 strata on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, 1993 and 1994.

Stratum	Year	Grassland types			Probability level ^a
		Native	Introduced	Switchgrass	
0-30 cm	1993	1981 (602)	1917 (1061)	ND ^b	0.480
	1994	1660AB ^c (473)	3183A (1252)	32B (32)	0.049
31 cm-2 m	1993	2067 (1303)	1836 (480)	ND	1.000
	1994	122AB (142)	3630A (1177)	8B (6)	0.043
>2 m	1993	106 (33)	39 (19)	ND	0.157
	1994	206A (62)	45AB (4)	0B (0)	0.016 ^d

^aMann-Whitney U test (Siegel 1956) (1993 data) or Kruskal-Wallis one-way analysis of variance (Siegel 1956) (1994 data)

^bND = No data collected in 1993.

^cMeans on the same line with the same letter are not significantly different ($P > 0.10$) (Kruskal-Wallis multiple comparison test (Siegel 1988)).

^dSignificant difference ($P < 0.10$) detected between native and introduced sites using the Mann-Whitney U test (Siegel 1956).

significantly ($P < 0.10$), while dead canopy cover and total dead canopy cover (comprised of dead canopy and litter cover) decreased. In addition, vertical cover in the 31 cm-2 m stratum increased on introduced sites, and woody canopy cover increased on native sites.

In 1994, native sites showed significant ($P < 0.10$) increases in height of live vegetation, forb canopy cover, and vertical cover at 0-30 cm from May to July (Tables 8 and 10). On introduced sites, litter cover, litter depth, and percent dead canopy cover decreased significantly, while height of live and dead vegetation, total live canopy cover, forb cover, and vertical cover in the 2 lowest strata increased significantly ($P < 0.10$) from May to July. On switchgrass sites, height of live vegetation and soil moisture increased, and litter cover decreased from May to July (Tables 8 and 10).

Principal components analysis

May, 1993

For May, 1993, the first 3 components of the principal components analysis (Morrison 1990) of vegetative variables on native and introduced sites accounted for 85% of the variance among vegetative variables (Fig. 3). Principal component 1, which explained 38% of the variance, represents a gradient from percent live and forb canopy cover to percent total dead canopy cover. Because total live and total dead canopy cover are mutually exclusive and include all cover variables except bare ground, it is expected that they would be inversely related to one another.

The second principal component described 35% of the variance and follows a gradient from percent bare ground to percent vertical cover at 31 cm-2 m and tree stem

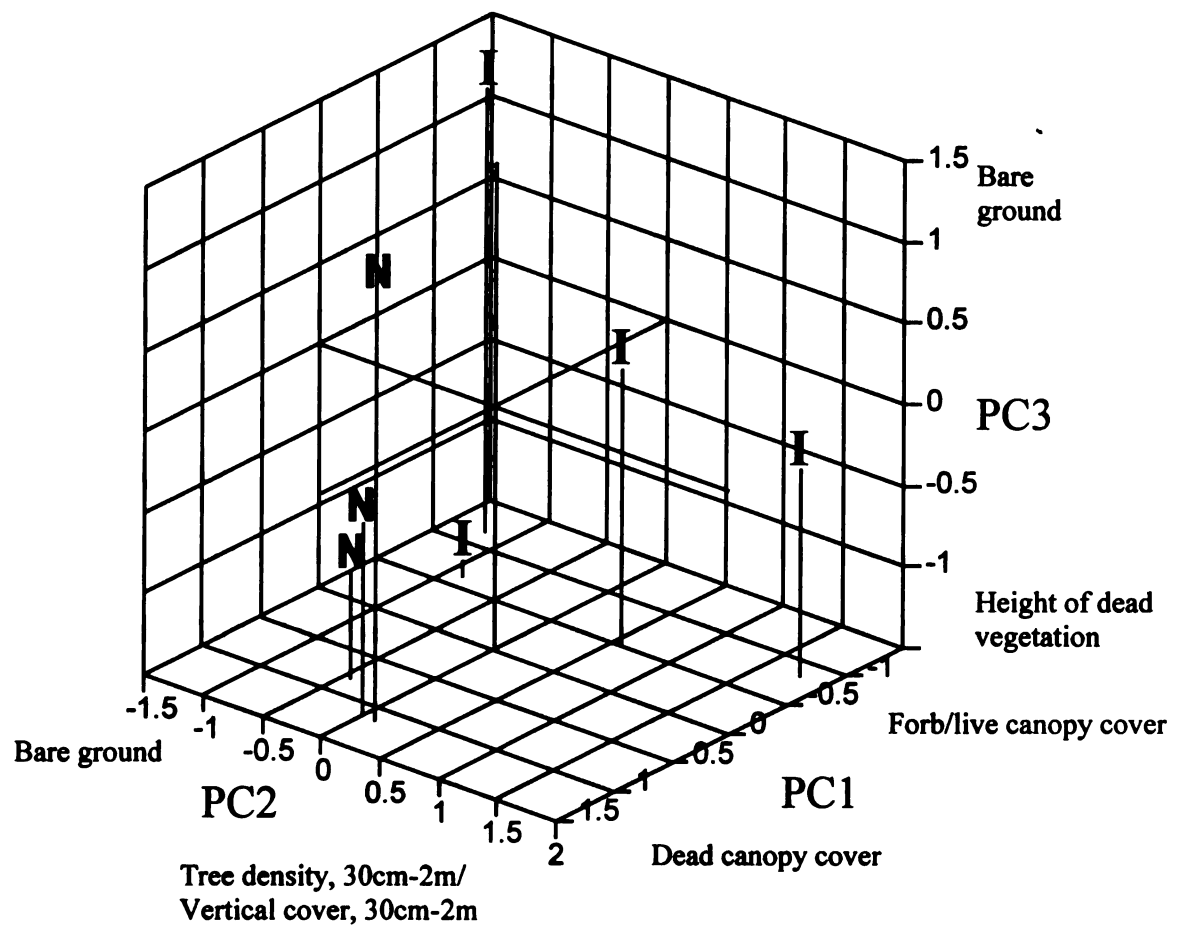


Figure 3. Principal component values of the first 3 principal components for native (N) and introduced (I) grasslands in Allegan County, Michigan, May, 1993.

density at 31 cm-2 m. Vertical cover should increase with tree density at the middle stratum, and reduce the percentage of bare ground present. The third principal component is a gradient from height of dead vegetation to percent bare ground.

In May, 1993, native sites were easily distinguished from introduced sites as having a greater proportion of dead vegetation in relation to live vegetation (Fig. 3). Along PC 2, native sites were characterized by intermediate amounts of bare ground and tree density/live cover from 31 cm-2 m, while half the introduced sites fell towards each end of the gradient. No distinction between native and introduced sites was evident along PC 3.

July, 1993

The first 3 principal components of the vegetative variables measured in July, 1993 explained 76% of the variance in these variables (Fig. 4). Thirty-five percent of the variance was accounted for by PC 1, which describes a gradient from density of trees >2 m to percent cover of live vegetation. A greater density of large trees may shade the ground or otherwise inhibit the growth of other forms of live vegetation. The second principal component, accounting for 26% of the variance, describes the relationship between height of live vegetation and percent grass canopy cover. Height of live vegetation may represent the height of forbs, which may be more prevalent on sites with less grass cover, and vice versa. Principal component 3 represents a gradient from live canopy cover >2 m to the density of trees 31 cm-2 m in height.

Introduced sites were weighted more heavily towards live canopy cover than towards tree density along principal component 1 (Fig. 4). While 2 of the native sites

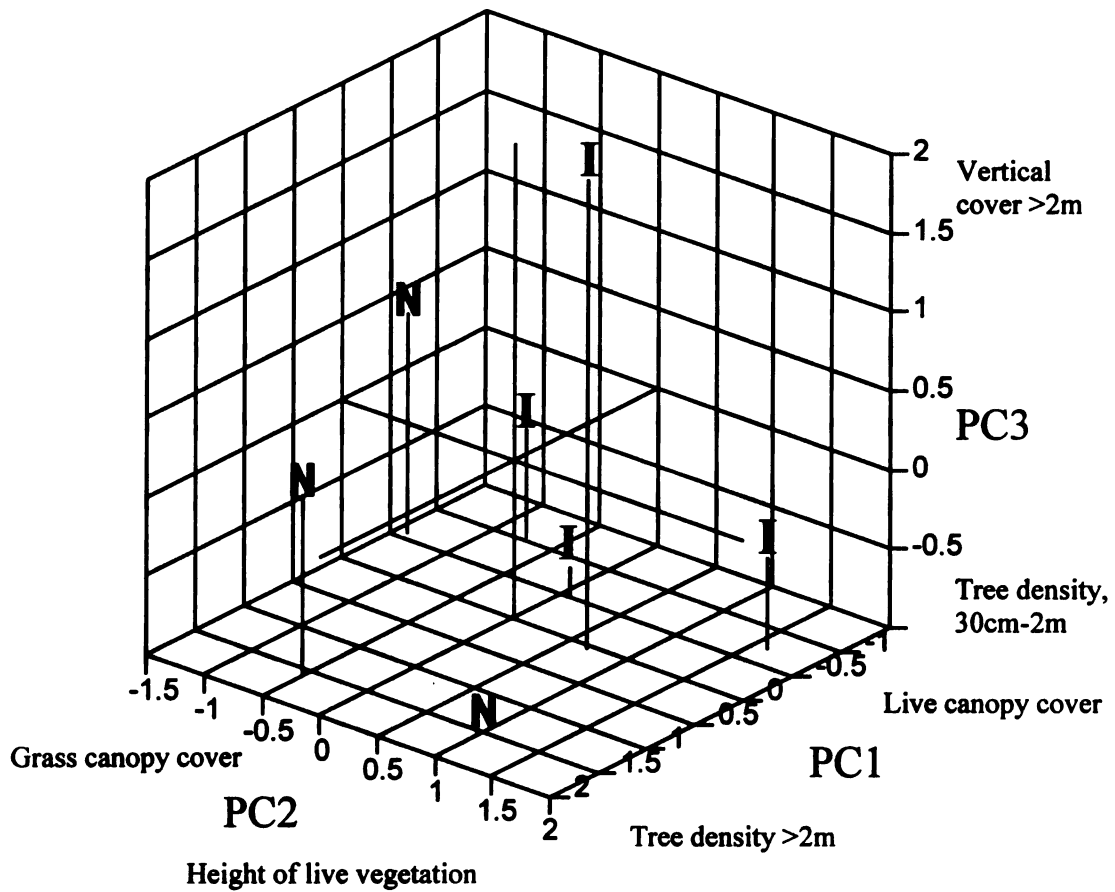


Figure 4. Principal component values of the first 3 principal components for native (N) and introduced (I) grasslands in Allegan County, Michigan, July, 1993.

exhibited the opposite of this relationship, with high tree densities in relation to total live canopy cover, 1 native site was weighted more heavily towards live canopy cover than tree density. Both native and introduced sites appeared to range widely along the gradients of PC 2 and PC 3.

May, 1994

The first 3 principal components of the analysis among vegetative variables for May, 1994 accounted for 81% of the variance (Fig. 5). The first of these components explained 41% of the variance, and represents a gradient from percent forb cover to a combination of height of dead vegetation and dead vegetative cover. Twenty-one percent of the variance was explained by PC 2, which describes a gradient between the density of trees <2 m in height and percent litter cover. The third principal component accounted for 18% of the variance and represents a relationship between total live vegetative cover and live canopy cover within the 31 cm-2 m stratum. This gradient may describe the relative importance of vegetation from 31 cm-2 m on a site in relation to the total percent live canopy cover present on a site.

