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A comparison of the effects of burning, haying and mowing on plants and small mammals in a tallgrass prairie reconstruction

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A COMPARISON OF THE EFFECTS OF BURNING, HAYING AND MOWING ON PLANTS AND SMALL MAMMALS IN A TALLGRASS PRAIRIE RECONSTRUCTION

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ABSTRACT

Fire is an effective management tool for reconstructed prairies. However, due to safety concerns, road departments and other prairie managers are sometimes reluctant to use fire. Therefore, alternative techniques to manage reconstructed prairie, such as mowing or haying, need to be considered. The goal of this study is to determine if mowing and/or haying can be used to manage vegetation in lieu of fire for prairie reconstructions. This study examines the effects of four management techniques on plant and small mammal species in a tallgrass prairie reconstruction. No management, mowing, haying, and burning were replicated six times using a split block design on the research site near Plainfield, Iowa. The entire area was seeded in 2006 with a seed mixture containing 53 native species (11 grasses, 38 forbs, and 4 sedges). Mowing and haying treatments were initiated in September 2009 and burning was conducted in April 2010. Biomass clippings were taken in July 2009 and July 2010. Basal cover was measured in June 2009 and July 2010. Small mammal trapping was conducted in June 2010 and October 2010.

The short time span of this study limited its ability to show significant changes in vegetative structure between the treatments. However, burning resulted in more grass biomass and more total vegetative, native vegetative, and warm-season grass basal cover, while decreasing duff. Haying and mowing produced limited change in vegetation, but mowing led to an increase in duff accumulation. No management led to a reduction in native vegetation production and increased cover of duff.

The vegetative changes produced by one application of treatments were not sufficient to cause changes in use of treatment areas by small mammals. Small mammal captures were significantly higher in treatment areas with standing vegetation during the trapping period.

Prairie managers should strive to use fire in vegetation management when it is possible. When burning is not an option, mowing and haying can produce some positive vegetative changes, but can also cause some negative changes. Leaving prairies unmanaged will result in their degradation. In some cases signs of degradation will be apparent in as little as one year.

This Study by: Ryan Allan Neuhaus

Entitled: A comparison of the effects of burning, haying and mowing on plants and small mammals in a tallgrass prairie reconstruction

has been approved as meeting the thesis requirement for the

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CHAPTER 1

INTRODUCTION

The tallgrass prairie ecosystem is estimated to have once covered 28.8 to 31.3 million acres in Iowa prior to Euro-American settlement (Smith 1998). In 1833, Euro-American settlers began to move across the Mississippi River into Iowa. The tallgrass prairie was a harsh land for early settlers who were trying to create a modest agricultural livelihood (Smith 1981). The rich, black soil produced by deep prairie roots over thousands of years made excellent land for cultivated crops, resulting in the quick demise of the tallgrass prairie. Just 80 years after settlement of Iowa began, Iowa Department of Agriculture records (1911) indicate that 97% of the Iowa landscape had been converted for agriculture.

Iowa wild hay harvest records from 1896 to 1946 show that prairie in Iowa continued to decline well into the 20^{th} century. Wild hay harvest fell to just 85,382 acres in 1946, indicating only about 0.3% of pre-settlement prairie remained. The remaining remnants had likely been disturbed by mowing or grazing (Smith 1998).

Recent estimates suggest that only 0.05 to 0.1% of Iowa's original prairie acreage remains, depending on how strictly a prairie remnant is defined (Smith 1998). As of 1998, more than 5,000 acres of remnant prairie had been preserved by the Iowa Department of Natural Resources, country conservation boards, the Iowa Natural Heritage Foundation, and the Iowa Chapter of The Nature Conservancy (Smith 1998).

With so few remnant acres remaining, opportunities to find and preserve remnant areas have lessened and much more attention is being devoted to prairie restoration.

Several large restoration projects are ongoing in Iowa. One of them is the Neal Smith National Wildlife Refuge near Prairie City, Iowa. The goal of the refuge is to reconstruct 5,000-6,000 acres of pre-settlement tallgrass prairie. Many restoration and reconstruction projects are being conducted by The Nature Conservancy in the Loess Hills of western Iowa. With the Broken Kettle Grasslands Preserve alone, they have protected more than 7,000 acres (Nature Conservancy 2014).

Roadside rights-of-way provide another avenue for prairie restoration. As early as 1926, the idea of establishing prairie in roadsides was proposed as a way of preserving Iowa's wildlife and making trips in Iowa more aesthetically pleasing (Pammel 1926). Later, Christiansen and Lyons (1975) suggested the use of prairie vegetation in roadsides based upon the idea that native prairie species would outcompete invasive weed species. In 1988, the Iowa Legislature provided legislation for Integrated Roadside Vegetation Management (IRVM) to establish and maintain prairie on Iowa roadsides.

The Iowa Department of Transportation (DOT) and many counties use IRVM practices to restore and reconstruct prairie in rights-of-way. These practices include reseeding native prairie species, reduced mowing frequency, selective application of herbicides, reduction of trees and brush, and prescribed burning. With 750,000 acres of Iowa roadside available for restoration, this effort could connect isolated prairie remnants and once again spread prairie across the state (IRVM 2011).

Prairie Management

Iowa prairies were historically maintained by fires, both natural and anthropogenic (Axelrod 1985), and by grazing by bison, elk, and deer (Davison and Kindscher 1999, Anderson 2006). Current management practices for prairies include prescribed burning, haying, mowing, and grazing (Smith et al. 2010). Management techniques are used to increase native prairie species, reduce invasive weed species and woody encroachment, increase the vigor of native species, and even to suppress certain native species to the benefit of others. The outcomes of management practices are not always easy to predict, however. For example, different effects may be found at different spatial scales and it is often unknown whether, or how, plant or animal assemblages were changing prior to the introduction of management (Collins 1992, Collins 2000).

The use of fire as a management technique is widespread. A number of factors are involved in the use of fire to manage vegetation. The results of prescribed fire can be affected by the seasonality, intensity or frequency of the fire, as well as by soil characteristics, moisture, topography, and other management techniques (Engle and Bidwell 2001, Towne and Kemp 2003, Ewing and Engle 1988, Towne and Owensby 1984, Hulbert 1988). Although natural fires could have occurred from early spring to early winter, the most common time for prescribed burns is in the spring during dormancy or just as vegetation is starting to green up, and there is a high ratio of dead to living plant material. Engle and Bidwell (2001) found that late dormant season burning leads to higher biomass production in areas where spring moisture is not a limiting factor and where excessive duff accumulation stunts plant growth if it is not removed by fire or heavy grazing.

Management that employs the use of grazing is typically found in the larger prairie tracts of Nebraska and Kansas, but is used less frequently in the smaller prairie remnants and reconstructions in Iowa. Grazing of prairies is somewhat controversial. Negative opinions are often derived from land manager's experiences with low species diversity on over-grazed prairie pastures (Davison and Kindscher 1999). Light to moderate, intermittent grazing has been suggested as a way to preserve rare prairie species that may depend on grazing for survival (Williams 1997). Davison and Kindscher (1999) recommend 60 acres as the minimal area needed to support large ungulate grazing. In Iowa, grazing may not be feasible as most prairie remnants and reconstructions are too small to support enough livestock even at low stocking rates.

Mowing and haying are sometimes favored by land managers who are hesitant to use fire due to the perceived risks of prescribed burns or the lack of trained burn crews and equipment. Mowing and haying are similar in that they both involve the manual cutting of vegetation, but mowing leaves vegetation on the ground while in haying it is collected and removed from the site.

Collins et al. (1998) found that mowing was better able to maintain plant diversity than burning. Other research supports the use of mowing to reduce invasive plant species, to promote the growth of native species, and to add forb species to an established prairie (Wilson and Clark 2001, Collins et al. 1998, Williams et al. 2007).

In a five year study, Wilson and Clark (2001) were able to reduce the cover of an invasive grass *Arrhenatherum elatius* while increasing the cover of native perennial grasses with annual mowing in late spring, however differences in treatment groups were only apparent after three years of annual mowing. Howe (1999) found that mowing increased the abundance of the native forb *Zizia aurea* when conducted in August, but had no effect on abundance if done in May. Both of these studies show the potential benefits of mowing, but indicate that seasonality and frequency of treatment applications can affect the results. Williams et al. (2007) used mowing to enhance an established warm-season grass planting. By mowing weekly through the first growing season after over-seeding with native forbs, they were able to increase the survivorship and abundance of forb seedlings. They showed that the diversity of an established prairie can be increased without eliminating dominant grass species already present on the site.

As noted earlier, mowing will increase the amount of vegetative duff on the ground by cutting standing plants and leaving them on the site. The resultant duff layer has been found to delay springtime emergence and growth and reduce vegetative production by 21.6% relative to plots where the duff had been removed (Weaver and Rowland 1952). When the duff is removed during the haying process, vegetative regrowth is often greater than when duff remains (Bishop and Nagel 1999). Begay et al. (2011) found that for most forbs there is no difference between forb size before haying and the year after haying has occurred, although prairies that have been annually hayed for an extended period often have vegetation that is reduced in size (Smith 2008). Many remnant prairies have survived because they were hayed for agricultural purposes and a family tradition of haying kept them from being plowed under (Smith 1998). Often, hayed prairie remnants are the most diverse prairies in an area (Jog et al. 2006) and serve as models for restoration. The repeated removal of above-ground biomass through haying is likely to impact plant species diversity and structure, but without undisturbed prairie remnants for comparison this effect cannot be confirmed.

