EVALUATION OF A GRAZING SYSTEM FOR MAINTAINING GRASSLAND INTEGRITY AND IMPROVING UPLAND BIRD HABITAT

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NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION INNOVATION GRANT

NRCS 68-3A75-5-203

PROJECT FINAL REPORT

31 December 2008

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MISSOURI DEPARTMENT OF CONSERVATION

Evaluation of a grazing system for maintaining grassland integrity and improving upland bird habitat

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SUMMARY

Animal performance and economics

- Daily gains of yearling cattle averaged about 1.5 lbs/hd·d^{-1}. Gain per acre varied widely among sites from 32 to about 88 lbs/acre.
- Despite lower stocking rates employed in patch-burn grazing on native forage and lower gain per acre, returns from patch-burn grazing are likely to exceed those from management-intensive grazing with an endophyte-infected tall fescue forage base.

Grazing distribution

- Improved forage palatability resulting from prescribed fire was an adequate attractant to control grazing distribution.
- Yearling cattle were observed grazing in the most recently burned patches about 64% of the time.

Vegetation structure

- In addition to the obvious effects of reduced vegetation height and density, patch-burn grazing increased heterogeneity of height, density, and litter depth both within and among patches in the grazing unit.

Birds

- Species richness was greater on PBG sites than on control sites.
- On PBG sites, four true grassland bird species occurred uniquely or predominately. Of these, two are species of management concern and one is a state endangered species.
- No true grassland species occurred uniquely or predominately on control units.

Plant species composition

- Across all sites and years, more plant species were documented in grazed treatment plots than ungrazed control plots.
- Analyses of vegetation composition data for 2005-2007 showed no significant differences in species richness or FQI among burn patches (P > 0.05).

Demonstration Efforts

- Project coordinators, collaborating scientists,and team members conducted or participated in ≥12 conferences, workshops, and field tours to share information on the practice of patch-burn grazing and provide updates on results of monitoring.
- We facilitated the development of magazine articles and posted an animated clip on YouTube® that demonstrates the process of patch-burn grazing. To view the video, direct your internet browser to: **http://www.mdc.mo.gov/18952**.

INTRODUCTION

Rotation burning in rangelands (a.k.a., patch-burn grazing) is a system that uses prescribed fire to control grazing distribution (Duvall and Whitaker 1964). Rather than burning all (or none) of a pasture, only a portion or "patch" is burned. The burned area, typically one-third of the total pasture, attracts the most grazing pressure resulting in disprortionate use of forage across the pasture within a growing season. In following years, different patches are burned shifting grazing pressure from one area to another among years.

Though patch-burn grazing was developed over 40 yrs ago, renewed interest in the approach has increased its popularity in the field of range ecology (Fuhlendorf and Engle 2001, 2004). Most popular approaches to range management have sought to reduce unequal forage utilization across a pasture to preserve sustainability that would be threatened by overgrazing. Cattlemen have traditionally controlled grazing distribution by using fences and strategic placement of other resources such as watering points or mineral supplement. In line with the goal of even utilization, burning a small area of the pasture was seen as counterproductive. However, some range ecologists have come to view partial burns as beneficial. Patch-burn grazing contrasts traditional grazing management in that equal forage utilization is distributed across a longer period (e.g., three years) rather than within a single growing season.

The most immediate and obvious difference resulting from patch-burn grazing versus traditional range management is greater heterogeneity in vegetation height and density across the grazed area. Many have suggested that this diversified cover may benefit grassland wildlife and that the variation in disturbance intensity across the unit may contribute to plant species diversity.

Missouri Department of Conservation land manageres were interested in implementing patch-burn grazing to diversify the height and density of grassland cover to provide better habitat for grassland birds. Management staff suggested that patch-burn grazing could create habitat structure that served a wider array of species than that created by using traditional disturbances such as fire or hay harvest. Traditional management practices tended to create uniform vegetation structure and disturbance effects were relatively short-lived when viewed across Missouri's long and mesic growing season. Early observations of the effects of patch-burn grazing on habitat structure appeared promising; however, some ecologists were concerned that the system may have deleterious effects on relatively rare plant species that appeared to be maintained under traditional management. Managers also questioned whether livestock performance under the system would be competitive with other currently favored systems—a factor that could affect acceptance by cattlemen that graze Department areas under grazing leases and the feasibility of its use on private lands where cattle production is a higher priority than wildlife conservation.

We initiated this 4-yr project in 2005 to demonstrate patch-burn grazing on five tallgrass prairie remnants in Missouri and monitor the influence of patch-burn grazing on 1) animal performance, 2) grazing distribution, 3) grassland bird habitat, 4) use by breeding grassland birds, and 5) plant species composition. Ray Moranz, a collaborating scientist at Oklahoma State University, documented use by adult butterflies. Results of butterfly surveys are presented elsewhere.