Based on the principal components analysis for May, 1994, native sites appear to occupy a position along PC 1 slightly favoring forb cover over height of dead vegetation/dead vegetative cover (Fig. 5). Introduced sites also had a substantial amount of forb cover, and relatively little dead canopy cover and low dead vegetation height. Switchgrass sites were grouped at the opposite end of this gradient, having relatively low amounts of forb cover and greater dead vegetative cover and vegetation height. Along PC 2, native sites were more heavily weighted towards litter cover than tree density <2m,

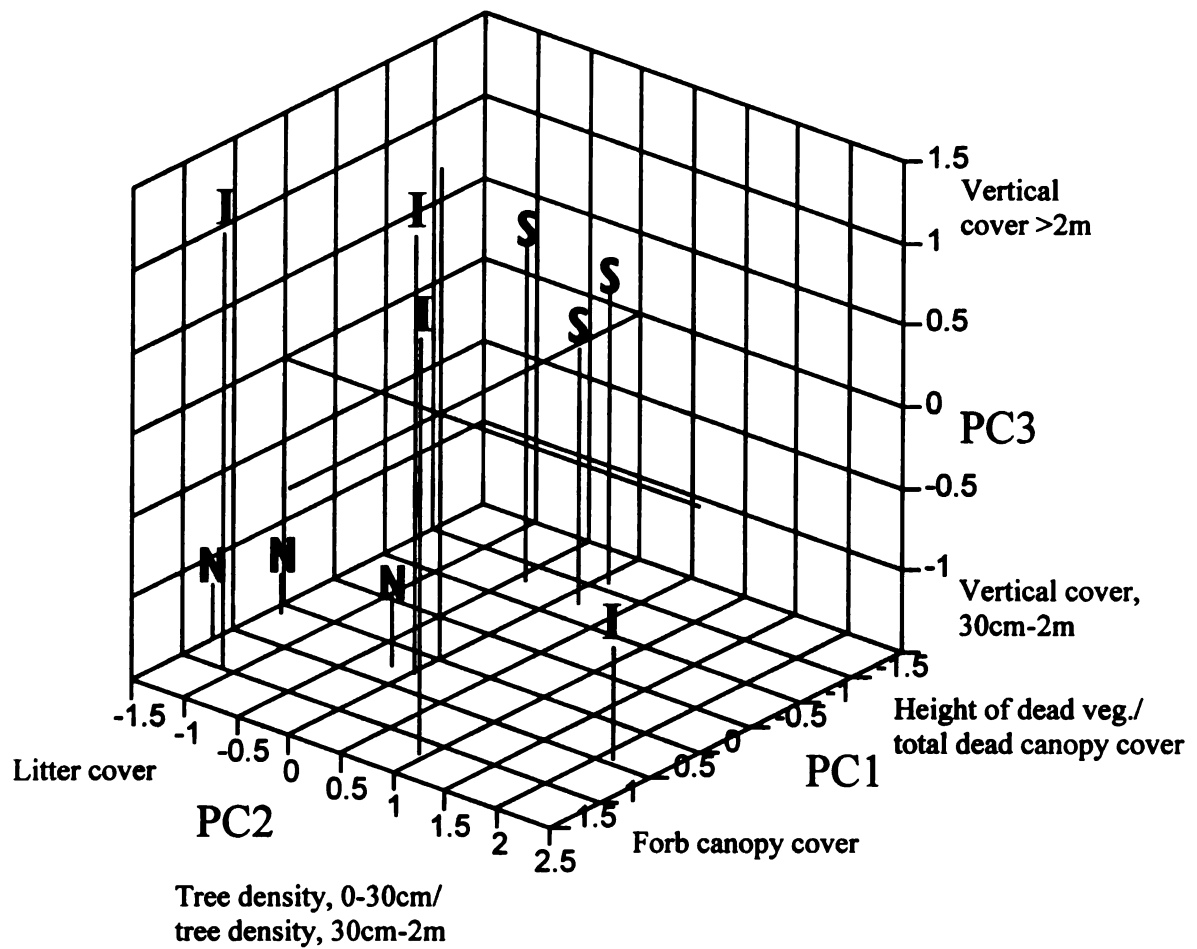


Figure 5. Principal component values of the first 3 principal components for native (N) and introduced (I) grasslands in Allegan County, and switchgrass (S) sites in Barry County, Michigan, May, 1994.

while introduced sites appeared scattered along this gradient, and switchgrass sites fell in the middle of the gradient. Native sites were also characterized by a prominent vegetation layer at 31 cm-2 m, while introduced sites had a lower proportion of vegetation in the 31 cm-2 m stratum, and switchgrass sites had a moderate proportion of live vegetation within this stratum.

July, 1994

In July, 1994, the first 3 principal components described 85% of the variation among variables (Fig. 6). Principal component 1 explained 52% of the variance and describes a gradient between percent live canopy cover in the 0-30 cm stratum and dead vegetative cover. Principal component 2 is a gradient from percent bare ground and tree density >2 m to total live vegetative cover, and accounted for 22 % of the variance. Principal component 3, explaining 11% of the variance, is a gradient from grass cover and the density of trees $\leq$ 30 cm to percent cover of live vegetation 0-30 cm in height. This relationship shows the relative importance of trees $\leq$ 30 cm and grass as a proportion of all live vegetation in this stratum.

Native and introduced sites were both characterized by fairly low amounts of dead vegetative cover and moderate amounts of live cover at ground level, while switchgrass sites were weighted heavily towards dead vegetative cover along PC 1 (Fig. 6). Principal component 2 shows that native sites also had more bare ground and a greater density of trees >2 m in relation to total live cover. Introduced sites generally exhibited the opposite relationship, with the exception of 1 site, while switchgrass sites were scattered along this gradient. No distinction among native, introduced, and switchgrass sites was apparent

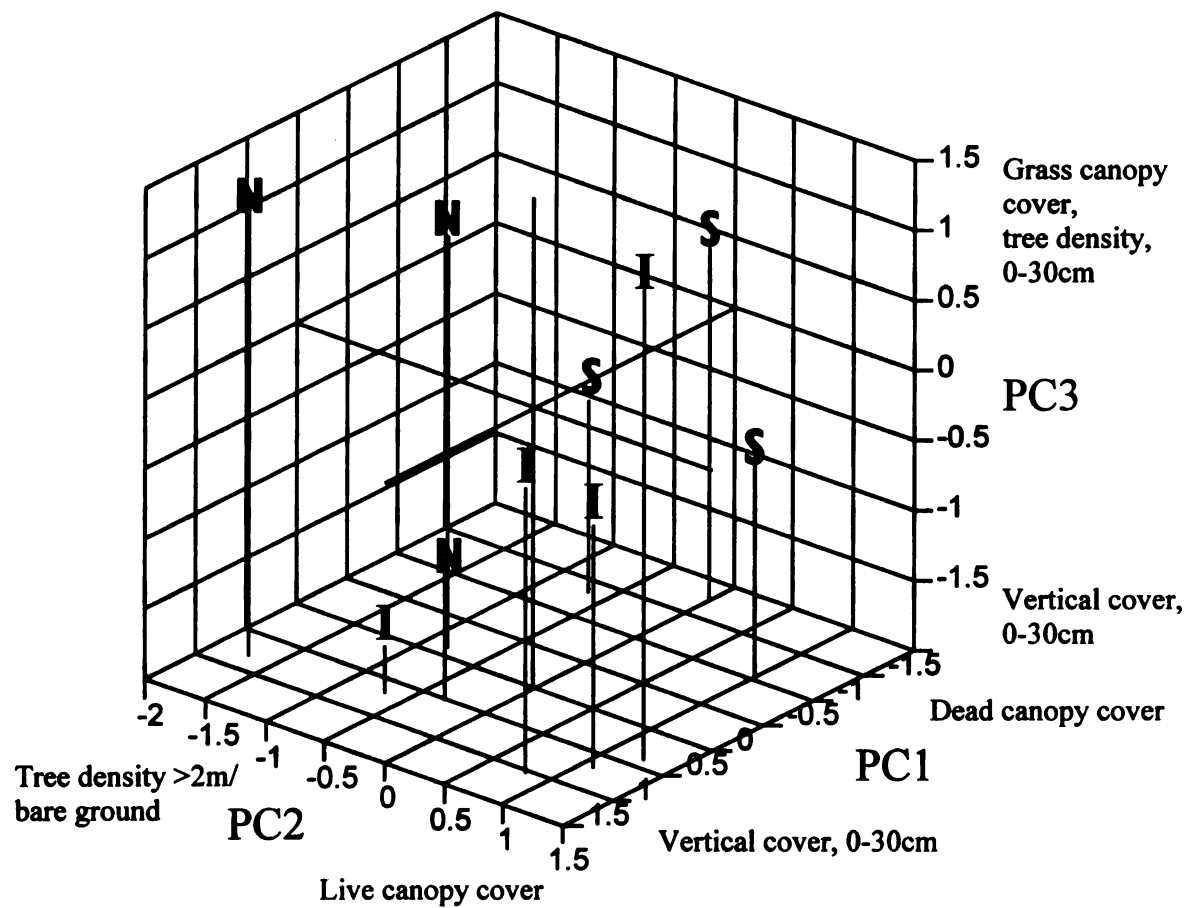


Figure 6. Principal component values of the first 3 principal components for native (N) and introduced (I) grasslands in Allegan County, and switchgrass (S) sites in Barry County, Michigan, July, 1994.

along PC 3.

Avian Species Composition and Diversity

Thirty-one bird species were censused on native sites in 1993 and 1994 (Appendix B), including 2 species, eastern kingbird (*Tyrannus tyrannus*) and red-winged blackbird (*Agelaius phoeniceus*), which were found only on native sites. A pair of red-winged blackbirds were observed only once, and most likely inhabited a nearby wetland. Thirty-four bird species were censused on introduced sites, 5 of which, including American crow (*Corvus brachyrhynchos*), eastern pewee (*Contopus virens*), European starling (*Sturnus vulgaris*), white-breasted nuthatch (*Sitta carolinensis*), and a migrant white-crowned sparrow (*Zonotrichia leucophrys*), were only observed on introduced sites. Although bird species with preferences for forest, edge, and savanna habitat were found on both types of sites, species that typically inhabit Midwest grasslands, such as the bobolink (*Dolichonyx oryzivorus*) or eastern meadowlark (*Sturnella magna*) (Herkert 1994) were not observed on study sites.

Few birds were observed during the winter census period on native and introduced sites. Black-capped chickadees (*Parus atricapillus*) were recorded on native and introduced sites. Blue jay (*Cyanocitta cristata*), tufted titmouse (*Parus bicolor*), and white-breasted nuthatch were also observed on introduced grasslands. A total of 7 individuals were recorded. Because of the small number of observations during this sampling period, no comparisons of species diversity were made for the winter birding period.

Species diversity of birds associated with introduced sites tended to be greater than on native sites for each census period, except July, 1994, when diversity was slightly greater on native sites. Significant differences in bird species diversity between grassland types occurred in May, 1994, and June and July, 1993 (Table 14). Diversity indices did not change significantly throughout the season; however, diversity appeared to increase from June to July on both types of sites in 1993 and in 1994.