Some prairie remnants and reconstructions are not actively managed. Lack of management typically leads to a large accumulation of duff on the ground and the invasion of woody plants (Bragg and Hulbert 1976). Often the encroachment of woody plants occurs on the edges of prairie and works inward (Robertson et al. 1995). Therefore as prairie size decreases there is a proportionally larger effect from woody encroachment as the ratio of edge to interior area becomes larger.

Small Mammals

Common small mammals in Iowa's tallgrass prairie include the white-footed mouse (*Peromyscus leucopus*), white-footed deer mouse (*Peromyscus maniculatus*), meadow vole (*Microtus pennsylvanicus*), prairie vole (*Microtus ochrogaster*), northern short-tailed shrew (*Blarina brevicauda*), western harvest mouse (*Reithrodontomys megalotis*), meadow jumping mouse (*Zapus hudsonius*), and several small shrews (*Sorex sp.*).

The *Peromyscus* species have been found in habitats ranging from sites sparse in vegetation to grasslands to wooded areas (Kantek 1983, Snyder and Best 1988). The *Microtus* species have been found to prefer dense grasslands (Eadie 1953) and the shrews are known to inhabit a wide variety of moist habitats (Wrigley et al. 1979). It seems that many of the common species need only food, water, and some vegetation for cover, but densities of individual species may vary based on specific vegetative characteristics (Kaufman et al. 1983).

Just as management techniques affect vegetation, they also change the habitat for small mammals. For example, the immediate effect of burning is a substantial decrease, but not elimination, of use of the area by small mammals (Springer 1986). Subsequent use by small mammals after burning appears to vary by species. Kaufman et al. (1988) noted that *Peromyscus maniculatus* was more likely to be found in areas that had been burned recently rather than areas burned several years before. On the other hand, *Reithrodontomys megalotis* was more likely to be found in areas that had been burned more than two years before than in those burned annually or in the previous year (Kaufman et al. 1988).

The effect of mowing on small mammals seems to vary in a species-specific manner. Slade and Crain (2006) found that immediately following the mowing of 15 m wide strips in a grassland, the abundance of *P. maniculatus*, *P. leucopus*, and *R. megalotis* did not change, but the abundance of *Sigmodon hispidus* and *Microtus ochrogaster* was reduced. This effect was temporary, and as the mowed vegetation recovered, all small mammals began to use the mowed area again.

There is evidence that long term haying results in a decreased abundance of small mammals (Sietman et al 1994, LoBue and Darnell 1959). The effect of haying on small mammals is probably similar to the effect of burning. It is likely that small mammals reduce their usage of the area until the vegetation recovers enough to afford the mammals some protection from predators. As the vegetation recovers, small mammal species use of the area is determined by vegetation characteristics that are different for each small mammal species.

As indicated earlier, woody vegetation increases and duff accumulates in areas that have not been managed (Bragg and Hulbert 1976). Since the physical characteristics of vegetation are thought to be factors in the distribution and abundance of small mammals (Sietman et al. 1994), species favoring woody vegetation and thick duff layers should be found more often in unmanaged areas. *P. leucopus* is known to favor habitats with more woody vegetation and is often found in old fields with woody growth (Sietman et al. 1994, Swihart and Slade 1990).

Research Objectives and Hypotheses

The effects of a single management technique are often studied (Begay et al. 2011, Collins 1992, Engle and Bidwell 2001), but rarely are several techniques studied on one site. Even rarer are studies of multiple management techniques on reconstructed prairie. Studies of multiple management practices often apply multiple practices to the exact same area (Bishop and Nagel 1999, Fuhlendorf and Engle 2004), which can reduce the ability of the study to determine precisely which management was the cause of any results that are found. In addition, with acres and acres of roadside prairies being planted in Iowa, more research is needed to determine effective and safe management techniques for these new prairies.

The objectives of this study were to assess and compare the effects of one season of burning, haying, mowing, and no management on vegetative basal cover, biomass production, and duff accumulation, and to determine how these management actions affect small mammal use of a reconstructed tallgrass prairie.

The hypotheses of this study are that one growing season after treatments are administered: 1) biomass production will be highest in burned plots and lowest in mowed plots, 2) basal cover of vegetation will be highest in burned plots and lowest in mowed plots, 3) ground cover of duff will be highest in mowed and control plots and lowest in burned and hayed plots, 4) small mammal usage will be highest in control and burned plots, and 5) due to differences in the timing of treatment application, small mammal usage of mowed and hayed plots will decrease immediately following treatments, and usage of control plots will not decrease.

CHAPTER 2

MATERIALS AND METHODS

Site Description

The study site is located on excess right-of-way northeast of the Plainfield Exit off Highway 218 in Bremer County, Iowa. Soils at the site include Lawler loam and Waukee loam with slopes from 0 to 2 percent (USDA NRCS Web Soil Survey, 2010). The south half of the site is flat while the north half has a slight north aspect. The total area of the site is approximately 64,800 m^2 (Figure 1).

The site was managed for annual row-crop production prior to initiation of this research project. Corn (*Zea mays*) was planted and harvested on the site in 2004 and corn debris was present throughout the study. Adjacent land use varies, with the north side being bordered by an approximately 65,000 m^2 tallgrass prairie reconstruction and borrow-area pond, with grazed pasture and mowed turf-grass lawn on the east side. Highway 188 right-of-way adjoins to the south, and Highway 218 right-of-way to the west. Both rights-of-way have been planted with a tallgrass prairie mixture.

Figure 1: Aerial view of the research site with the mowed lanes between plots visible (Iowa Geographic Map Server).

<u>Seed Source and Seed Mixture</u>

A seeding mix of 15 grasses and sedges and 38 forbs was designed to create a high diversity tallgrass prairie reconstruction similar to what is used for roadside prairie reconstructions. Seed was purchased from Allendan Seed (1966 175th Lane, Winterset, IA 50273), Ion Exchange (1878 Old Mission Drive, Harpers Ferry, IA 52146), Prairie

Moon Nursery (32115 Prairie Lane, Winona, MN 55987), and the Tallgrass Prairie Center (University of Northern Iowa, Cedar Falls, IA 50614). Prior to sowing, the seed was stored dry in a temperature and humidity controlled room at the Tallgrass Prairie Center. A Pure Live Seed (PLS) test was provided by the seed vendor or conducted by Hulsey Seed Laboratory (P.O. Box 132, Decatur, GA 30031) for each species used in the mix. The results of the PLS test were used to calculate the amount of seed needed for each species to obtain the desired number of viable seeds per square foot. A single seed mixture was used for the entire research area and buffer areas around the site (Table 1).

Table 1: List of species used in seeding.

Scientific Name	**Common Name**
Graminoids	
Andropogon gerardii	big bluestem
Bouteloua curtipendula	side-oats grama
Bromus kalmii	prairie brome
Calamagrostis canadensis	bluejoint grass
Carex bicknellii	copper-shouldered oval sedge
Carex brevior	plains oval sedge
Carex molesta	field oval sedge
Carex vulpinoidea	fox sedge
Elymus canadensis	Canada wildrye
Panicum virgatum	Switchgrass
Schizachyrium scoparium	little bluestem
Sorghastrum nutans	Indiangrass
Spartina pectinata	prairie cordgrass
Sporobolis asper	tall dropseed
Sporobolis heterolepsis	prairie dropseed

(Table continues)

Forbs

Allium stellatum	prairie onion
Amorpha canescens	Leadplant
Anemone canadensis	Canada anemone
Anemone cylindrica	Thimbleweed
Artemisia ludoviciana	prairie sage
Asclepias incarnata	swamp milkweed
Asclepias tuberosa	butterfly milkweed
Astragalus canadensis	Canada milk vetch
Baptisia leucantha	white wild indigo
Cassia fasiculata	partridge pea
Coreopsis palmata	prairie coreopsis
Dalea purpurea	purple prairie clover
Desmodium canadense	showy tick trefoil
Echinacea pallida	pale purple coneflower
Eryngium yuccifolium	rattlesnake master
Euphorbia corollata	flowering spurge
Heliopsis helianthoides	ox-eye sunflower
Lespedeza capitata	round-headed bush clover
Liatris pycnostachya	prairie blazingstar
Monarda fistulosa	wild bergamot
Parthenium integrifolium	wild quinine
Penstemon digitalis	foxglove penstemon
Phlox pilosa	prairie phlox
Pycnanthemum virginianum	common mountain mint
Ratibida pinnata	yellow coneflower
Rudbeckia hirta	black-eyed Susan
Rudbeckia subtomentosa	brown-eyed Susan
Silphium integrifolium	Rosinweed
Silphium laciniatum	compass plant
Solidago rigida	stiff goldenrod
Solidago speciosa	showy goldenrod
Symphotrichum azureus	sky blue aster
Symphotrichum laevis	smooth blue aster
Symphotrichum novae-angliae	New England aster
Tradescantia bracteata	prairie spiderwort
Tradescantia ohiensis	Ohio spiderwort
Veronicastrum virginicum	Culvers root
Zizia aurea	golden Alexanders

Site Preparation and Seeding

The site was prepared for seeding by spraying with Round-up® herbicide on April 20, 2005. On May 5, 2005 the site was seeded with a cover crop of oats (*Avena sativa*) to aid in weed control, and the oats were harvested in August 2005. The site was again sprayed with Round-up® herbicide on May 5, 2006 to kill weeds that had re-appeared. The site was seeded with the prairie seed mix using a Truax no-till seed drill on June 23, 2006.

The entire site was mowed on July 18 and August 21, 2006 to aid native seedling establishment by reducing weeds and removing weed canopy cover to allow more light to reach the soil surface (Williams et al. 2007). The mowing was conducted with a rotary mower attached to either a John Deere 950 or 5325 utility tractor. The vegetation was mowed to a height of about six inches each time.