The size of study sites was relatively small in comparison to the territory size likely to be used by birds observed on the study sites. For example, field sparrows (*Spizella pusilla*) require an average territory size of 0.8 ha (Best 1977), and black-capped chickadees may establish nests within territories averaging between 1.8 and 2.6 ha (Stefanski 1967). Sites in this study ranged from 1.0 to 2.9 ha. A large proportion of the bird observations on each site were of species more often associated with a forested habitat, such as the eastern pewee (*Contopus virens*) and great-crested flycatcher (*Myiarchus crinitus*) rather than species associated with grasslands, such as the bobolink or grasshopper sparrow (*Ammodramus savannarum*). The species observed were probably using the study sites less intensively than they were using the surrounding habitat, and may not have been representative of species that are dependent on grassland habitat.

To compare the importance of native and introduced grasslands to species which are likely to use these habitats most intensively, a list of birds observed at a relative frequency $\geq 5\%$ on each type of site was extracted from the complete set of bird data (Table 15), and the diversity analyses performed on the initial data set were repeated.

Table 14. Mean Shannon-Weaver diversity indices (standard errors) for avian species censused on native and introduced grasslands in Allegan County, Michigan, May-July, 1993 and 1994.

Year	Grassland types			
	Sampling period	Native	Introduced	Probability level ^a
1993				
	May	0.54 (0.13)	0.84 (0.11)	0.157
	June	0.52 (0.21)	0.88 (0.07)	0.077
	July	0.60 (0.15)	1.14 (0.08)	0.034
1994				
	May	0.88 (0.15)	1.48 (0.20)	0.077
	June	1.05 (0.07)	1.43 (0.15)	0.157
	July	1.57 (0.25)	1.55 (0.16)	1.000

^aMann-Whitney U test (Siegel 1956).

Table 15. Bird species censused on native and introduced grasslands at a relative frequency $\geq 5\%$ during at least 1 sampling period in Allegan County, Michigan, May-July, 1993 and 1994.

Native	Native and Introduced	Introduced
Scarlet tanager	American goldfinch	Brown-headed cowbird
	American robin	Indigo bunting
	Black-capped chickadee	Northern oriole
	Chipping sparrow	Rose-breasted grosbeak
	Eastern bluebird	
	Field sparrow	
	Rufous-sided towhee	
	Song sparrow	
	Tufted titmouse	

This yielded a set of bird species which may be likely to use grasslands for nesting, such as field sparrows and eastern bluebirds (*Sialia sialis*), as well as some birds which have broad habitat requirements, such as American robins (*Turdus migratorius*), that may have selected their habitat based on less specific features.

As expected, species diversity was lower on each site when the analysis was restricted to species that occurred at a relative frequency $\geq 5\%$. Diversity of birds associated with introduced sites still tended to be greater than on native sites, but the only census period in which a significant difference was detected occurred in May, 1994, when species diversity was significantly greater on introduced sites than on native sites (Table 16).

Avian use of study sites was further characterized by observing the behavioral activities of birds on study sites. Activities observed included foraging, singing, calling, perching, attending a nest, and moving on the study site without performing one of the above activities. Calling was defined as vocalization that was not a song, and birds were classified as perching if they occupied one spot, often in a treetop, without moving around or engaging in another behavior. Although birds may have performed more than one activity during the 30 minute census period, the first activity observed was the one recorded. Slightly less than half the observations on native and introduced grasslands for which behavioral activities were recorded fell into the moving category (Table 17). Birds classified as moving often appeared briefly on a site and then left, or moved about in the trees of the study sites without overtly engaging in a more specific activity. Behavioral activities of birds observed at a relative frequency $\geq 5\%$ on native and introduced

Table 16. Mean Shannon-Weaver diversity indices (standard errors) for avian species censused at a relative frequency $\geq 5\%$ on native and introduced grasslands in Allegan County, Michigan, May-July, 1993 and 1994.

Year	Species diversities on grassland types		
Sampling period	Native	Introduced	Probability level ^a
1993			
May	0.44 (0.12)	0.63 (0.11)	0.157
June	0.25 (0.13)	0.50 (0.10)	0.157
July	0.65 (0.26)	0.90 (0.10)	0.480
1994			
May	0.37 (0.19)	1.18 (0.19)	0.034
June	0.61 (0.22)	0.68 (0.16)	1.000
July	1.19 (0.58)	0.71 (0.15)	0.157

^aMann-Whitney U test (Siegel 1956).

Table 17. Behavioral activities of all birds observed and bird species observed at a relative frequency $\geq 5\%$ on native and introduced grasslands in Allegan County, Michigan, May-July, 1994.

Behavioral activity	Percent of observations on grassland types			
	Native		Introduced	
	All birds	Frequency $\geq 5\%$	All birds	Frequency $\geq 5\%$
Foraging	17.5	22.5	10.0	15.1
Singing	29.0	27.1	28.5	33.3
Calling	6.3	7.1	5.2	5.5
Perching	2.8	6.1	3.5	3.4
Nesting	3.7	0.0	3.5	1.9
Moving	40.6	37.1	49.3	40.9

grasslands were similar to observations of all birds on the grasslands, although on introduced sites, the percentage of birds singing and foraging was slightly greater than it had been for the original data set. Most of the observations of foraging activities on both types of grasslands were of sparrows or cedar waxwings (*Bombycilla cedrorum*), which were among the most common species on both types of grasslands, while observations of singing on the grasslands included almost all species recorded.

Although all study sites were searched monthly for bird nests, the majority of nests were discovered while conducting other field activities, such as small mammal trapping. On native sites, an average of 1.7 bird nests were found per site, at an average density of 0.9 nests/ha. Nests identified included field sparrow, chipping sparrow (*Spizella passerina*), and vesper sparrow (*Pooecetes gramineus*) nests. On introduced sites, an average of 7.25 nests/site were found, at an average density of 4.2 nests/ha. These nests included field sparrow, vesper sparrow, brown thrasher (*Toxostoma rufum*), northern oriole (*Icterus galbula*), cedar waxwing, and robin nests. An average of 3.3 nests per site, representing field sparrow, mallard (*Anas platyrhynchos*), wild turkey (*Meleagris gallopavo*), and mourning dove (*Zenaida macroura*) nests were discovered on switchgrass sites, and occurred at a density of 1.8 nests/ha.

Small Mammal Relative Abundance and Diversity

In 1993, high water levels on all wet native sites precluded trapping until August and September on these sites. In 1994, 1 of the wet native sites was dry enough to be trapped from May through September; however, the other 2 sites maintained standing

water until the August trapping period.

Trapping success was relatively low in 1993, but in 1994, capture rates on all sites were much higher and were accompanied by an increase in both the number of individuals and the number of species caught on each site. Five species of small mammals were captured on native sites throughout the spring and summer of 1993 and 1994 (Tables 18 and 19). One masked shrew (*Sorex cinereus*) was trapped on a native site and was not captured on any other types of sites. Six species were trapped on introduced sites, including meadow jumping mice (*Zapus hudsonius*), which were not captured on native sites, and eastern chipmunks (*Tamias striatus*), which were not found on native or switchgrass sites. Six species were captured on wet native sites, and 6 species were trapped on switchgrass sites from May-September of 1994. Switchgrass and wet native sites were the only grassland types on which least weasels (*Mustela nivalis*) were captured.

On native sites, mice (*Peromyscus* spp.) were the only species of which more than a few individuals were captured (Tables 18 and 19). Meadow voles (*Microtus pennsylvanicus*) and short-tailed shrews (*Blarina brevicauda*) were caught in very low numbers, and only 1 thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) and 1 masked shrew were caught during the 2 years of the study. *Peromyscus* species composed the largest proportion of captures on introduced sites, although meadow voles and short-tailed shrews were also caught in substantial numbers. More *Peromyscus* species were trapped on wet native sites than on all other sites. Wet native sites also contained significant numbers of meadow voles and meadow jumping mice. Switchgrass

Table 18. Mean number (standard errors) of mammals, per 1500 trap nights, captured on native, introduced, and wet native grasslands in Allegan County, Michigan, May-September, 1993.

Species	Grassland types			Probability level ^a
	Native	Introduced	Wet native	
Mice spp. (<i>Peromyscus</i> spp.)	9.67A ^b (3.18)	10.25AB (1.11)	30.69B (5.19)	0.050
Meadow Vole (<i>Microtus pennsylvanicus</i>)	0.00A (0.00)	2.25A (0.48)	6.84A (4.38)	0.100
Thirteen-lined Ground Squirrel (<i>Spermophilus tridecemlineatus</i>)	0.33A (0.33)	0.50A (0.50)	0.00A (0.00)	0.619
Eastern Chipmunk (<i>Tamias striatus</i>)	0.00A (0.00)	1.00A (1.00)	0.00A (0.00)	0.472
Short-tailed Shrew (<i>Blarina brevicauda</i>)	1.00A (1.00)	0.25A (0.25)	0.00A (0.00)	0.565
Meadow Jumping Mouse (<i>Zapus hudsonius</i>)	0.00A (0.00)	0.00A (0.00)	8.33A (4.41)	0.075
Least Weasel (<i>Mustela nivalis</i>)	0.00A (0.00)	0.00A (0.00)	1.84A (1.84)	0.311
All species	11.00A (2.65)	14.25AB (0.85)	47.70B (7.85)	0.046

^aKruskal-Wallis one-way analysis of variance (Siegel 1956).

^bMeans on the same line with the same letter are not significantly different ($P > 0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

Table 19. Mean number (standard errors) of mammals, per 1500 trap nights, captured on native, introduced, and wet native grasslands in Allegan County and switchgrass sites in Barry County, Michigan, May-September, 1994.

Species	Grassland types				Probability level ^a
	Native	Introduced	Wet native	Switchgrass	
Mice spp. (<i>Peromyscus</i> spp.)	16.67A ^b (7.26)	24.00A (4.14)	87.17A (6.69)	15.90A (6.65)	0.072
Meadow Vole (<i>Microtus pennsylvanicus</i>)	2.67A (1.20)	17.75A (7.02)	25.83A (10.64)	21.67A (10.99)	0.209
Thirteen-lined Ground Squirrel (<i>Spermophilus tridecemlineatus</i>)	0.00A (0.00)	1.00A (1.00)	0.00A (0.00)	3.44A (2.44)	0.047
Eastern Chipmunk (<i>Tamias striatus</i>)	0.00A (0.00)	2.00A (1.68)	2.67A (0.17)	0.00A (0.00)	0.056
Short-tailed Shrew (<i>Blarina brevicauda</i>)	2.00A (0.58)	9.25A (1.49)	2.67A (1.45)	8.23A (3.55)	0.061
Masked Shrew (<i>Sorex cinereus</i>)	0.33A (0.33)	0.00A (0.00)	0.00A (0.00)	0.00A (0.00)	0.343
Meadow Jumping Mouse (<i>Zapus hudsonius</i>)	0.00A (0.00)	27.83AB (8.69)	13.33B (1.45)	17.5AB (7.59)	0.024
Least Weasel (<i>Mustela nivalis</i>)	0.00A (0.00)	0.00A (0.00)	0.00A (0.00)	0.33A (0.33)	0.343

Table 19 (Cont).

Species	Grassland types				Probability level
	Native	Introduced	Wet native	Switchgrass	
All species	21.67A (7.45)	58.00AB (9.34)	146.17B (20.71)	67.06AB (4.09)	0.016

^aKruskal-Wallis one-way analysis of variance (Siegel 1956).

^bMeans on the same line with the same letter are not significantly different ($P > 0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

sites were the only sites on which *Peromyscus* spp. were not the most abundant species trapped. Instead, meadow voles were the dominant small mammal species on these sites, based on the number of individuals captured. Switchgrass sites were also inhabited by the greatest numbers of meadow jumping mice of the 4 types of sites, as well as by substantial numbers of mice.

Differences in capture rates between those observed on the grids and assessment lines are not directly comparable because 2 traps were placed at each grid station, and 1 trap was placed at each assessment line station. However, some patterns were observed. On each type of site on which assessment lines were used, members of the genus *Peromyscus* were the species captured most often on the assessment lines, as well as on the grid (Table 20). On all 3 types of sites, mice, short-tailed shrews, and chipmunks were captured more frequently on assessment lines than on the grid.

On introduced sites, the capture rate of meadow voles was lower on assessment lines than on grids, while on native and wet native sites, voles were captured on assessment lines at a rate comparable to their capture rate on grids (Table 20). These results may be because assessment lines on native and wet native grasslands often ran through adjacent grassy areas that could provide attractive meadow vole habitat. Meadow jumping mice were captured at similar rates on grids and assessment lines of introduced sites, but were not captured at all on native sites. Chipmunks and an opossum (*Didelphis virginiana*) were trapped on assessment lines of native sites but had not been captured on the grid. One least weasel (*Mustela nivalis*) was also captured adjacent to a wet native site.

Table 20. Mean small mammal capture rates (standard errors), per trap night, for trapping grids and assessment lines on native, introduced, and wet native grasslands in Allegan County, Michigan, May-September, 1994.

Species	Native		Introduced		Wet native ^a	
	Grid	Lines	Grid	Lines	Grid	Lines
Mice spp. (<i>Peromyscus</i> spp.)	0.28 (0.12)	0.82 (0.20)	0.40 (0.07)	0.92 (0.19)	0.86 (0.27)	1.37 (0.29)
Meadow vole (<i>Microtus pennsylvanicus</i>)	0.05 (0.02)	0.04 (0.02)	0.29 (0.07)	0.17 (0.05)	0.19 (0.06)	0.22 (0.11)
Thirteen-lined ground squirrel (<i>Spermophilus tridecemlineatus</i>)	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)
Eastern chipmunk (<i>Tamias striatus</i>)	0.00 (0.00)	0.08 (0.05)	0.03 (0.03)	0.15 (0.06)	0.03 (0.01)	0.20 (0.11)
Short-tailed shrew (<i>Blarina brevicauda</i>)	0.03 (0.01)	0.37 (0.15)	0.15 (0.03)	0.38 (0.13)	0.03 (0.01)	0.15 (0.10)
Meadow jumping mouse (<i>Zapus hudsonius</i>)	0.00 (0.00)	0.00 (0.00)	0.07 (0.02)	0.11 (0.07)	0.22 (0.03)	0.03 (0.02)
Least weasel (<i>Mustela nivalis</i>)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.01)
Masked shrew (<i>Sorex cinereus</i>)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Opossum (<i>Didelphis virginiana</i>)	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

^aTwo of the 3 wet native sites were trapped only in August and September.

In May and June of 1993, only 1 species was caught on each site, so all diversity indices were 0 for those months. Although average diversity values tended to be greater on introduced sites than on native sites for the remaining months of 1993, these differences were not statistically significant (Table 21). In 1994, higher capture rates resulted in mean monthly diversity indices as high as 0.7 for native sites and 1.2 for introduced and switchgrass sites. The dominance of *Peromyscus* spp. on native sites is reflected in the significantly lower species diversity of native sites compared with introduced sites in June, July, August, and September, 1994. Significant differences among all 4 types of sites were found in July and August of 1994. In July, small mammal diversity was significantly greater ($P < 0.10$) on introduced sites than on native sites. In August, diversity was greater on both introduced and switchgrass sites than on native sites.

Invertebrate Abundance and Diversity

In 1993, 7 orders and 1 class of invertebrates, including Coleoptera (beetles), Diptera (flies), Hemiptera (bugs), Homoptera (aphids and leafhoppers), Hymenoptera (ants and bees), Lepidoptera (butterflies and moths), Orthoptera (grasshoppers and crickets) and the class Arachnida (spiders) were collected on native sites from May through August. In addition to the 7 taxa identified in 1993, insects belonging to the class Odonata (dragonflies and damselflies) were identified on native sites in 1994. Taxa collected on introduced sites in 1993 and 1994 included those collected on native sites, as well as an additional order, Neuroptera (lacewings), collected in 1993. All taxa except

Table 21. Mean Shannon-Weaver diversity indices (standard errors) for mammalian species trapped on native, introduced, and wet native grasslands in Allegan County and switchgrass sites in Barry County, Michigan, May-September, 1993 and 1994.

Year	Species diversities on grassland types				
	Sampling period	Native	Introduced	Switchgrass	Wet native
1993					Probability level ^a
	May	0.00 (0.00)	0.00 (0.00)	NT ^b	NT
	June	0.00 (0.00)	0.00 (0.00)	NT	NT
	July	0.21 (0.21)	0.14 (0.14)	NT	NT
	August	0.23 (0.23)	0.51 (0.21)	NT	0.00 ^c
	September	0.22A ^a (0.22)	0.57A (0.20)	NT	0.84A (0.12)
1994					
	May	0.00A (0.00)	0.42A (0.26)	0.14A (0.14)	0.00
	June	0.00A (0.00)	0.56A (0.19)	0.45A (0.28)	0.80
	July	0.23A (0.23)	0.72B (0.15)	0.99AB (0.15)	0.88
	August	0.69A (0.08)	1.21AB (0.03)	1.24B (0.13)	0.84AB (0.12)
	September	0.56A (0.30)	1.17A (0.08)	0.94A (0.17)	0.98A (0.16)

^aMann-Whitney U test (Siegel 1956) and Kruskal-Wallis one-way analysis of variance (Siegel 1988).

^bNT = Not trapped.

^cOnly 1 wet native site trapped.

^dSignificant difference ($P < 0.10$) detected between native and introduced sites using the Mann-Whitney U test.

^eMeans on the same line with the same letter are not significantly different ($P > 0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

Neuroptera were identified on switchgrass sites in 1994.

The order Orthoptera composed the largest proportion of biomass, followed by Homoptera, on all types of sites (Figs. 7 and 8). Mean biomass per 10 sweeps was consistently greater on introduced sites than native sites for each month in 1993 and 1994 (Table 22). Biomass on switchgrass sites was comparable to that on introduced sites, but was greater than on native sites throughout the 1994 sampling periods. In 1994, significant differences among all 3 types of grasslands were detected in June and July (Table 22). Further testing with the Kruskal-Wallis multiple comparison test failed to identify a difference between pairs of grassland types in June, but showed that biomass was significantly greater on introduced than on native sites in July.

Biomass tended to increase steadily throughout the season on native and introduced sites, but fluctuated on switchgrass sites. In 1993, biomass increased significantly from May to August and from June to August on both native and introduced grasslands. In 1994, biomass increased significantly from May to June and from May to July on native sites, from May to July on introduced sites, and from May to June on switchgrass fields.

Invertebrate taxonomic diversity was significantly greater on introduced than on native sites in June, 1993, but no other significant differences were observed among grassland types (Table 23). Diversity was not significantly different among months except on introduced sites in 1994 when a significant decrease from May to July was observed.

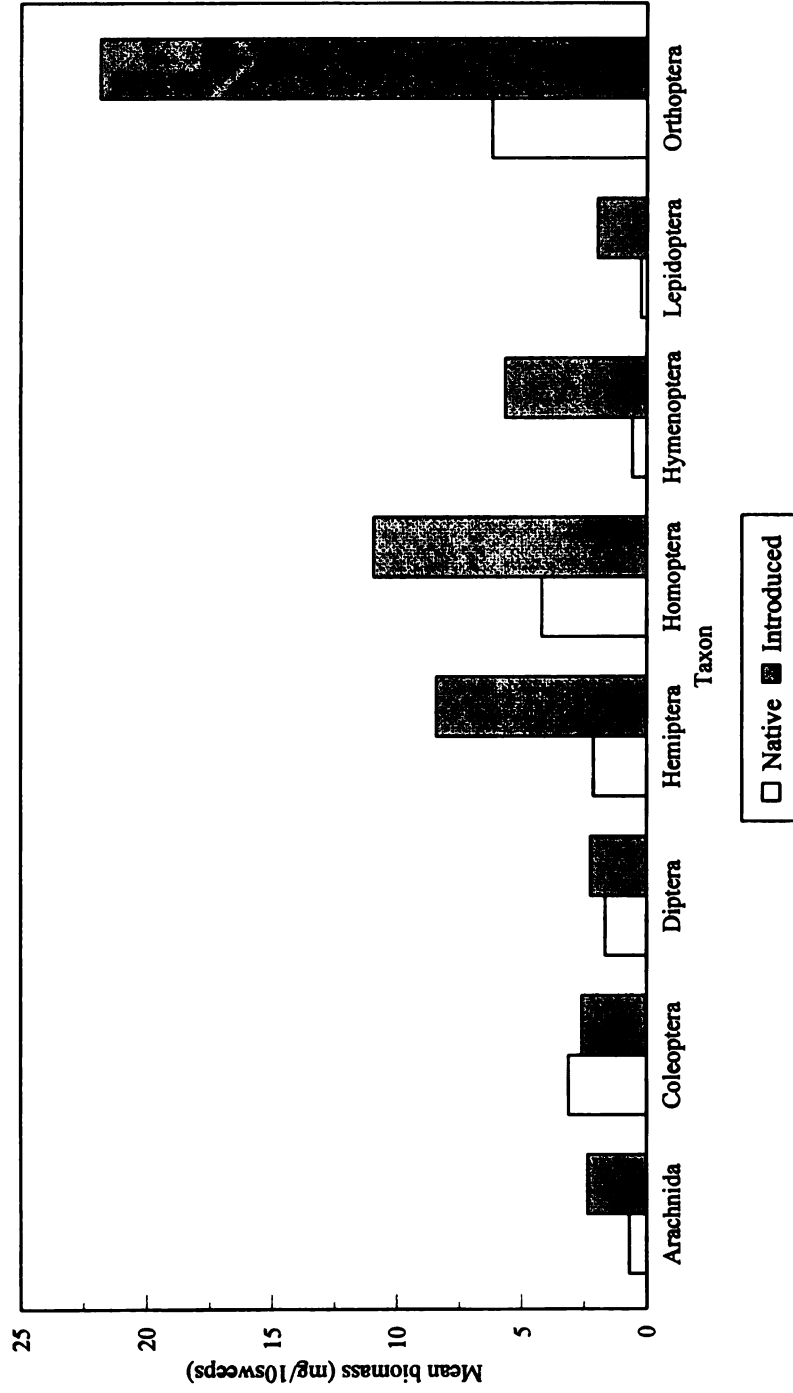


Figure 7. Mean monthly invertebrate biomass, by taxon, on native and introduced grasslands in Allegheny County, Michigan, May-August 1993.