Experimental Design

Due to some differences in soil and slope aspect on the site a randomized block design with two blocks (North and South) was used. The North Block was 90% Lawler Loam and 10% Waukee Loam, and the South Block was 75% Lawler Loam and 25% Waukee Loam (USDA NRCS Web Soil Survey 2010). A 6 m wide mowed strip separated the two blocks. This strip was seeded with the same prairie seed mix at the same time as the two experimental blocks to limit the introduction of non-native plant species. The research site is wider on the northern boundary than on the southern boundary, so the area of the North Block (36,000 m^2) was 25% greater than the South Block (28,800 m^2).

The study compared four treatments (mowing, haying, burning, and a no management control). Plots were scaled to use the entire area in each block, so plots in the North Block were about 50 × 60 m, while plots in the South Block were about 40 × 60 m. Plots were measured and marked with stakes at the corner of each plot. Plot boundaries were marked by 6 m wide mowed lanes that were maintained throughout the growing season. There were three replicates of each treatment in each block for a total of six plots of each treatment in the study (Table 2). Each plot was randomly assigned one of four different treatments; mowing, haying, burning, or a no management control (Figure 2).

Table 2: Treatments and number of replicates.

Treatment	Replicates/ block	Total plots
1 = Burn	3	6
2 = Hay	3	6
3 = Mow	3	6
4 = Control	3	6

North Block	2	4	3	2	3	1
	1	3	1	4	2	4

South Block	1	4	3	2	4	2
	1	2	4	1	3	3

Figure 2: Experimental design showing blocks and treatments for each plot.

Experimental Comparisons

Experimental blocks and random plots for the treatments were measured and marked in spring 2007. During the 2007 growing season, and subsequent growing seasons, 6 m wide lanes between plots and blocks were mowed every three to four weeks at a height of about six inches.

The treatments consisted of annual mowing, annual haying, annual burning, and control (no management). The six replicate mow plots were mowed at a height of about six inches on September 12, 2009, and September 4, 2010. The six replicate hay plots were hayed on September 9, 2009, and August 23, 2010. Plots were hayed by mowing and windrowing the vegetation using a New Holland Swather. After drying, the vegetation was baled into large round bales. An attempt was made to apply prescribed fire to the burn plots in fall 2009, but the vegetation was too sparse and damp to carry a fire at that time. The six replicate burn plots were burned by a prescribed fire crew from the Tallgrass Prairie Center at the University of Northern Iowa on April 14, 2010. No management was conducted in control plots.

Vegetation Sampling and Analysis

The vegetation sampling technique consisted of sampling quadrats along line transects. Two 10 m transects were located in each plot using a random number table. Transects were placed at least one meter from the edge of the plots in order to minimize edge effects. Vegetation was sampled in $0.1m^2$ quadrats at one meter intervals along transects with a total of 20 quadrats sampled in each plot. All native plants and weeds were identified to species, and the basal coverage of each species was estimated at a height of 2.54 cm above the ground. Above ground biomass was sampled from five randomly selected quadrats in each plot. All vegetation in the quadrat was clipped at a height of 2.54 cm above the ground. Clippings were separated in the field into groups of native grasses, native forbs and weeds, and were placed into paper bags. Only species included in the seed mix were considered to be native species; all other plant species were considered to be weeds. Dead plant material laying on the group was collected by hand as a measurement of duff. The clippings were dried in drying ovens at 60° C for 72 hours. After drying, the vegetation was weighed and recorded to the nearest tenth of a gram.

Vegetation was sampled twice in each plot. Pre-treatment, baseline basal cover data were collected June 29 – July 1, 2009, and post-treatment data were collected July 21 – 31, 2010. Above ground biomass was collected July 15 – 22, 2009 (pre-treatment) and July 26 – 27, 2010 (post-treatment).

Quadrats were treated as subsamples and were averaged to generate plot means for each measured variable. Basal coverage and biomass plot means were compared using a two-way ANOVA. A Tukey's test was performed if significant differences were found in the ANOVA. Data were checked for normality. Non-normal data were square root transformed for use in the ANOVA, and reported values were all back-transformed.

Small Mammal Sampling and Analysis

Small mammals were sampled using grids of H.B. Sherman live traps (Model LFATGD, 7.6 × 8.9 × 22.9cm). In the North Block, each plot had 20 traps in a 4 × 5 grid spaced 10 m apart (Figure 3), and in the South Block each plot had 15 traps arranged in a 3 × 5 grid (Figure 3). Different sized trapping grids were used because North Block plots were slightly larger than South Block plots. Traps were placed at least 10 m from the edge of the plot. Traps were baited with balls of peanut butter and rolled oats placed in wax paper. The bait balls supplied trapped small mammals with energy and cotton balls were placed in each trap for insulation to reduce mortality. Traps were set for three consecutive nights and checked each morning. Captured mammals were marked with permanent marker in order to determine if an individual was recaptured during a three night trapping session. Trapping protocols were approved by the University of Northern

Iowa's Animal Care and Usage Committee and trapping was permitted by the Iowa Department of Natural Resources (SC 867).

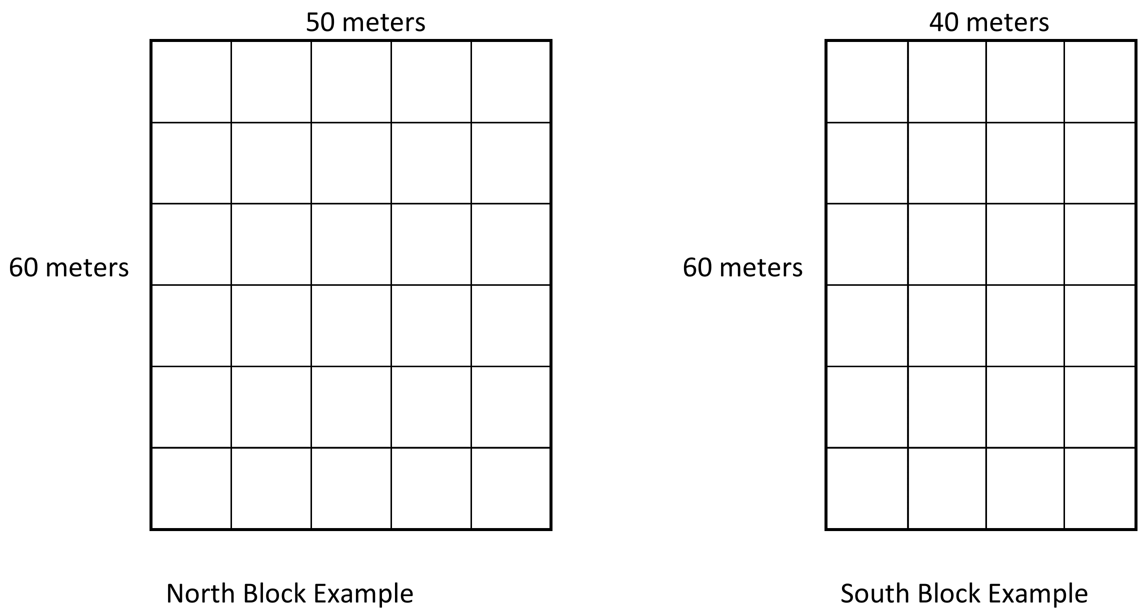

Figure 3: Small mammal trapping grid examples. The solid lines are the outside of one block in either the North or South Block. Dotted lines are shown at 10 meter intervals and one trap would be placed at each intersection of two dotted lines.

Small mammals in each block were sampled on three different three-night periods between June 29 and July 22, 2010, and another three-night period between October 8 and October 13, 2010. The following data were collected for each capture if possible: location of capture, species, age class, sex, and weight.

Catch per unit effort (CPUE) was calculated by dividing the number of total captures of target species in each plot by the number of trap nights for that plot. Target species were mice (*Peromyscus* sp., *Reithrodontomys megalotis* and *Zapus hudsonius*), voles (*Microtus* sp.) and shrews (*Blarina brevicauda* and *Sorex* sp.). For data sets with a normal distribution, data was statistically analyzed using a two-way ANOVA by block and treatment to determine if there was a difference in the density of small mammals in each treatment. A Tukey's test was conducted if significant differences were found in the two-way ANOVA. Non-normally distributed data was analyzed using a Kruskal-Wallis Analysis of Variance.

CHAPTER 3

RESULTS

Biomass

Pre-treatment (2009) biomass sampling revealed the plots were uniform between treatments for all biomass factors, although there were several significant differences between blocks (Figure 4, Table 3). In all cases of block differences, the North Block had greater biomass production than the South Block (Appendix A).