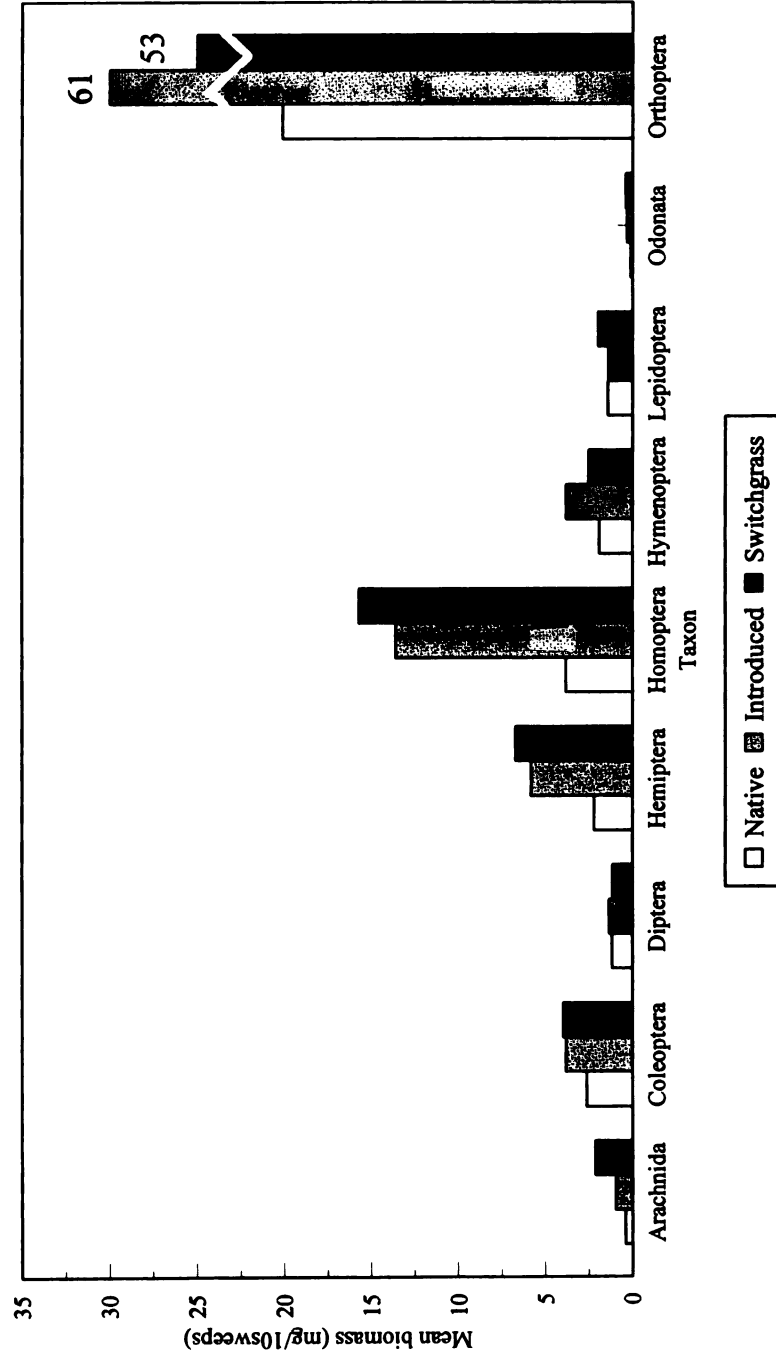


Figure 8. Mean monthly invertebrate biomass, by taxon, on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, May-July, 1994.

Table 22. Mean biomass (standard errors), in mg/10 sweeps, of invertebrates collected on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, 1993 and 1994.

Year	Grassland types			Probability level ^a
Sampling period	Native	Introduced	Switchgrass	
1993				
May	1.03 (0.32)	1.64 (0.49)	NS ^b	0.289
June	1.27 (0.08)	3.09 (0.63)	NS	0.034
July	1.37 (0.26)	7.35 (0.42)	NS	0.034
August	3.99 (0.39)	10.42 (2.12)	NS	0.034
1994				
May	0.76A ^d (0.17)	1.62A (0.31)	1.28A (0.75)	0.186 ^c
June	3.96A (0.55)	9.37A (0.90)	14.87A (8.81)	0.089 ^c
July	5.49A (2.00)	16.65B (3.06)	10.24AB (5.02)	0.089 ^c

^aMann-Whitney U test (1993 data) and Kruskal-Wallis one-way analysis of variance (1994 data) (Siegel 1956).

^bNS = Not sampled in 1993.

^cSignificant difference ($P < 0.10$) detected between native and introduced sites using the Mann-Whitney U test (Siegel 1956).

^dMeans on the same line with the same letter are not significantly different ($P > 0.10$) (Kruskal-Wallis multiple comparison statistic (Siegel 1988)).

Table 23. Mean Shannon-Weaver diversity indices (standard errors) for invertebrate taxa collected on native and introduced grasslands in Allegan County and switchgrass sites in Barry County, Michigan, 1993 and 1994.

Year	Grassland types			Probability level ^a	
	Sampling period	Native	Introduced		Switchgrass
1993					
	May	1.30 (0.12)	1.58 (0.09)	NS ^b	0.157
	June	1.29 (0.12)	1.74 (0.05)	NS	0.034
	July	1.53 (0.23)	1.64 (0.04)	NS	0.724
	August	1.52 (0.03)	1.45 (0.13)	NS	0.480
1994					
	May	1.42 (0.05)	1.58 (0.13)	1.36 (0.04)	0.352
	June	1.60 (0.17)	1.30 (0.05)	1.38 (0.25)	0.283
	July	0.92 (0.19)	0.83 (0.15)	1.33 (0.16)	0.132

^aMann-Whitney U test (1993 data) and Kruskal-Wallis one-way analysis of variance (1994 data) (Siegel 1956).

^bNS = Not sampled in 1993.

Herptile Species Composition

Herptiles observed on introduced sites included the blue racer (*Coluber constrictor*), Eastern box turtle (*Terrapene carolina*), painted turtle (*Chrysemys picta*), and red-backed salamander (*Plethodon cinereus*). Blue racers and 1 unidentified turtle were seen on native sites. Garter snakes (*Thamnophis sirtalis*) and painted turtles were observed on switchgrass sites.

DISCUSSION

Plant Species Composition and Diversity

The shift in relative occurrences of different grass species on native sites from May to July occurred because many of the native grasses, such as big bluestem (*Andropogon gerardii*) and little bluestem, are warm-season grasses which remain dormant throughout spring and early summer, and begin growth after many introduced cool-season grasses have flowered (Tables 2-5). Growth of poverty oatgrass peaked in July, and little bluestem and purple needlegrass (*Aristida purpurascens*) did not mature until August. Growth of panic grasses on native sites was evident throughout the May and July sampling periods, and flowering occurred in July. The most common grasses on introduced sites, Kentucky bluegrass and quackgrass (Tables 2-5), are cool-season grasses that flowered in May and June. Although study sites were classified as "native" or "introduced" based on whether native or introduced grasses were most prevalent, grasses of both origins were present in varying proportions on most sites. Two introduced sites also had a small native grass component which became evident in the frequency values for July (Tables 4 and 5).

The relatively high number of plant species (24) that were restricted to the upland native sites illustrates the unique nature of the plant community present on these sites.

The upland native grasslands examined can be characterized as oak savanna, and more specifically, oak barrens, based on the presence of prairie vegetation, such as big and little bluestem, blazing star (*Liatris* spp.), and flowering spurge (*Euphorbia corollata*), and their transitional relationship with closed canopy oak forest (Mich. Dept. Nat. Resour. 1993). Introduced grasslands resembled old field sites, containing common introduced grasses such as quackgrass and Kentucky bluegrass, and a greater proportion of introduced forb species than native sites (Tables 2-5). Switchgrass sites were different from the other types of sites studied in that the dominance of switchgrass was achieved through planting, and the remainder of forbs and grasses are likely a result of the disturbance associated with planting switchgrass. Planting of switchgrass sites also explains the low plant species richness (Fig. 2) and the slightly lower plant species diversity in comparison to native and introduced sites (Table 6).

Vegetative Structure

Differences among grassland types

Native sites consistently had less live vegetative cover than introduced sites. Of the 3 measurements that comprise live cover (forb cover, grass cover, and woody cover), differences in forb cover contributed most heavily to the total live cover values. A combination of several factors could be responsible for the relative lack of vegetative cover on native sites. One potential source of the difference between native and introduced sites may be differences in soil moisture. While native and introduced sites occurred on the same general soil type (Oakville fine sand), soils tended to be drier on

native than introduced sites (Tables 8-11). The lower soil moisture on native sites may be an effect of less vegetative cover on native sites, or it may be one of the factors allowing native grasses to outcompete introduced grasses on these sites. Beirne (1995) found that sites with poor quality soil types were dominated by native grass species, and a greater proportion of introduced species occurred on sites with better quality soils. He reasoned that native species have evolved to cope with the more stressful environmental conditions associated with poorer quality soils, while introduced grasses had evolved where more resources were available. In this study, soil moisture may have been a limiting resource that similarly influenced plant species composition and productivity on native and introduced sites.

The history of fire suppression and lack of disturbances on the study sites may also have played a critical role in the current vegetative structure and composition of native sites. Natural wildfires are considered to have been a dominant force in shaping the native grassland communities of the Midwest (Daubenmire 1968, Anderson 1970). Wildfires also maintained grasslands in an early successional stage by preventing invasion of woody species, although the frequency at which these fires occurred is not known (D. Albert, MNFI, pers. commun.). The native sites investigated in this study appear to be undergoing woody encroachment as a result of fire suppression. While introduced sites tended to have more woody saplings and seedlings, native sites had significantly greater densities of woody species, primarily oaks, accompanied by more woody canopy cover than introduced sites (Table 13). Development of woody vegetation on native sites may limit the amount of light to ground vegetation, reducing soil

temperature and productivity. Under dry conditions, trees may help retain soil moisture, but under conditions of normal precipitation, trees can also reduce throughfall to the ground beneath their canopies, which may in turn limit productivity of a site (Ko and Reich 1993).

Many native forb and grass species are adapted to the effects of wildfires and increase growth in response to a burn. Numerous studies (Kucera and Koelling 1964, Rice and Parenti 1978, Niering and Dreyer 1989, Tester 1989) have demonstrated increased growth and vigor of prairie grasses, such as big and little bluestem, *Panicum oligosanthos*, and switchgrass, in response to burning. Certain native forbs present on native and introduced sites, including round-headed bushclover (*Lespedeza capitata*) and flowering spurge (*Euphorbia corollata*) may also respond to burning with increased growth (Dubis et al. 1988, Tester 1989). Because the dominant grasses and a greater percentage of forbs on introduced sites did not evolve in response to fire, the absence of fire is not as likely to have a dramatic effect on the composition of introduced sites. However, the introduction of fire to these sites could increase the native species component that is present on these sites.

Switchgrass sites also had significantly less forb cover than introduced sites, but this difference was partially balanced by a greater proportion of grass cover on switchgrass sites than on other sites (Tables 9 and 11). The greater ratio of grass cover to forb cover on switchgrass sites is a logical result of the advantage given to switchgrass through mechanical planting. The combination of grass and forb cover contributed to a live cover value that was not significantly different from the other types of sites, but this

value was still considerably lower than on introduced sites.

Based on the limited vegetation sampling conducted on wet native sites, these grasslands appeared structurally similar to switchgrass sites. Both types of grasslands had an abundance of tall grass and layers of dead vegetation (Tables 9 and 11). Very few trees were present on wet native sites, presumably because of the water level fluctuations that occur. The soil moisture measurements on the 1 site that was sampled are not representative of the other wet native sites. In 1994, this site was dry when sampling began, and remained dry throughout the summer. The other 2 sites remained flooded until the end of July, and even after standing water disappeared, the soil was often mucky, and sites flooded again at the end of the summer after a period of heavy rain.