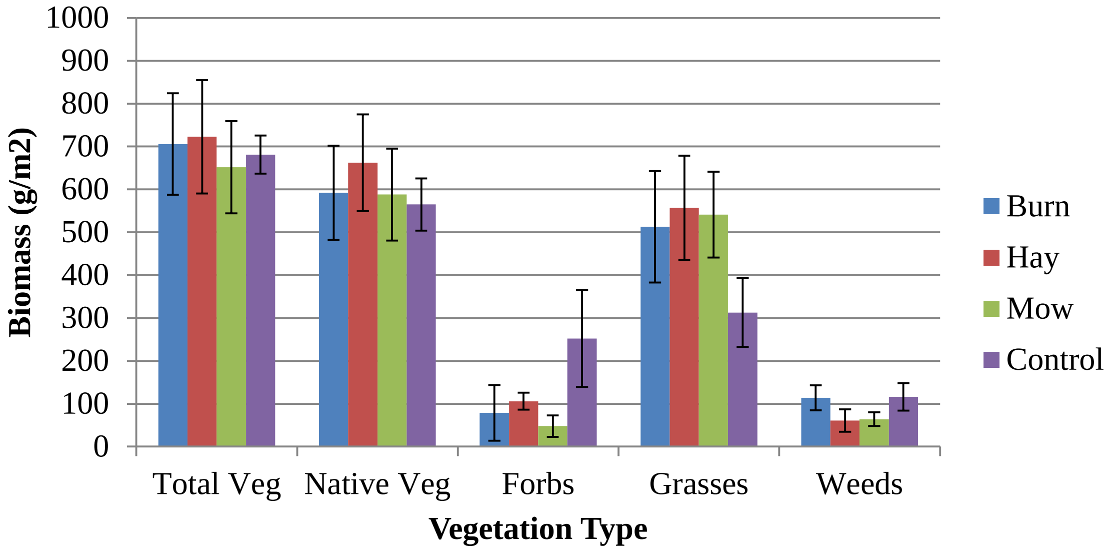

Figure 4: Pre-treatment (2009) biomass production means of vegetation types for each treatment. Values are the average of 6 plots for each treatment ± 1 SE.

Table 3: Pre-treatment (2009) and post-treatment (2010) biomass means and statistical results.

		2009				2010			
Variable	**Term**	***F***	**Treatment**	**Mean**	**SE**	***F***	**Mean**	**SE**	**% Change**
Total Veg	block	12.01*	Burn	705.9	118.4	1.17	856.4	109.1	21
Biomass	treatment	0.15	Hay	722.9	132.4	2.40	691.5	77.6	-4
(g/m2)	b x t	2.06	Mow	651.7	107.3	0.46	594.0	66.0	-9
			Control	681.0	44.4		557.7	72.9	-18
Native	block	8.60*	Burn	592.1	110.0	0.33	794.0	113.9	34
Biomass	treatment	0.28	Hay	662.3	113.1	2.11	588.9	94.5	-11
(g/m2)	b x t	2.40	Mow	588.1	107.5	0.34	508.0	47.3	-14
			Control	564.9	61.6		496.1	84.1	-12
Forb	block	0.82	Burn	78.9	64.9	0.07	230.5	62.0	192
Biomass	treatment	1.53	Hay	105.6	20.5	1.34	85.5	49.2	-19
(g/m2)	b x t	0.31	Mow	47.6	24.8	0.40	190.0	35.4	299
			Control	251.8	113.2		190.0	49.2	-25
Grass	block	11.35**	Burn	513.2	129.7	2.30	563.5^{A}	73.1	10
Biomass	treatment	1.71	Hay	556.6	122.4	5.28*	503.4^{A,B}	102.7	-10
(g/m2)	b x t	1.62	Mow	540.5	100.3	0.52	239.7^{B}	50.2	-56
			Control	313.1	80.2		238.3^{B}	61.4	-24
Weed	block	3.74	Burn	113.8	29.4	3.89	62.4	9.1	-45
[Biomass	treatment	1.52	Hay	60.6	25.5	1.01	102.6	29.5	69
(g/m2)	b x t	1.02	Mow	63.7	15.5	3.70*	85.6	31.9	34
			Control	116.1	32.3		61.7	21.0	-47
Duff	block	-	Burn	-	-	0.32	9.3^{A}	1.8	-
Biomass	treatment	-	Hay	-	-	4.03*	55.1^{A,B}	13.1	-
(g/m2)	b x t	-	Mow	-	-	0.08	157.0^{B}	19.1	-
			Control	-	-		139.0^{A,B}	58.8	-

F-ratio interpretation: * p<0.05, ** p<0.01

For vegetation variables analyzed for all plots (N=24), df were 3 for treatment, 1 for block, and 3 for block x treatment.

Shared letters (a,b,c) down rows indicate no significant differences among vegetation treatment means (p>0.05).

Post-treatment (2010) biomass sampling showed the plots were still fairly uniform between treatments. There were no significant differences between treatments for total vegetative production (p=0.106), native vegetation production (p=0.139), forb production (p=0.298), or weed production (p=0.416) (Figure 5, Table 3). There were significant treatment differences for grass (p=0.010) and duff biomass (p=0.026). Grass biomass was significantly greater in burned plots than in mowed plots (p=0.034) and unmanaged plots (p=0.033) (Figure 5, Table 3). Duff biomass was significantly lower in burn plots than in mow plots (p=0.038) (Figure 5, Table 3).

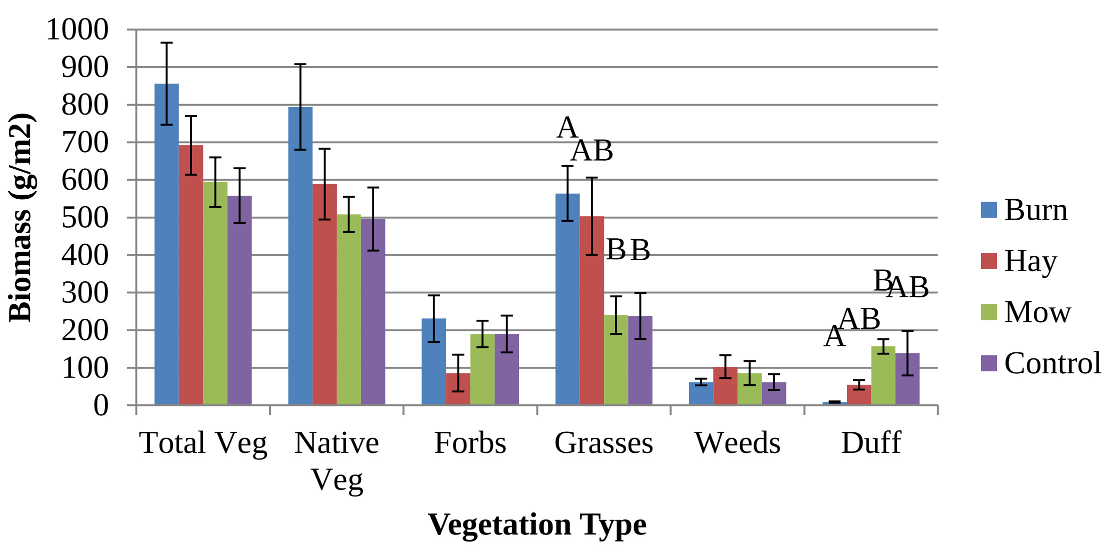

Figure 5: Post-treatment (2010) biomass production means of vegetation types for each treatment. Values are the average of 6 plots for each treatment ± 1 SE. Different letters indicate significant treatment differences.

Total vegetative biomass in burned plots increased 21% from 2009 to 2010 while all other treatments had decreases in production (Table 3). This trend was also evident in native and grass biomass means (Table 3).

Additionally, I found there were no significant block differences after one application of treatments (Table 3).

Basal Cover

Basal cover of all plant functional groups were uniform between treatments in 2009 prior to the application of the treatments (Table 4, Appendix B). There were two significant block differences before treatments were applied: warm-season grasses (p=0.003) and forb basal cover (p=0.018) (Table 4). In both cases there was greater basal cover in the South Block than in the North Block (Appendix A). There were no block differences in graminoid basal cover (p=0.373), native basal cover (p=0.376), or total vegetative basal cover (p=0.347) (Table 4).

Post-treatment (2010) there were significant differences among treatments in basal cover of total vegetation (p=0.013), native vegetation (p=0.009), warm season grasses (p=0.034), and duff (p=0.001) (Figure 6, Table 4). Total vegetative basal cover was greater in burn (p=0.024) and hay (p=0.017) plots than unmanaged plots. Native basal cover was significantly greater in burn plots than unmanaged plots (p=0.005) (Table 4).

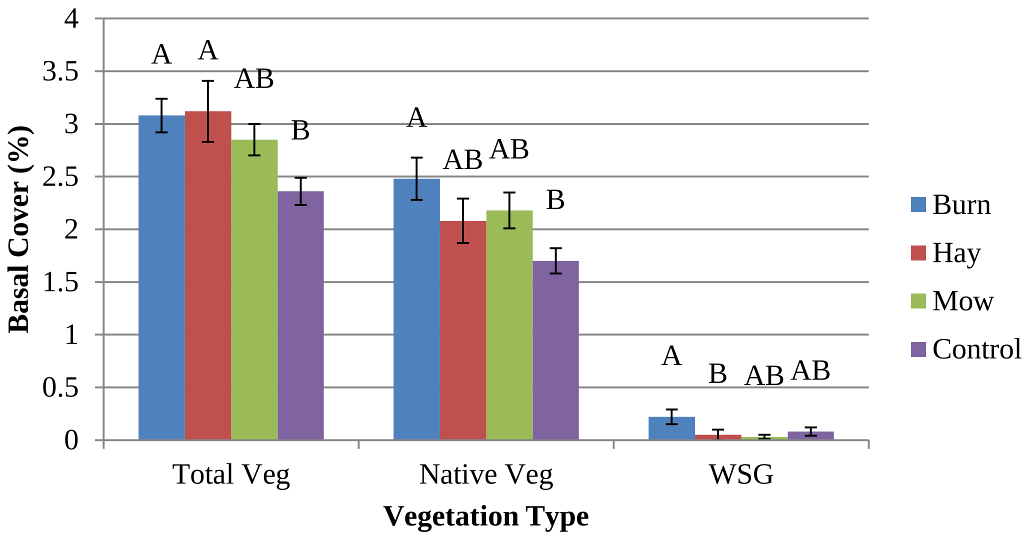

Figure 6: Post-treatment (2010) basal cover means of vegetation types for each treatment. Values are the average of 6 plots for each treatment ± 1 SE. Different letters indicate significant treatment differences.