Grass cover was greater on introduced than on native sites in May (Tables 8 and 9), primarily as a result of the earlier flowering time of the dominant introduced grass species. In July, this difference disappeared as growth of some native grasses accelerated (Tables 10 and 11). The increase in grass growth was particularly evident in July of 1993 (Table 10), and can be attributed to the prevalence of big bluestem, which tends to grow more vigorously and accounts for more cover in proportion to its frequency than little bluestem, on 1 of the native sites. This site was the one that was burned the following spring and the site that replaced it in 1994 sampling had a much lower proportion of big bluestem. Therefore, average grass cover of native sites in July, 1994 were not as great as in July, 1993.

Contrary to reports of other native grasslands that had not been recently burned, litter accumulation was not excessive on native or introduced sites examined in this

study. Other researchers have noted litter depths from 7 cm (Rice and Parenti 1978) up to 30 cm (Hulbert 1988) on tallgrass prairies that had remained unburned for as little as 4 years. Although litter covered a substantial proportion of the ground on most sites in this study, litter depth did not exceed an average of 1.8 cm on any of the sites. Native and introduced sites did not differ in the percentage of ground covered by litter, but litter on introduced and switchgrass sites tended to be deeper than on native sites, and probably reflected the greater vegetative cover associated with these sites.

The taller live vegetation on introduced sites compared to native sites throughout the study may reflect the time of year in which sampling occurred, and the fact that some native grasses may not achieve their maximum height until August or September, while the introduced grasses flowered in May and June (Tables 8-11). This variable may also have been influenced by the abundance of forbs on introduced sites, which often grew taller than the grasses, and may have dominated the measurements of maximum live height on introduced sites. Switchgrass sites had the tallest vegetation of the 3 types of sites, mainly due to the combination of switchgrass' tall growth form and slightly more productive soils (Coloma loamy sand) present on switchgrass sites (Tables 9 and 11).

Horizontal cover at ground level (0-30 cm) tended to be greater on both introduced and switchgrass sites than on native sites, suggesting that more hiding cover is available to wildlife on these 2 types of grasslands (Table 12). At strata above 30 cm, horizontal cover was greater on native and switchgrass sites than on introduced sites. Greater cover on the switchgrass sites is most likely due to the height of the grass, while the greater cover on native sites is probably attributable to the greater density of mature

trees on these sites (Table 13).

Differences between sampling periods

As the growing season progressed from May to July, live vegetative cover and height increased on all sites. Litter cover, litter depth, and dead canopy cover decreased significantly as the dead vegetation decomposed over the summer and was replaced by new growth (Tables 8-11). In this study, dead vegetation was distinguished from litter as vegetation that was still attached to the ground, while vegetation lying loose on the ground was considered litter. On switchgrass sites, litter cover decreased from May to July while dead vegetative cover and the maximum height of dead vegetation remained constant. Dead vegetation height represents the height of dead switchgrass, and the fact that this variable remained constant indicates that it was the height of dead switchgrass, rather than forbs, that did not change. Because percent dead vegetative cover also did not change during the summer, one may conclude that forb material decomposed throughout the summer, while dead switchgrass resisted decomposition. The persistence of dead switchgrass makes it especially valuable to wildlife as a source of cover during winter when cover may be limiting elsewhere (Frank and Woehler 1969, Birney et al. 1976).

Principal Components Analysis

Principal components analysis of vegetative variables measured on native, introduced, and switchgrass sites was useful for describing the characteristics of each type of site, relative to the other sites included in the analysis. Results of PCA also corroborate differences in vegetative structure determined by nonparametric comparisons

among sites.

In May, 1993, native grasslands were characterized as having a high proportion of dead vegetation and a low proportion of live vegetation (Fig. 3). Introduced grasslands, however, were distinguished based on their greater ratio of live to dead canopy cover. This difference was also detected with the Mann-Whitney U test, and appears to be a critical variable for describing differences between native and introduced grasslands within this sampling period.

Although the second principal component allows native sites to be described as having a balance between bare ground, and trees and live vegetation at the middle stratum, introduced sites had characteristics at both extremes of the gradient. Therefore, none of these variables were descriptive of all introduced sites for the May sampling period. Similarly, the variables of the third principal component, describing a gradient from dead vegetation height to bare ground, were not useful for characterizing a particular type of grassland.

In July, 1993, the first principal component showed that 2 native sites had greater tree densities >2 m in relation to percent live canopy cover (Fig. 4). One native site and the 4 introduced sites had more live cover and fewer trees. The one native site weighted more heavily towards live cover was the same site noted previously for a surge in grass canopy cover in July due to the prevalence of big bluestem, and this may explain its discontinuity with the other 2 sites. Apparently, percent live canopy cover is the most useful variable for describing introduced sites throughout the 1993 sampling period. On native sites, dead vegetation is the most useful variable for describing native sites in May,

while in July, tree density >2 m is the most descriptive variable, in relation to the other variables measured.

Principal component analyses from 1993 and 1994 are not directly comparable because of the addition of switchgrass sites to the analysis in 1994. In May, 1994, native sites were described as having a moderate proportion of forb cover to dead canopy cover and dead vegetation height (PC 1), greater litter cover in relation to tree density <2 m (PC 2), and a large proportion of vegetation in the 31 cm-2 m stratum (Fig. 5). The relationship between litter cover and density of trees <2 m is unclear, and may be a consequence of the different techniques used to measure each variable (square plots vs. belt transects). The tendency of tree seedlings to occur in clumps, while litter cover was more homogeneously distributed throughout a site, may also have obscured this relationship.

Introduced grasslands had a very high ratio of forb canopy cover to dead canopy cover (PC 1), and a less prominent canopy layer at 31 cm-2 m (PC 3), but could not be distinguished on the basis of litter cover and tree density (PC 2) in May, 1994 (Fig. 5). Switchgrass sites had very low forb cover in relation to dead canopy cover and dead vegetation height, moderate proportions of litter cover and tree density <2 m, and a moderate proportion of vegetation in the middle stratum. The prevalence of dead vegetation and the relatively taller dead vegetation on switchgrass sites was also recognized in nonparametric comparisons of the 3 types of grasslands. However, it is difficult to describe switchgrass fields in terms of the second principal component (litter cover and tree stem density). Trees were virtually absent from switchgrass sites, and the

relationship of this observation to PCA results is ambiguous.

In July, 1994, the first principal component explained over half the total variance. This component again described switchgrass sites as having a greater proportion of dead canopy cover to forb cover, with native and introduced sites resembling each other in terms of these 2 variables (Fig. 6). Principal component 2 distinguished native sites as having a relatively greater tree density and more bare ground, as opposed to introduced sites, which had a greater proportion of forb canopy cover in relation to tree density and bare ground. Switchgrass sites tended to have low values for percent bare ground, tree density, and live canopy cover, with little evidence of a relationship among the variables. Therefore, switchgrass sites did not occupy a discrete position along the gradient described by PC 2.

Bird Species Composition and Diversity

No consistent differences in bird species composition were observed between native and introduced sites. Although a number of bird species observed on introduced sites were not encountered on native sites, these birds occurred sporadically and did not appear to have a strong association with introduced sites.

The relatively small size of the grasslands in this study makes it unlikely that avian communities associated with the grasslands were distinct from the surrounding habitat. Both types of grasslands in this study were clearly dominated by birds associated with edge and woody habitats (Table 15). For example, the rufous-sided towhee (*Pipilo erythrophthalmus*) and indigo bunting (*Passerina cyanea*) are associated with a range of

forest block sizes (Forman et al. 1976), and both black-capped chickadees and tufted titmice nest in tree cavities. With study sites of such a relatively small size, measures of bird species diversity do not provide information about the strength of birds' dependence on the study sites to meet their habitat requirements, but they may give an indication of the abundance and taxonomic distribution of birds appearing on these grasslands during census periods.

Species diversity of birds censused on introduced sites was generally greater than that on native sites. Often only 1 species was observed using native sites during a given point count, resulting in a diversity value of 0 for that observation, while several species were usually recorded using introduced sites at a time. Lower bird species diversities on native sites in this study may be related to the later flowering times observed for native grasses such as little bluestem, panic grasses, and purple needlegrass present on native grass sites, and to significantly less grass and forb cover on native sites (Tables 8-11, Figs. 3-6)). Auffenorde and Wistendahl (1985) observed 2 graminaceous flowering pulses, one in late May and another in August, presumably corresponding to the flowering times of the introduced and native grasses, respectively, found on their grassland study area. The phenology of grasses dominating each type of site in this study may have influenced foraging opportunities for birds and the availability of hiding cover within the grasslands.

In July of 1994, bird species diversity on native sites was slightly greater than on introduced sites, and higher than in any previous census periods (Table 14). Diversity values may have been boosted by the activities of recently fledged young, since no

corresponding shifts in vegetative characteristics or weather patterns were evident that might account for the apparent surge in diversity. Bird species diversity on both types of sites also appeared to be greater in 1994 than in 1993 (Table 14), and this pattern may be attributed to a decrease in the number of unidentified birds as field observers became more experienced at bird identification.

A cutoff point of a relative observation frequency $\geq 5\%$ was used to identify the birds that are most likely using the grassland study sites to meet their habitat requirements. By focusing analyses on bird species that used the study sites most intensively, the influence of birds associated more strongly with the surrounding habitat could be minimized. Although fewer significant differences were detected in bird species diversity between grassland types, and diversity in general was reduced, no new patterns in diversity became obvious through this procedure (Table 16).

The most frequently observed activity of birds censused on study sites was moving through the site (Table 17). Many of these birds may have been able to meet all of their habitat requirements in the surrounding habitat, and were only using the grasslands sporadically. However, many birds seen moving could also have been feeding or socializing in some way that was not apparent to the observers, or observers may only have been alerted to the birds' presence when the birds were moving. Singing was the second most frequently observed activity of birds using the study sites (Table 17). Birds heard singing may have been defending a portion of the grassland resources that fell within their territory, or they may have been using the visibility provided by the open grassland to attract a mate.

Very few active bird nests were found on native sites, compared to introduced sites. Nests found on native sites represented 3 different bird species, and nests belonging to 6 bird species were identified on introduced sites. Additional species, particularly cavity nesters whose nests may be inconspicuous during a nest search, may also have used native and introduced study sites for breeding activities. Apparently, however, only a small subset of species censused on each site, such as field sparrows and vesper sparrows, actually nest within the grassland. The majority of birds on both types of sites probably nest in the surrounding forest and utilize the grassland to meet additional habitat requirements. For example, rose-breasted grosbeaks (*Pheucticus ludovicianus*) nest in trees or shrubs in deciduous forests (Carlson 1991), and scarlet tanagers (*Piranga olivacea*) commonly breed in oak woodlands (Pinkowski 1991). Furthermore, in a related study of bird communities in forests adjacent to the grassland sites used in this study, blue jays, tufted titmice, eastern wood pewees, and black-capped chickadees were all frequently observed in the adjacent forest, although they were also observed on grasslands (Meier et al., unpubl. data).

Nest density on switchgrass sites was intermediate between native and introduced sites, and represented nests of 4 bird species. A substantial amount of cover was provided by standing dead switchgrass (Tables 9 and 11), and the turkey and mallards probably chose to nest on switchgrass sites because of the concealment provided by the tall, dense switchgrass. Vegetation height may also be an important factor determining avian nesting success, since nests placed in relatively taller vegetation may be less susceptible to mammalian predation (Best 1978). Because switchgrass sites were not

censused for songbirds, and small mammal traps covered a smaller proportion of the field on these sites, fewer opportunities existed to discover nests outside of nest searching. As a result, nest density was undoubtedly underestimated on switchgrass sites.