Total vegetative and native basal cover increased in all treatments except control (no management) from 2009 to 2010. Burning increased basal cover of native species by 23% and did so through a 340% increase in warm season grass and a 91% increase in forb basal cover (Table 4). Haying and mowing increased native basal cover by 22% and 15%, respectively, largely through increases in cool season grass basal cover (Table 4).

Weed basal cover increased in all treatments from 2009 to 2010 (Table 4). Increases were less than 40% in all treatments except from haying which increased weed basal cover by 167% (Table 4).

After one application of treatments all pre-treatment block differences disappeared (Table 4).

Table 4: Pre-treatment (2009) and post-treatment (2010) basal cover means and statistical results.

		2009				2010			
Variable	**Term**	***F***	**Treatment**	**Mean**	**SE**	***F***	**Mean**	**SE**	**% Change**
Total Veg	block	0.94	Burn	2.45	0.23	3.05	3.08[A]	0.16	26
Basal Cover	treatment	0.72	Hay	2.02	0.21	4.92*	3.12[A]	0.29	54
(%)	b x t	0.33	Mow	2.39	0.15	3.54*	2.85[A,B]	0.15	19
			Control	2.48	0.33		2.36[B]	0.13	-5
Native	block	0.83	Burn	2.02	0.23	2.02	2.48[A]	0.20	23
Basal Cover	treatment	0.23	Hay	1.70	0.19	5.38**	2.08[A,B]	0.21	22
(%)	b x t	0.73	Mow	1.89	0.27	5.10*	2.18[A,B]	0.17	15
			Control	1.90	0.35		1.70[B]	0.12	-11
WSG	block	12.80**	Burn	0.05	0.03	0.78	0.22[A]	0.07	340
Basal Cover	treatment	1.11	Hay	0.07	0.04	3.70*	0.05[B]	0.05	-29
(%)	b x t	0.44	Mow	0.04	0.04	1.15	0.03[A,B]	0.02	-25
			Control	0.12	0.05		0.08[A,B]	0.04	-33
CSG	block	1.78	Burn	1.41	0.23	2.82	1.20	0.09	-15
Basal Cover	treatment	0.23	Hay	1.14	0.19	1.43	1.55	0.32	36
(%)	b x t	0.71	Mow	1.39	0.29	2.09	1.66	0.26	19
			Control	1.37	0.34		1.23	0.11	-10
Graminoid	block	0.84	Burn	1.46	0.23	3.27	1.42	0.11	-3
Basal Cover	treatment	0.23	Hay	1.21	0.17	0.91	1.60	0.29	32
(%)	b x t	0.62	Mow	1.43	0.28	1.76	1.70	0.25	19
			Control	1.49	0.32		1.31	0.09	-12
Forb	block	6.98*	Burn	0.56	0.28	0.39	1.07	0.27	91
Basal Cover	treatment	0.17	Hay	0.43	0.14	2.09	0.48	0.15	12
(%)	b x t	1.03	Mow	0.45	0.19	1.11	0.49	0.23	9
			Control	0.40	0.13		0.39	0.19	-3

(Table continues)

Weed	block	0.18	Burn	0.43	0.08	0.69	0.60	0.07	40
Basal Cover	treatment	0.74	Hay	0.39	0.05	1.77	1.04	0.18	167
(%)	b x t	0.74	Mow	0.51	0.15	0.24	0.67	0.07	31
			Control	0.58	0.10		0.66	0.11	14
Duff	block	0.31	Burn	70.58	6.53	0.91	13.35[A]	4.09	-81
Basal Cover	treatment	1.13	Hay	80.73	5.65	9.76**	38.91[A,B]	11.02	-52
(%)	b x t	0.22	Mow	76.72	3.72	1.63	76.76[B]	10.69	0
			Control	61.19	11.33		69.93[B]	11.47	14

F-ratio interpretation: * $p<0.05$, ** $p<0.01$

For vegetation variables analyzed for all plots (N=24), df were 3 for treatment, 1 for block, and 3 for block x treatment.

Shared letters (A,B,C) down rows indicate no significant differences among vegetation treatment means ($p>0.05$).

Small Mammals

During the course of this study I captured 648 small mammals from at least 10 species during 4,478 trap nights. Due to difficulty in accurately differentiating *Peromyscus leucopus* from *P. maniculatus* and *Microtus pennsylvanicus* from *M. ochrogaster* in the field, captures have been grouped into *Peromyscus* sp. and *Microtus* sp. groups. *Sorex* species were also combined into a *Sorex* sp. group.

The summer trapping session was conducted in July 2010 during the growing season following the application of the management treatments. The 2010 biomass and basal cover data describe the vegetative characteristics present during this trapping session. I captured 522 small mammals from at least 10 species during 3,452 trap nights over the course of summer trapping. The three most commonly captured species were *Microtus* sp. (41.4% of captures), *Peromyscus* sp. (24.5%), and *Blarina brevicauda*

(20.7%) (Table 5). Despite marking small mammals, no marked individuals were recaptured.

Table 5: Summer small mammal captures by species.

Species	Burn	Control	Hay	Mow	Total
Microtus sp.	33	69	52	62	216
Peromyscus sp.	52	6	35	35	128
Blarina brevicauda	35	33	12	28	108
Sorex sp.	6	4	3	9	22
Reithrodonymus megalotis	2	6	5	7	20
Spermopholis tridecimlineatus	4	2	7	3	16
Mustela sp.	0	7	0	4	11
Zapus hudsonicus	1	0	0	0	1

Spermopholis tridecimlineatus and *Mustela* sp. captures and trap nights were removed from the data, because they were not target species. All other species were aggregated to produce a CPUE value for each plot (Appendix C). There was no significant block (p=0.053) or treatment (p=0.585) differences in CPUE found during the summer (Table 6).

Table 6: Summer small mammal means and Krustal-Wallis Test results.

Variable	**Term**	***p* value**	**Treatment**	**Mean**	**SE**
Summer	block	0.053	Burn	0.149	0.016
(CPUE)	treatment	0.585	Hay	0.124	0.018
			Mow	0.189	0.051
			Control	0.147	0.021

For block term, $X^2 = 3.746$, df = 1.
For treatment term, $X^2 = 1.938$, df = 3.

Hay plots were hayed a second time on August 23, 2010, and mow plots were mowed a second time on September 4, 2010, but the control and burn plots underwent no additional management in Fall 2010. In October, 2010, a fall trapping session was conducted. In this session 126 small mammals of at least eight species were captured during 1,026 trap nights. The most commonly captured species were *Blarina brevicauda* (59.5% of captures), *Peromyscus* sp. (17.5%), and *Microtus* sp. (15.1%) (Table 7).

Table 7: Fall small mammal captures by species.

Species	Burn	Control	Hay	Mow	Total
Blarina brevicauda	34	40	1	0	75
Peromyscus sp.	14	3	5	0	22
Microtus sp.	9	7	0	3	19
Reithrodonymus megalotis	3	2	0	0	5
Sorex sp.	2	1	0	0	3
Zapus hudsonicus	2	0	0	0	2

During fall trapping there were significant block (p=0.006, *F*=9.99, df=1), treatment (p<0.001, *F*=34.30, df=3), and block by treatment differences (p=0.003, *F*=7.06, df=3). Fall CPUE in the North Block showed significant treatment differences (p=0.001), with burn plots having significantly greater CPUE than mow plots (p=0.015), and control plots having significantly greater CPUE than hay plots (p=0.003) and mow plots (p=0.001) (Table 8). In the South Block, there were also significant treatment differences (p<0.001), with the burn plots having significantly greater CPUE than hay (p<0.000), mow (p<0.000), and unmanaged (p=0.002) plots, and unmanaged plots having significantly greater CPUE than hay (p=0.003) and mow (p=0.003) plots (Table 8). In both the North and South Blocks, burn and control plots had significantly greater CPUE than mow and hay plots. This is the immediate effect of the second application of mow and hay treatments in Fall 2010, approximately 6 weeks prior to small mammals sampling.

Table 8: Fall small mammal means and ANOVA results.

	North Block				**South Block**		
Variable	***F***	**Treatment**	**Mean**	**SE**	***F***	**Mean**	**SE**
Fall	16.35**	Burn	$0.223^{A,D}$	0.069	56.07***	0.220^{A}	0.014
(CPUE)		Hay	$0.055^{A,B}$	0.019		0.016^{B}	0.016
		Mow	$0.007^{B,C}$	0.007		0.016^{B}	0.008
		Control	0.333^{D}	0.019		0.116^{C}	0.013

F-ratio interpretation: ** p<0.01, *** p<0.001, df = 3.
Shared letters (A,B,C) down rows indicate no significant differences among treatments.

CHAPTER 4

DISCUSSION

Many acres of roadside prairies have been planted in Iowa in recent decades (IRVM 2011), and public interest in prairie reconstruction is growing continually (Smith 2014). With this increased investment of resources there is a corresponding need to understand how these new plantings should be managed. This study investigated the effects of haying, mowing, burning, and no management on a tallgrass prairie reconstruction. Another aspect of this study examined how these treatments may affect use of the area by small mammals.

Prairie reconstructions are often judged by how well they resemble prairie remnants. Prairie managers generally look to increase the number and diversity of native prairie plant species, while reducing the number and amount of weed species. Managers have many techniques in their arsenal to affect change on a reconstructed prairie. I chose haying, mowing, burning, and no management, because they are commonly used prairie management techniques. When evaluating the effectiveness of prairie management techniques, increases in native species, warm season grasses and forbs, and decreases in weeds and duff are desirable outcomes. Changes in total vegetation, cool season grasses and graminoids need to be considered in terms of specific species.