Small Mammal Abundance and Diversity

Factors similar to those affecting avian use of study sites may have been responsible for differential use of native, introduced, wet native, and switchgrass sites by small mammals. Geier and Best (1980) found that forb cover and plant species abundance were the variables most often related to small mammal abundance within different habitat types. They noted a negative relationship between small mammal abundance and plant species richness, and a positive association between mammal abundance and percent forb cover. In this study, small mammal abundance was greatest on wet native sites and lowest on native sites (Tables 18 and 19), while mammal species diversity was greatest on introduced and switchgrass sites (Table 21).

In 1993, trapping success was low on all study sites, compared to 1994. This may have been due to natural population fluctuations, as reported by other researchers (Grant and Birney 1979, Eaton 1986). Rainfall was also exceptionally heavy in 1993, as documented by weather stations in the Allegan area, where above average precipitation was recorded in June, 1993 (Natl. Oceanic and Atmos. Adm. 1993). Soil moisture levels were also significantly greater in 1993 than in 1994 on native and introduced sites. Heavy rains may have restricted small mammal movement and caused traps to spring accidentally.

The dominance of *Peromyscus* on native sites may reflect the relatively low forb cover and the presence of mature trees on the native grasslands examined. Deer mice (*Peromyscus maniculatus*) are often associated with areas of relatively little vegetative cover (Peterson et al. 1985, Dubis et al. 1988), and white-footed mice (*P. leucopus*) are found in a variety of habitats, often in the presence of trees (Getz 1961a) or in open areas with moderate amounts of cover (Dubis et al. 1988). Deer mice use nests below ground and are not dependent on a litter layer in their habitat (Peterson et al. 1985), as are other small mammals. Thus, the sparser ground cover on native sites may have provided habitat that was primarily suited to *Peromyscus* species. Of the 4 types of grasslands, *Peromyscus* were most abundant on wet native sites (Table 19). However, since wet native sites had well developed layers of live and dead grasses, and very little woody vegetation, a variable other than sparse vegetative cover was probably responsible for the large number of captures on these sites. Perhaps the availability of grasses and grass seeds on wet native sites provided an attractive food source to *Peromyscus* species.

Meadow voles avoid wooded areas and prefer grassy habitats that provide sufficient cover to accommodate the runway systems they use (Getz 1961b). Getz (1961b) considered grass to be the most important component of the meadow vole's diet and reported an avoidance of areas containing only forbs, while Huntly and Inouye (1987) found *Microtus* abundance to be positively correlated with total plant cover and suggested that forbs, as the preferred food source, may be limiting in some habitats. The dominance of meadow voles on switchgrass sites supports Getz's findings, since switchgrass sites had an abundance of grassy vegetation and very low forb cover (Tables

9 and 11, Fig. 5). Additionally, Furrow (1994) observed an abundance of meadow voles associated with areas of dense litter and grass cover. Meadow voles might have avoided native sites because a lack of cover may have hindered their construction of runways and limited their food supply and protection from predators. Schwartz and Whitson (1986) also cited low abundances of meadow voles on a restored prairie, which they attributed to a lack of litter accumulation caused by frequent burning, mowing, and herbicide treatments.

Meadow jumping mice are known to inhabit a range of vegetative conditions, but are found most frequently in moist habitats. They avoid sparsely vegetated areas, presumably because moisture is low (Getz 1961a). Thus, it is not surprising that meadow jumping mice were abundant on wet native sites, in which the ground was often wet, as well as on switchgrass and introduced sites where enough vegetation was present to meet the habitat requirements of this species (Table 19). Again, native grass dominated sites most likely lacked the vegetative resources necessary for meadow jumping mice to occur.

Short-tailed and masked shrews likewise avoid extremely dry areas, and are found in a variety of habitats where moisture is adequate (Getz 1961c). There is also evidence that shrews prefer areas with an accumulation of leaf litter (Schramm and Wilcutts 1983), and when present in open habitats, may choose sites with more shrubs and tree saplings (Cranford and Maly 1986). Short-tailed shrews were trapped on all 4 types of sites, but tended to be more common on introduced and switchgrass sites (Table 19). Assessment line capture rates were greater than grid capture rates for native, introduced, and wet native grasslands, indicating that shrews prefer the forested areas adjacent to the

grassland habitat (Table 20). It is surprising that so few shrews were captured on wet native sites, since these would be expected to meet their moisture requirements. Shrews were caught at similar rates on the assessment lines of native and introduced sites, but at a lower frequency on the assessment lines of wet native sites, suggesting that the low abundance of shrews may extend beyond the limits of the grassland on wet native sites. It is also likely that the abundance of shrews was underestimated with the trapping method and the bait used, since shrews may burrow beneath leaf litter and are primarily insectivorous. Perhaps bait with a higher protein content, such as peanutbutter, would have been preferable to the mixture of lard, oats, and anise extract that was used for catching shrews.

Chipmunks, which are known to be associated with woody vegetation (Geier and Best 1980), were only captured on the grids of introduced and wet native sites (Tables 18 and 19). These captures always occurred along the perimeter of smaller study sites, where traps were located in close proximity to the adjacent forest. Chipmunks also were trapped on the assessment lines of the 3 types of grasslands on which assessment lines were used, where these lines ran through wooded habitat (Table 20).

The lower small mammal species diversity on upland native and wet native grasslands may be attributed to the abundance of *Peromyscus* spp., which were the dominant species captured, while all other species occurred in much smaller numbers. Introduced sites had more equal proportions of *Peromyscus* spp. and meadow voles, as well as representation of a number of other species, and species diversity was correspondingly greater. In May and June, 1994 diversity appeared to be much greater on

introduced than on native sites, but differences were not statistically significant because there was high variance among the diversity values for introduced sites (Table 21).

Finally, switchgrass sites provided a habitat that was utilized almost equally by *Peromyscus* spp., meadow voles, and meadow jumping mice, along with lower numbers of additional species. The vegetative structure of switchgrass sites may offer the advantage of allowing small mammals to move around beneath the snow more easily in the winter, making this habitat more attractive to small mammals.

Invertebrate Abundance and Diversity

Information about invertebrate relative abundance and diversity on each type of grassland is important because insects are a primary food source for many birds (Cody 1985), as well as for some small mammals such as shrews (Getz 1961c). Also, insects often depend on a specific plant species for a portion of their life cycle and may be particularly susceptible to degradation of their habitat (Panzer 1988). This is the case with the federally endangered Karner blue butterfly (*Lycaeides melissa samuelis*), which is dependent on the presence of wild lupine (*Lupinus perennis*) in an oak barrens habitat, and which was present on at least 1 native site.

Differences in invertebrate biomass between native and introduced sites throughout the summer (Table 22) may partially explain the bird species diversity values associated with each type of site. The lower insect abundance on native sites may again have been related to the lower amounts of vegetation, particularly forbs, present on these sites (Tables 8-11). Evans (1988) reported that the number of grass-feeding grasshoppers

was independent of the amount of grass present on a site, but the number of forb-feeding grasshoppers was limited by the abundance of forbs. Differences in insect biomass may also be a result of the collecting method used, because the efficiency of sweepnets may depend on the vegetative attributes of a particular habitat. For example, because native sites tended to have more large trees, a significant segment of the insect community may not have been represented in the data, and any other insects outside of the herbaceous layer were also excluded by the sampling technique used.

Insect biomass generally tended to increase throughout the season, most likely in response to the concurrent increase in plant abundance (Table 22). The apparent fluctuation in biomass on switchgrass sites among May, June, and July is due primarily to 1 field having a very high abundance of grasshoppers in June.

In all but 1 sampling period, invertebrate taxonomic diversity did not differ statistically among the different types of grasslands (Table 23). Identification of insects to Order may not be sufficient to detect differences in insect communities among study sites, and if differences exist, more explicit identification at the Family level or below may be necessary to reveal them.

SUMMARY AND RECOMMENDATIONS

Data collected in 1993 and 1994 on unmanaged native, introduced, and wet native grasslands, and planted switchgrass fields, indicated that vegetative attributes, and songbird, small mammal, and invertebrate abundance and diversity differed among grassland types. Native sites were characterized by shorter vegetation, less vertical cover, less horizontal cover at ground level, and drier soils than introduced grasslands and switchgrass sites. Switchgrass and native sites also tended to have more horizontal cover >30 cm than introduced sites, while introduced sites had the greatest amounts of forb cover. Plant species composition differed among grassland types as well, with native sites having the greatest number of unique plant species.

Species diversity of birds associated with introduced grasslands was generally greater than on native sites. Bird species composition and diversity may have been influenced by the amount of ground vegetation available for foraging and hiding cover, and by structural variables such as the height of the vegetation and degree of woody vegetation present in the habitat.

Coastal plain marshes (wet native grasslands) and planted switchgrass sites were examined to a lesser extent than native and introduced grasslands, but both types of sites appeared to provide habitat for an abundance of small mammals. Small mammal species

diversity tended to be greater on introduced and on switchgrass sites than on native sites, while wet native sites contained the greatest densities of small mammals. Differences in the amount of hiding cover available and the availability of grasses are variables that may have influenced the species and abundance of small mammals that used each type of grassland.

Because Michigan is at the northernmost range of the historic occurrence of tallgrass prairie (Transeau 1935), native grasslands are in an ecologically precarious position, making them sensitive to small shifts in disturbance patterns that would allow other vegetation types to dominate. The unique plant community of native grasslands examined in this study is evidence of their ecological importance, but competition from introduced grasses and invasion of woody vegetation pose a threat to these systems. Wildlife responses to upland native grasslands, compared with introduced grass dominated sites, indicated that these native grasslands may be providing a narrow range of habitat conditions for invertebrates, birds and small mammals. It is important to implement management to perpetuate the unique characteristics of these systems, and by doing so, habitat for grassland wildlife species may also be improved.

Fire has historically been a controlling force in Michigan's native grassland communities (Daubenmire 1968), and is likely to be useful in the management of these areas. Prescribed burning of native and introduced grasslands could increase the cover of native grasses and forbs, while maintaining the structural variation necessary for a diversity of wildlife. Burning will also set back succession, thereby maintaining open grasslands for species that require early successional habitat. Although the frequency at

which fires naturally occurred in Michigan native grasslands is not known, periodic burning at 5 to 10 year intervals may achieve the results that likely occurred under a natural fire regime. More frequent burning might prevent accumulation of litter, and less frequent intervals could allow woody encroachment onto the grasslands. Over time, burning may also help extend the boundaries and increase the area of native grasslands, which is critical for providing habitat for grassland birds that require a larger grassland area than is currently provided by study sites. Selective tree removal within grasslands may also provide a more immediate means of setting back succession.

Competition with introduced grass species has most likely narrowed the range of site conditions under which native grasses can grow successfully to sites where fewer resources are available. Some of the introduced sites examined currently have a native grass component which competition with introduced grasses may be suppressing. On these sites, it may be desirable to implement prescribed burning as a means of controlling some of the introduced species. For example, spring burning in March or April, when native grasses are dormant, can shift the competitive advantage away from Kentucky bluegrass towards native forb species (Curtis and Partch 1948, Abrams and Hulbert 1987). Burning has also been found to decrease the cover of nonnative forbs such as sheep sorrel (*Rumex acetosella*) (Niering and Dryer 1989) and northern dewberry (*Rubus flagellaris*) (Dubis et al. 1988), 2 very pervasive plants on both native and introduced sites.