It is important to keep in mind that this study only examined effects of one growing season following a single application of each treatment, and the immediate effect on small mammals of a second application of mowing and haying. Although the study was short, several significant effects were detected and other non-significant trends were noted. Finding statistically significant shifts in vegetation after just one treatment is a notable finding by itself, as response time has been much longer in other studies (Wilson and Clark 2001, Howe 2000).

Vegetation

The results of this study support burning as the best form of management for this prairie reconstruction. Desirable vegetative changes from pre-treatment to post-treatment included increases in basal cover of native species, warm season grasses and forbs, and a decrease in duff. Basal cover of warm season grasses increased 340%. The changes in basal cover were paralleled by positive changes in biomass. The only undesirable change was an increase in basal cover of weeds, but weed biomass decreased.

Comparisons of post-treatment (2010) data support burning as the best management tool. Burning had a large effect on duff resulting in the lowest amount of duff biomass and basal cover of duff. Burned plots had significantly less duff biomass than mowed plots, and significantly less coverage of duff than either the mow or control plots.

Burning seemed to have a greater effect on grasses than other suites of plants. Biomass production of grasses was significantly higher in the burn treatment than the mow and control treatments. In addition, basal cover of warm season grasses was significantly higher in burned plots than hayed plots, while cool season grasses tended to have a lower than average basal cover in burned plots. These results are in line with Howe (2000) who found that eight years of annual burning led to a significant increase in biomass production of warm season grasses and a decrease in biomass production of cool season grasses. Other research supports the idea that burning native prairie leads to an increase in biomass production (Engle and Bidwell 2001, Towne and Kemp 2003). There are also indications that variations in soil moisture and weather patterns play a large role in biomass production (Briggs and Knapp 1995, Towne and Kemp 2003).

The results of the other two forms of management, haying and mowing, were somewhat mixed. Both showed a 15-20% increase in native vegetation basal coverage from pre-treatment to post-treatment years, and to a lesser degree an increase in forb basal cover, but burning was more effective. Forb biomass in mowed plots tripled post-treatment, but decreased slightly in hayed plots. Weed basal cover and biomass increased in hayed and mowed plots, but hayed plots saw a much larger increase than mowed plots.

Post-treatment (2010) duff biomass and basal cover in mowed plots were both significantly higher than the burn treatment. Grass biomass was significantly lower than the burn treatment, but this may be due to the timing of treatment applications. There were many similar data trends between mowed and control plots and in no instance were they significantly different. I think the duff layer created by mowing had a similar effect as the duff layer of the control plots in delaying springtime emergence and growth. This is in keeping with prior research that has shown the duff layer is directly responsible for delayed emergence and growth during the growing season (Weaver and Rowland 1952).

Post-treatment (2010) results revealed duff in hayed plots was not significantly different from any other treatment, but hayed plots had more duff biomass and basal cover than burned plots. There was significantly more total vegetative basal cover in hayed plots relative to control plots, and less warm season grass basal cover in hayed plots relative to burned plots. Plots that were hayed tended to have more weed biomass and basal cover than any other treatment, and the increase in weed basal cover and biomass from pre-treatment to post-treatments years was greater than in other treatments. It is possible these findings are a result of soil disturbance from the haying equipment, or the removal of the vegetative canopy allowing for increased sunlight and germination of weed seeds in the seed bank, but is more likely due to weed seed inadvertently brought into the plots on haying equipment.

My finding of less warm season grass in hayed plots is in contrast to the findings of Foster and Lovett (2003). They found warm season grasses, including *Andropogon gerardii* and *Sorghastrum nutans*, significantly increased with annual haying. The timing of haying would certainly have different effects on warm season grasses if applied in different seasons. The application of fall haying in my study may have disrupted the ability of warm season grasses to produce mature seed.

Prairie ecologists often suggest that haying of prairie leads to grasses and forbs that are shorter in stature than their un-hayed counterparts (Smith 2008, Begay et al. 2011), even though the plant diversity, and therefore number of forbs, remains the same (Jog et al. 2006). Although not statistically significant, the forb biomass in hayed plots was less than all other treatments while the basal cover of forbs remained similar through all treatments. This may be an early indication of a reduction in size of the forb species in hayed plots.

My results suggest a lack of management is not a good option. Post-treatment, none of the factors favoring a prairie reconstruction were present in the unmanaged plots, with the exception of a drop in weed biomass. A comparison of post-treatment (2010) results found there was less native biomass produced in no management areas than all other treatments. Control plots showed trends of lower total vegetative biomass production, native biomass production, and weed biomass production. Control plots had significantly less grass biomass production relative to burned plots. All measured basal cover factors, except weeds, decreased from pre-treatment to post-treatment sampling. Post-treatment basal cover of all vegetation and native vegetation was significantly lower in control plots relative to burned plots. Additionally, control plots had significantly greater amounts duff biomass and basal cover relative to burned plots. The duff layer developed as annual plant growth was left on the ground and was not removed by burning or by collection and removal through haying. The increased duff probably contributed to the drop in weed biomass from pre-treatment to post-treatment sampling. Overall, results from the unmanaged plots indicate a general degradation of a prairie planting. Other studies have indicated that a lack of management causes a gradual degradation of the prairie area as an increase of duff and woody plants stifle the native vegetation (Bragg and Hulbert 1976, Weaver and Rowland 1952).

Small Mammals

Previous research has shown that changes in microhabitat will produce changes in the abundance of small mammals that occupy that area (Geier and Best 1980). Although the application of treatments led to significant changes in biomass production and basal cover, I did not find that small mammal usage differed between treatments during my summer trapping session. In a longer study vegetative characteristics may have changed enough to change the distribution of small mammals between treatments.

The plots generally fell into two categories during the fall trapping session. The hay and mow plots had just had their treatments applied and had virtually no standing vegetation while the control and burn plots had a whole growing season of standing vegetation in them. With that in mind it would be expected that the burn and control plots would have significantly more captures than the hay and mow plots, and that was exactly what I found.

Interestingly, there was no statistical difference in CPUE between the hay and mow plots, even though the mow plots had a thick duff layer on the ground while the hay plots had almost no duff. I expected more small mammals would be using the mowed plots since there was a duff layer that could conceal them from predators and harbor food, but this seemed not to be the case. Perhaps the small mammals were staying under the duff layer and not venturing out of concealment in order to enter the traps, or they were using both mowed and haying plots in an equally reduced manner.

During fall trapping in the North Block, the overall CPUE was about 0.154, but the distribution of captures in each treatment shifted dramatically. Captures in the recently hayed and mowed plots fell, while captures in the plots with standing vegetation (burn and control plots) increased. Just as I found, Springer (1986) noted a marked decrease, but not elimination, of small mammal use of recently burned areas while the vegetation was recovering. In my study, the overall CPUE remained virtually unchanged between summer and fall sampling, so I believe the overall number of small mammals utilizing the study area was unchanged, but there was a shift in the parts of the study area they used.

Use of an area by small mammals is largely due to the vegetative structure and heterogeneity of the area (Sietman et al. 1994). If this study had been conducted over several years it is likely I would have been able to correlate changes in vegetation to changes in small mammal community size and structure. For example, many studies have found a correlation between *Peromuscus leucopus* and woody vegetation, and between *Microtus ochrogaster,* grasses, and duff (Sietman et al. 1994).

The home ranges of these mammals generally vary from 500 to 1100 m^2 (Damuth 1981, Wolff 1985). Plot sizes in this study ranged 2,400 m^2 to 3,000 m^2. An individual small mammal's home range could have been entirely contained in one of my study plots, but it is likely the home range for a given small mammal would overlap at least two study plots. Small mammals often travel outside of their home range, and dispersal movements of 1.2 km and 3.22 km have been recorded for *M. pennsylvanicus* and *P. maniculatus*, respectively (Bowman et al. 2002).

Geier and Best (1980) state *Microtus pennsylvanicus*, *Blarina brevicauda*, and *Reithrodontomys megalotis* have a low susceptibility to live trapping. For *M. pennsylvanicus* and *B. brevicauda* I found that not to be the case. These two species were in the top three species for captures in summer and fall trapping, and *B. brevicauda* accounted for 59.5% of my fall captures.

B. brevicauda captures accounted for 20.7% of summer small mammal captures, but accounted for 59.5% of fall captures. This increase in captures could be a result of increased predation and caching of prey by *B. brevicauda* as they tried to increase their body mass to prepare for winter (Merritt 1986, Robinson and Brodie 1982).

It is likely I captured both *Microtus pennsylvanicus* and *M. ochrogaster*. *Microtus pennsylvanicus* and *M. ochrogaster* can be differentiated by the number of toe pads on the hind foot, but this difference can be difficult to tell under field conditions. I am confident I captured both *Peromyscus leucopus* and *P. maniculatus*, but positive field differentiation of these two species is more tenuous than the *Microtus* species. There is not a single defining difference between the two that can be identified in the field, but rather a series of small differences that must be considered together. For that reason I cannot say precisely how many of each *Peromyscus* species I captured during this study. Future studies should consider tissue samples for genetic analysis, and collection of voucher specimens to aid in species identification.

Capture rates were quite high in my study with an overall CPUE of 0.145. For comparison, Snyder and Best (1988) had a CPUE of 0.058, and Sietman et al. (1994) had a CPUE of 0.036 in native prairie. Despite a high capture rate, I did not have a single instance a recapture of a marked individual. It is possible that marking the small mammals with a permanent marker was not a reliable method, but I have witnessed recaptures in other studies using the same method.

Prairie Management

My study indicates that the best way to manage prairie plantings is with the use of fire. Just one application of fire can lead to many statistically significant shifts in the vegetative composition of a prairie reconstruction. Increases in native basal cover and native plant biomass resulting from just one application of fire may have long lasting effects on the reconstruction by increasing the vigor of native species and giving them an increased ability to outcompete invasive weed species.

Unfortunately, many prairie managers are not able to burn their plantings due to a lack of manpower and training, or concern about the risk involved with prescribed burns. Often governmental organizations are risk averse and concerned about the smoke blowing over roadways, runaway fires, and potential for injury to firefighters. Concern regarding these risks can eliminate the possible use of prescribed fire for vegetation management.

Haying and mowing are common techniques for managing prairie reconstructions, but my study found they had a mixed effect, and were less effective than burning, after one application. Between 2009 and 2010 mowing and haying resulted in a decrease in native and total vegetative biomass production, but they both increased native and total vegetative basal cover. Weeds in hayed plots increased greatly from pre-treatment to post-treatment sampling. Mowing led to significantly less grass biomass production than burning, and haying resulted in significantly less warm-season grass basal cover than burning. Additionally, mowing led to a significant increase in duff biomass and duff ground cover when compared with burning. However, mowing and haying may be reasonable choices when burning is not an option, because they produce more positive outcomes than no management.

My research indicates a lack of management is not good for prairie. No management led to significantly less grass biomass, total basal cover and native vegetative basal cover than in burned areas, and significantly more duff biomass than burned areas. As these reconstructions continue to go unmanaged, duff will continue to accumulate and further reduce the vigor of the native vegetation planted there (Weaver and Rowland 1952).

The ability of prairie managers to produce and maintain high quality prairie tracts could have positive effects for nature other than plants. Although often ignored, small mammals produce benefits to the ecosystem by causing soil disturbances, dispersing seeds and creating burrows that are used by native pollinating insects and bees (McFrederick and LeBuhn 2006, Brewer and Rejmanek 1999).

In fall small mammal trapping, many more mammals were caught in plots with standing vegetation (burn and control plots) than plots where standing vegetation had been removed due to recent mowing and haying. The idea that small mammals will decrease their use of an area where vegetation has been removed is supported by Springer (1986). The effects of removal of standing vegetation are likely short lived. Although my burn plots had had all standing vegetation removed by the application of fire in April 2010, summer trapping showed CPUE was equal among all treatments.

Instituting a patch burning management regime would be beneficial as small mammals are virtually excluded from plots that had been recently managed. Small mammals and insects could inhabit unburned areas while vegetation in the burned area recovered (Fuhlendorf and Engle 2004). In subsequent years the managed areas could be rotated in order that all parts of the reconstruction would be managed, but not all at the same time.

Across the prairie states, numbers of bird and mammal prairie specialists are declining substantially (Johnson and Igl 2001, Swengel 1996). Roadside prairies could serve as travel corridors for these animals to traverse between larger prairie remnants and reconstructions which are largely isolated from one another. Each management technique causes changes in the vegetation of the area. Changes in vegetation drive changes in the bird and mammal species that will use the area (Swengel 1996). Management regimes that cause vegetative heterogeneity in an area have been shown to increase the number of grassland bird species that will choose to use that area

(Fuhlendorf et al. 2006). The manner in which all of the management techniques used in my study are applied can create or inhibit heterogeneity. Incomplete, or patchy, burns increase heterogeneity, as can applying mowing or haying to parts of an area while leaving other parts unmanaged.

Study Limitations

One limiting factor of this study is its short time span. Although I did find significant differences between treatments after only one application, many other differences may have become evident if the study would have continued into subsequent years. In a study involving yearly mowing, Wilson and Clark (2001) found it took three years for an effect to materialize. Other studies have taken even longer to find vegetative effects from fire. Howe (2000) found differences is grass composition after two applications of fire over six years, and Towne and Kemp (2008) didn't find significant cool-season graminoid effects until eight years of annual application of fire.

I planned to burn my burn plots in Fall 2009 in order to have all of my treatments applied in the Fall to remove seasonality of treatment application as a possible variable, however, the vegetation was too green, sparse and wet for a fire to carry through the vegetation in Fall 2009. Haying and mowing were applied in late summer, so the seasonality of treatment may also have had an effect that masked or accentuated the results. Many studies have shown that seasonality of application can change the effect of a single treatment. Studies have found different effects between May and August fire dates (Howe 2000), and also between April and May fire dates (Nagel 1980). Fire is not the only treatment that can have varying effects when applied in different seasons. Howe (1999) found May mowing had no effect on *Zizia* auria population size, but he doubled the population size through an August mowing treatment.

The study site itself may have had some effect on the results. There were two soil types present in the study area: Lawler loam and Waukee loam. Lawler and Waukee loams are both described as fine-loamy soil over sandy alluvium, but the Lawler series is somewhat poorly drained while the Waukee series is well drained (USDA NRCS Official Soil Series Descriptions 2008). This difference in soil drainage may have caused some parts of the study area to retain more soil moisture than others. Annual precipitation, along with the ability of the soil to hold moisture, would control the amount of moisture available for plants during the growing season. In a long study of the effects of meteorological variability, Briggs and Knapp (1995) found growing season soil moisture to be the strongest indicator of grass and total aboveground biomass production. I found significant block differences in basal cover of warm-season grass in my 2009 vegetative sampling, but not in 2010. Perhaps soil moisture differences between the blocks altered the germination or survival of warm-season grasses during establishment of my research prairie. Future study of the effects of soil moisture and precipitation on basal cover and biomass could be warranted.

Schramm (1990) describes four stages of succession of prairie reconstructions. Stage I starts with the initial growing season following planting and the last stage, Stage IV, usually doesn’t arrive for 13 to 20 years. Schramm’s successional stages describe the competition between and eventual dominance of certain prairie species as they form the climax community structure. In my study, the experimental treatments were applied during the fourth growing season. If Schramm's timeline is correct, it is possible some of my results were influenced by the normal progression of succession in a prairie planting and were not due to the experimental treatments. However, one has to assume that all areas would have continued undergoing similar succession in the absence of the treatments. Since my results varied among treatments, it is more likely the treatments influenced succession.

Conclusions

The short time span of this study limited its ability to show significant changes in vegetative structure between the treatments. However, burning resulted in more grass biomass and more total vegetative, native vegetative, and warm-season grass basal cover, while decreasing duff. Haying and mowing produced limited change in vegetation, but mowing led to an increase in duff accumulation. No management led to a reduction in native vegetation production and increased cover of duff.

The vegetative changes produced by one application of treatments were not sufficient to cause changes in use of treatment areas by small mammals. Small mammal captures were significantly higher in treatment areas with standing vegetation during the trapping period. It appears small mammals moved from plots without vegetation to those with vegetation, but did not leave the research area.

Prairie managers should strive to use fire in vegetation management when it is possible. When burning is not an option, mowing and haying can produce some positive vegetative changes, but can also cause some negative changes. Leaving prairies unmanaged will result in their degradation. In some cases signs of degradation will become apparent in as little as one year.

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APPENDIX A

YEARLY PLOT BIOMASS MEANS

Block	Plot	Year	Treatment	Tot. Veg.	Nat. Veg.	Forbs	Grasses	Weeds	Duff
North	1	2009	Control	83.76	65.94	58.00	7.94	17.82	NS
North	2	2009	Hay	98.06	81.16	11.16	70.00	16.90	NS
North	3	2009	Burn	100.88	93.44	1.10	92.34	7.44	NS
North	4	2009	Hay	78.08	74.60	12.30	62.30	3.48	NS
North	5	2009	Mow	102.82	101.28	11.58	89.70	1.54	NS
North	6	2009	Burn	37.68	32.62	0.00	32.62	5.06	NS
North	7	2009	Mow	55.97	47.79	3.63	44.16	8.18	NS
North	8	2009	Burn	111.16	91.02	4.48	86.54	20.14	NS
North	9	2009	Mow	91.24	78.44	0.00	78.44	12.80	NS
North	10	2009	Control	57.00	33.82	3.84	29.98	23.18	NS
North	11	2009	Hay	120.44	110.12	4.06	106.06	10.32	NS
North	12	2009	Control	60.10	51.96	0.00	51.96	8.14	NS
South	1	2009	Burn	65.04	53.66	40.16	13.50	11.38	NS
South	2	2009	Mow	54.18	48.50	13.14	35.36	5.68	NS
South	3	2009	Burn	54.10	34.06	1.16	32.90	20.04	NS
South	4	2009	Hay	37.14	35.42	5.12	30.30	1.72	NS
South	5	2009	Mow	33.30	28.02	0.00	28.02	5.28	NS
South	6	2009	Control	75.26	72.26	22.88	49.38	3.00	NS
South	7	2009	Hay	52.56	49.88	16.84	33.04	2.68	NS
South	8	2009	Hay	47.46	46.18	13.90	32.28	1.28	NS
South	9	2009	Control	73.32	68.96	60.98	7.98	4.36	NS
South	10	2009	Mow	53.54	48.82	0.20	48.62	4.72	NS
South	11	2009	Burn	54.68	50.48	0.44	50.04	4.20	NS
South	12	2009	Control	59.16	46.00	5.40	40.60	13.16	NS
North	1	2010	Control	44.50	38.66	31.64	7.02	5.84	9.62
North	2	2010	Hay	77.52	63.50	0.86	62.64	14.02	5.92
North	3	2010	Burn	54.36	45.50	0.00	45.50	8.86	1.38
North	4	2010	Hay	68.40	63.84	2.12	61.72	4.56	2.36
North	5	2010	Mow	42.22	41.84	20.08	21.76	0.38	11.62
North	6	2010	Burn	90.40	86.46	38.62	47.84	3.94	0.98
North	7	2010	Mow	35.58	33.00	21.04	11.96	2.58	15.70
North	8	2010	Burn	91.02	85.66	34.28	51.38	5.36	0.76
North	9	2010	Mow	67.16	65.00	5.32	59.68	2.16	13.76