Coastal plain marshes are extremely important because of their limited geographic distribution. These areas may be sensitive to the same factors that threaten upland native

grasslands, and may benefit from less frequent controlled burning as a means of emulating natural disturbance patterns. Spring burning on wet native sites may be useful for preventing woody encroachment and maintaining a diversity of native grasses and forbs. Coastal plain marshes also contain several threatened and endangered plant species, which should be considered before implementing any management.

Switchgrass sites have been more recently managed than the other types of sites, but as they age, litter accumulation may lead to a decrease in plant productivity, and a decline in wildlife habitat quality. Some form of disturbance to reduce litter buildup, such as fire, may also be beneficial in maintaining the vigor of switchgrass stands, and may contribute to an increase in forb species diversity. Burning frequency on switchgrass sites should be based on rates of litter accumulation, and their effects on the productivity of the stand.

Because none of the study sites, except switchgrass sites, have been recently managed, it is important to investigate the effects of prescribed burning on each type of grassland. Little is known about historic fire frequencies on each type of grassland, and in addition to the effects of prescribed burning, research is also needed on the specific conditions under which burning would most successfully maintain the desired habitat conditions on each type of grassland. In determining the best approach for managing these areas, it may also be useful to consider the influence of small native grasslands on plant and wildlife populations at a larger spatial scale. The impact of the habitat surrounding the grasslands is apparent in the bird communities associated with the study sites, but the role of these grasslands on wildlife populations throughout the game area,

and the influence of any management practices that might be implemented on these sites, should be investigated as well.

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APPENDICES

Appendix A. Plant species identified on native and introduced grasslands in Allegan County, and switchgrass sites in Barry County, Michigan, May-July, 1993 and 1994.

Species	Scientific name
Big bluestem (I,N)	<i>Andropogon gerardii</i>
*Black oatgrass (N)	<i>Stipa avenacea</i>
Canada bluegrass (I,N)	<i>Poa compressa</i>
*Commons panic grass (I,N)	<i>Panicum commonsianum</i>
Downy chess (S)	<i>Bromus tectorum</i>
*Few-flowered panic grass (I,N)	<i>Panicum oligosanthos</i>
*Junegrass (N)	<i>Koeleria cristata</i>
Kentucky bluegrass (I,N)	<i>Poa pratensis</i>
*Little bluestem (I,N)	<i>Andropogon scoparius</i>
*Panic grass (I,N,S)	<i>Panicum capillare</i>
*Poverty oatgrass (I,N)	<i>Danthonia spicata</i>
*Purple needlegrass (N)	<i>Aristida purpurascens</i>
Quackgrass (I,N,S)	<i>Agropyron repens</i>
Rye (S)	<i>Secale cereale</i>
Smooth brome (I)	<i>Bromus inermis</i>
*Starved panic grass (I,N)	<i>Panicum depauperatum</i>
*Switchgrass (S)	<i>Panicum virgatum</i>
*Ticklegrass (N)	<i>Agrostis hyemalis</i>
Bastard toadflax (I,N)	<i>Comandra umbellata</i>
Black-eyed Susan (I)	<i>Rudbeckia hirta</i>
Blue toadflax (N)	<i>Linaria canadensis</i>
Bouncing bet (N)	<i>Saponaria officinalis</i>
Bracken fern (I,N)	<i>Pteridium aquilinum</i>
Bull thistle (S)	<i>Cirsium vulgare</i>
Butterflyweed (I,N)	<i>Asclepias tuberosa</i>
Clammy ground cherry (I,N)	<i>Physalis heterophylla</i>
Cleavers (I)	<i>Galium aparine</i>
Common cinquefoil (S)	<i>Potentilla simplex</i>
Common mullein (I,S)	<i>Verbascum thapsus</i>
Common St. Johnswort (I,N,S)	<i>Hypericum perforatum</i>
Corn speedwell (I,S)	<i>Veronica arvensis</i>
Cow vetch (I)	<i>Vicia cracca</i>
Cylindric blazing star (N)	<i>Liatris cylindracea</i>
Deptford pink (S)	<i>Dianthus armeria</i>
Dwarf dandelion (N)	<i>Krigia virginica</i>
False boneset (I)	<i>Kuhnia eupatorioides</i>
Field hawkweed (I,N,S)	<i>Hieracium caespitosum</i>
Field pansy (I,S)	<i>Viola raffinesquii</i>
Field peppergrass (I)	<i>Lepidium campestre</i>

Appendix A (Cont).

Species	Scientific name
Flowering spurge (I,N)	<i>Euphorbia corollata</i>
Frostweed (I,N)	<i>Helianthemum canadense</i>
Goat's rue (N)	<i>Tephrosia virginiana</i>
Goldenrod spp. (N)	<i>Solidago</i> spp.
Gray goldenrod (N)	<i>Solidago nemoralis</i>
Greenbrier (N)	<i>Smilax rotundifolia</i>
Hairy bedstraw (N)	<i>Galium pilosum</i>
Hairy bushclover (N)	<i>Lespedeza hirta</i>
Hairy hawkweed (N)	<i>Hieracium gronovii</i>
Hairy vetch (I,N,S)	<i>Vicia villosa</i>
Hoary alyssum (I,S)	<i>Berteroa incana</i>
Hoary puccoon (I,N)	<i>Lithospermum canescens</i>
Honeysuckle (N)	<i>Lonicera</i> spp.
Horsemint (I,N,S)	<i>Monarda punctata</i>
Horse nettle (I,N,S)	<i>Solanum carolinense</i>
Horseweed (S)	<i>Conyza canadensis</i>
Hyssop (S)	<i>Hyssopus officinalis</i>
Lance-leaved coreopsis (I,N)	<i>Coreopsis lanceolata</i>
Late low blueberry (I)	<i>Vaccinium angustifolium</i>
Long-bearded hawkweed (N)	<i>Hieracium longipilum</i>
Long-headed thimbleweed (I,N)	<i>Anemone cylindrica</i>
Milkweed (N,S)	<i>Asclepias</i> spp.
Northern dewberry (I,N,S)	<i>Rubus flagellaris</i>
Ohio spiderwort (I)	<i>Tradescantia ohiensis</i>
Orange hawkweed (N)	<i>Hieracium aurantiacum</i>
Pasture rose (I,N)	<i>Rosa carolina</i>
Pennsylvania sedge (I,N)	<i>Carex pennsylvanica</i>
Poison ivy (I)	<i>Toxicodendron radicans</i>
Prickly pear (N)	<i>Opuntia humifusa</i>
Queen Anne's lace (N)	<i>Daucus carota</i>
Racemed milkwort (N)	<i>Polygala polygama</i>
Rough blazing star (N)	<i>Liatris aspera</i>
Rough-fruited cinquefoil (I,N,S)	<i>Potentilla recta</i>
Round-headed bush clover (I,N)	<i>Lespedeza capitata</i>
Sheep sorrel (I,N,S)	<i>Rumex acetosella</i>
Slender knotweed (I)	<i>Polygonum tenue</i>
Smooth Solomon's seal (I)	<i>Polygonatum biflorum</i>
Smooth tick trefoil (N)	<i>Desmodium marilandicum</i>
Spotted knapweed (I,N,S)	<i>Centaurea maculosa</i>
Spreading dogbane (I)	<i>Apocynum androsaemifolium</i>

Appendix A (Cont).

Species	Scientific name
Sweet everlasting (I,N,S)	<i>Gnaphalium obtusifolium</i>
Tall wormwood (I,N)	<i>Artemisia campestris</i>
Thyme-leaved sandwort (I,S)	<i>Arenaria serpyllifolia</i>
Tower mustard (I,N)	<i>Arabis glabra</i>
Venus' looking glass (S)	<i>Triodanis perfoliata</i>
Wandlike bushclover (N)	<i>Lespedeza intermedia</i>
Western ragweed (I)	<i>Ambrosia psilostachya</i>
Whorled milkweed (N)	<i>Asclepias verticillata</i>
Wild bergamot (I)	<i>Monarda fistulosa</i>
Wild lettuce (S)	<i>Lactuca canadensis</i>
Wild lupine (I,N)	<i>Lupinus perennis</i>
Wild peppergrass (I,S)	<i>Lepidium virginicum</i>
Wild strawberry (I,N,S)	<i>Fragaria virginiana</i>
Winged sumac (N)	<i>Rhus copallina</i>
Yarrow (I,S)	<i>Achillea millefolium</i>
Yellow goatsbeard (N,S)	<i>Tragopogon pratensis</i>
Yellow wood sorrel (S)	<i>Oxalis stricta</i>
American birch (N)	<i>Betula papyrifera</i>
Black cherry (I,N)	<i>Prunus serotina</i>
Red oak (I,N)	<i>Quercus rubra</i>
Sassafras (I,N)	<i>Sassafras albidum</i>
White oak (I,N)	<i>Quercus alba</i>

* = Native grass species

^aI = Found on introduced sites, N = Found on native sites, S = Found on switchgrass sites

Appendix B. Bird species censused on native and introduced grasslands in Allegan County, Michigan, May-July, 1993 and 1994.

Species	Scientific name
American goldfinch (I,N) ^a	<i>Carduelis tristis</i>
American robin (I,N)	<i>Turdus migratorius</i>
American crow (I)	<i>Corvus brachyrhynchos</i>
Black-capped chickadee (I,N)	<i>Parus atricapillus</i>
Blue jay (I,N)	<i>Cyanocitta cristata</i>
Blue-winged warbler (I,N)	<i>Vermivora pinus</i>
Brown-headed cowbird (I,N)	<i>Molothrus ater</i>
Brown thrasher (I,N)	<i>Toxostoma rufum</i>
Cedar waxwing (I,N)	<i>Bombycilla cedrorum</i>
Chipping sparrow (I,N)	<i>Spizella passerina</i>
Common flicker (I,N)	<i>Colaptes auratus</i>
Downy woodpecker (I,N)	<i>Picoides pubescens</i>
Eastern bluebird (I,N)	<i>Sialia sialis</i>
Eastern kingbird (N)	<i>Tyrannus tyrannus</i>
Eastern pewee (I)	<i>Contopus virens</i>
Eastern phoebe (I,N)	<i>Sayornis phoebe</i>
European starling (I)	<i>Sturnus vulgaris</i>
Field sparrow (I,N)	<i>Spizella pusilla</i>
Gray catbird (I,N)	<i>Dumetella carolinensis</i>
Great crested flycatcher (I,N)	<i>Myiarchus crinitus</i>
Indigo bunting (I,N)	<i>Passerina cyanea</i>
Mourning dove (I,N)	<i>Zenaida macroura</i>
Northern cardinal (I,N)	<i>Cardinalis cardinalis</i>
Northern oriole (I,N)	<i>Icterus galbula</i>
Red-tailed hawk (I,N)	<i>Buteo jamaicensis</i>
Red-winged blackbird (N)	<i>Agelaius phoeniceus</i>
Rose breasted grosbeak (I,N)	<i>Pheucticus ludovicianus</i>
Rufous-sided towhee (I,N)	<i>Pipilo erythrophthalmus</i>
Scarlet tanager (I,N)	<i>Piranga olivacea</i>
Song sparrow (I,N)	<i>Melospiza melodia</i>
Tree swallow (I,N)	<i>Tachycineta bicolor</i>
Tufted titmouse (I,N)	<i>Parus bicolor</i>
Vesper sparrow (I,N)	<i>Pooecetes gramineus</i>
White-breasted nuthatch (I)	<i>Sitta carolinensis</i>
White crowned sparrow (I)	<i>Zonotrichia leucophrys</i>
Unidentified vireo (I,N)	<i>Vireo spp.</i>

^aI = Censused on introduced sites, N = Censused on native sites

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