(Table continues)

North	10	2010	Control	41.22	24.84	2.26	22.58	16.38	28.06
North	11	2010	Hay	69.60	65.58	31.78	33.80	4.02	3.62
North	12	2010	Control	71.74	69.52	12.26	57.26	2.22	2.64
South	1	2010	Burn	52.78	45.54	9.20	36.34	7.24	1.08
South	2	2010	Mow	71.32	58.36	26.38	31.98	12.96	15.38
South	3	2010	Burn	111.48	103.14	26.04	77.10	8.34	0.16
South	4	2010	Hay	98.22	93.80	4.26	89.54	4.42	3.32
South	5	2010	Mow	73.62	54.58	12.74	41.84	19.04	13.02
South	6	2010	Control	73.94	69.50	30.32	39.18	4.44	4.84
South	7	2010	Hay	40.52	27.92	0.84	27.08	12.60	6.64
South	8	2010	Hay	60.64	38.70	11.46	27.24	21.94	11.18
South	9	2010	Control	69.42	64.70	26.22	38.48	4.72	35.80
South	10	2010	Mow	66.28	52.02	28.46	23.56	14.26	24.74
South	11	2010	Burn	113.78	110.10	30.16	79.94	3.68	1.24
South	12	2010	Control	33.82	30.42	11.28	19.14	3.40	2.46

APPENDIX B

YEARLY PLOT BASAL COVER MEANS

Block	Plot	Year	Rx	T Veg	N Veg	WSG	CSG	Grams	Forbs	Weeds	Duff
North	1	2009	Ctrl	1.16	0.77	0.02	0.51	0.53	0.23	0.39	24.33
North	2	2009	Hay	1.28	0.92	0.02	0.77	0.78	0.14	0.36	54.67
North	3	2009	Burn	1.80	1.40	0.01	1.38	1.39	0.00	0.40	57.83
North	4	2009	Hay	1.89	1.69	0.02	1.38	1.40	0.29	0.20	79.20
North	5	2009	Mow	2.41	2.25	0.00	2.22	2.22	0.02	0.17	83.00
North	6	2009	Burn	1.86	1.48	0.01	1.34	1.35	0.13	0.38	70.33
North	7	2009	Mow	2.30	1.90	0.01	1.04	1.05	0.85	0.40	63.50
North	8	2009	Burn	2.94	2.33	0.00	2.21	2.21	0.12	0.61	85.33
North	9	2009	Mow	1.79	0.58	0.00	0.48	0.48	0.10	1.20	66.67
North	10	2009	Ctrl	3.39	2.88	0.03	2.64	2.67	0.22	0.51	76.33
North	11	2009	Hay	2.67	2.24	0.00	1.94	1.94	0.29	0.43	92.67
North	12	2009	Ctrl	3.06	2.62	0.05	2.13	2.18	0.44	0.44	87.33
South	1	2009	Burn	2.47	1.82	0.00	0.63	0.63	1.19	0.65	47.33
South	2	2009	Mow	2.45	1.94	0.01	1.73	1.74	0.13	0.58	82.67
South	3	2009	Burn	2.40	2.25	0.13	1.83	1.96	0.29	0.15	89.33
South	4	2009	Hay	1.66	1.54	0.00	1.02	1.02	0.12	0.51	89.17
South	5	2009	Mow	2.91	2.43	0.00	2.04	2.04	0.39	0.48	83.67
South	6	2009	Ctrl	2.08	1.05	0.21	0.78	0.98	0.07	1.03	75.50
South	7	2009	Hay	2.41	2.07	0.20	1.00	1.21	0.86	0.34	80.00
South	8	2009	Hay	2.21	1.76	0.20	0.70	0.90	0.85	0.47	88.67
South	9	2009	Ctrl	2.72	2.27	0.09	1.20	1.29	0.94	0.49	76.33
South	10	2009	Mow	2.48	2.24	0.22	0.83	1.05	1.20	0.24	80.83
South	11	2009	Burn	3.21	2.84	0.17	1.05	1.22	1.62	0.37	73.33
South	12	2009	Ctrl	2.45	1.80	0.31	0.96	1.27	0.53	0.64	27.33
North	1	2010	Ctrl	2.19	1.53	0.25	1.04	1.29	0.25	0.65	53.60
North	2	2010	Hay	3.69	2.77	0.00	2.51	2.51	0.25	0.92	14.25
North	3	2010	Burn	2.83	1.97	0.08	1.23	1.32	0.66	0.86	32.25
North	4	2010	Hay	4.16	2.43	0.00	1.58	1.58	0.85	1.73	51.75
North	5	2010	Mow	3.39	2.72	0.00	2.72	2.72	0.00	0.68	97.05
North	6	2010	Burn	2.78	2.24	0.53	1.37	1.90	0.35	0.54	16.95
North	7	2010	Mow	2.91	2.46	0.05	0.89	0.94	1.52	0.46	81.65
North	8	2010	Burn	3.45	2.81	0.27	0.97	1.24	1.58	0.64	5.85
North	9	2010	Mow	3.06	2.18	0.00	1.47	1.47	0.71	0.89	92.50

(Table continues)

North	10	2010	Ctrl	2.37	1.62	0.00	1.44	1.44	0.18	0.75	99.00
North	11	2010	Hay	2.97	2.43	0.00	2.30	2.30	0.13	0.54	12.90
North	12	2010	Ctrl	2.06	1.38	0.00	1.38	1.38	0.00	0.68	92.75
South	1	2010	Burn	3.50	2.96	0.17	1.16	1.33	1.63	0.54	7.95
South	2	2010	Mow	2.81	2.30	0.09	1.89	1.98	0.32	0.51	88.55
South	3	2010	Burn	3.32	2.97	0.21	0.98	1.19	1.78	0.35	9.05
South	4	2010	Hay	2.70	1.61	0.00	1.53	1.53	0.08	1.09	28.75
South	5	2010	Mow	2.33	1.49	0.06	1.22	1.28	0.21	0.84	75.05
South	6	2010	Ctrl	2.18	1.54	0.01	1.37	1.38	0.16	0.63	42.30
South	7	2010	Hay	2.22	1.58	0.03	0.86	0.89	0.69	0.63	41.25
South	8	2010	Hay	2.98	1.68	0.27	0.53	0.80	0.88	1.30	84.55
South	9	2010	Ctrl	2.39	2.18	0.15	0.75	0.90	1.28	0.21	93.50
South	10	2010	Mow	2.58	1.96	0.00	1.80	1.80	0.16	0.62	25.75
South	11	2010	Burn	2.59	1.94	0.04	1.49	1.53	0.41	0.66	8.05
South	12	2010	Ctrl	2.98	1.94	0.07	1.42	1.49	0.46	1.03	38.20

APPENDIX C

SMALL MAMMAL TRAPPING MEANS

Block	Plot	Treatment	Season	Captures	Trap Nights	CPUE
North	1	Control	Summer	10	85	0.118
North	2	Hay	Summer	18	167	0.108
North	3	Burn	Summer	33	166	0.199
North	4	Hay	Summer	25	169	0.148
North	5	Mow	Summer	27	168	0.161
North	6	Burn	Summer	16	170	0.094
North	7	Mow	Summer	34	86	0.395
North	8	Burn	Summer	27	157	0.172
North	9	Mow	Summer	44	171	0.257
North	10	Control	Summer	32	168	0.190
North	11	Hay	Summer	24	171	0.140
North	12	Control	Summer	36	171	0.211
South	1	Burn	Summer	15	131	0.115
South	2	Mow	Summer	18	135	0.133
South	3	Burn	Summer	21	135	0.156
South	4	Hay	Summer	10	134	0.075
South	5	Mow	Summer	22	133	0.165
South	6	Control	Summer	22	134	0.164
South	7	Hay	Summer	26	133	0.195
South	8	Hay	Summer	11	132	0.083
South	9	Control	Summer	9	135	0.067
South	10	Mow	Summer	4	135	0.030
South	11	Burn	Summer	21	135	0.156
South	12	Control	Summer	18	131	0.137
North	1	Control	Fall	10	27	0.370
North	2	Hay	Fall	1	49	0.020
North	3	Burn	Fall	6	47	0.128
North	4	Hay	Fall	3	48	0.063
North	5	Mow	Fall	0	48	0.000
North	6	Burn	Fall	8	44	0.182
North	7	Mow	Fall	0	26	0.000
North	8	Burn	Fall	19	53	0.358

(Table continues)

North	9	Mow	Fall	1	50	0.020
North	10	Control	Fall	15	47	0.319
North	11	Hay	Fall	4	48	0.083
North	12	Control	Fall	13	42	0.310
South	1	Burn	Fall	10	45	0.222
South	2	Mow	Fall	0	40	0.000
South	3	Burn	Fall	9	37	0.243
South	4	Hay	Fall	2	43	0.047
South	5	Mow	Fall	1	40	0.025
South	6	Control	Fall	6	44	0.136
South	7	Hay	Fall	0	40	0.000
South	8	Hay	Fall	0	38	0.000
South	9	Control	Fall	5	41	0.122
South	10	Mow	Fall	1	44	0.023
South	11	Burn	Fall	8	41	0.195
South	12	Control	Fall	4	44	0.091