METHODS

Study Area and Project Design

We selected 5 tallgrass prairie remnants in west-central Missouri on which to establish and monitor patch-burn grazing treatments (Figure 1). Sites were owned by the Missouri Department of Conservation (MDC) or The Nature Conservancy (TNC). Sites owned by TNC were managed cooperatively by MDC and TNC staff. Site selection was non-random and based on 1) the ability of the area to encompass a grazing unit ≥100 acres in size and a control unit of similar size, and 2) the ability to provide a reliable water source under average climatic conditions, and 3) the feasibility of installing infrastructure prior to the mid-April 2005 start date. We established one grazing management unit and a similarly sized control unit at each site. Grazing units ranged in size from about 154 acres to 262 acres (Table 1), and were defined by a barbed wire or high-tensile electric boundary fence. Interior fencing was limited to that used to exclude cattle from stock ponds or other sensitive areas that comprised <1% of the total area of the grazing unit. One water source was provided in each grazing unit.

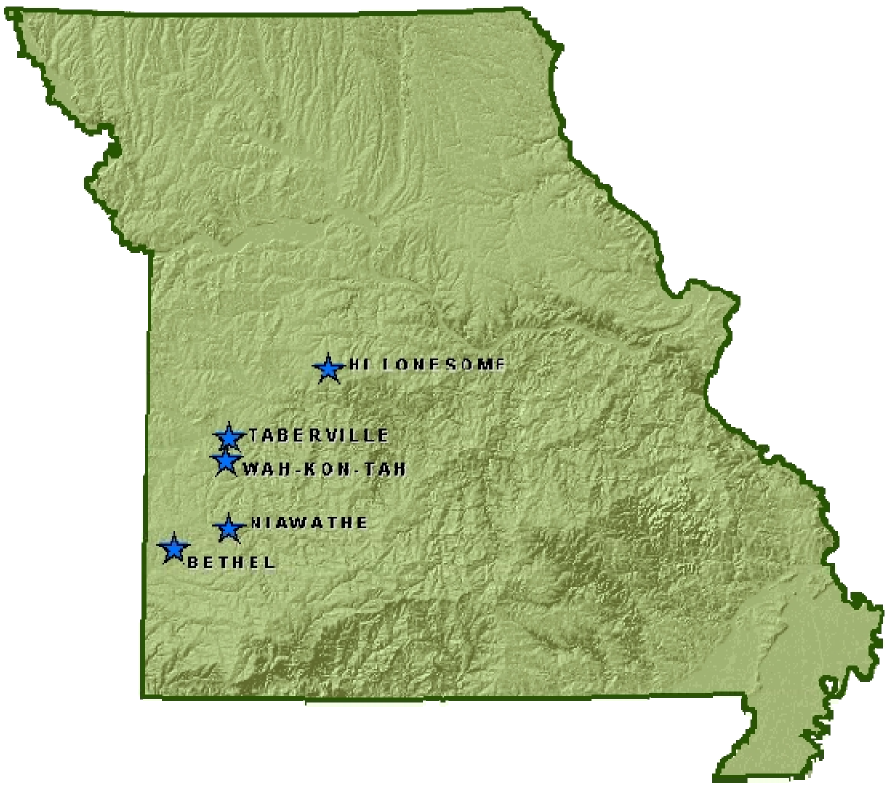


Figure 1. Missouri Department of Conservation lands and properties of The Nature Conservancy at which patch-burn grazing was demonstrated and monitored from 2005 through 2008.

Table 1. Ownership and area (acres) of patch-burn grazing units and control units on five tallgrass prairie remnants in west-central and southwestern Missouri.

		Acres	
Site Name	Owner	Grazing Unit	Control Unit
Bethel Prairie Conservation Area	MDC	153.5	104.2
Hi Lonesome Prairie Conservation Area	MDC	261.8	213.0
Niawathe Prairie	MDC and TNC	173.3	145.0
Taberville Prairie Conservation Area	MDC	241.8	217.9
Wah' Kon-Tah Prairie	MDC and TNC	242.6	239.8

Each control unit and each grazing unit was divided into 3 patches that each comprised about one-third the area of the total unit. To employ the patch-burn grazing system, one patch in each unit was burned during spring. Grazing units were stocked with yearling cattle at a rate of 5.5 acres/AU for 120 d. Control units received only prescribed fire.

Timeline and Sampling Schedule

Managers installed infrastructure, including exterior fencing and water sources, during 2004 in preparation for spring of 2005. We burned one patch in each control and grazing unit between 15 March and 10 April each year from 2005 through 2007. Although the day of year on which we conducted prescribed burns varied among sites and years, we always burned patches in control units on the same day as the patches in grazing units to eliminate date-of-burn effects at the site level. An arsonist started a wildfire on 1 March 2006 that burned a portion of the Wah' Kon-Tah study site. The fire burned a narrow corridor through the eastern one-third of each control unit patch, the eastern one-third of the 2005 burn patch in the grazing unit, and most of the 2006 burn patch in the grazing unit (Figure 2).

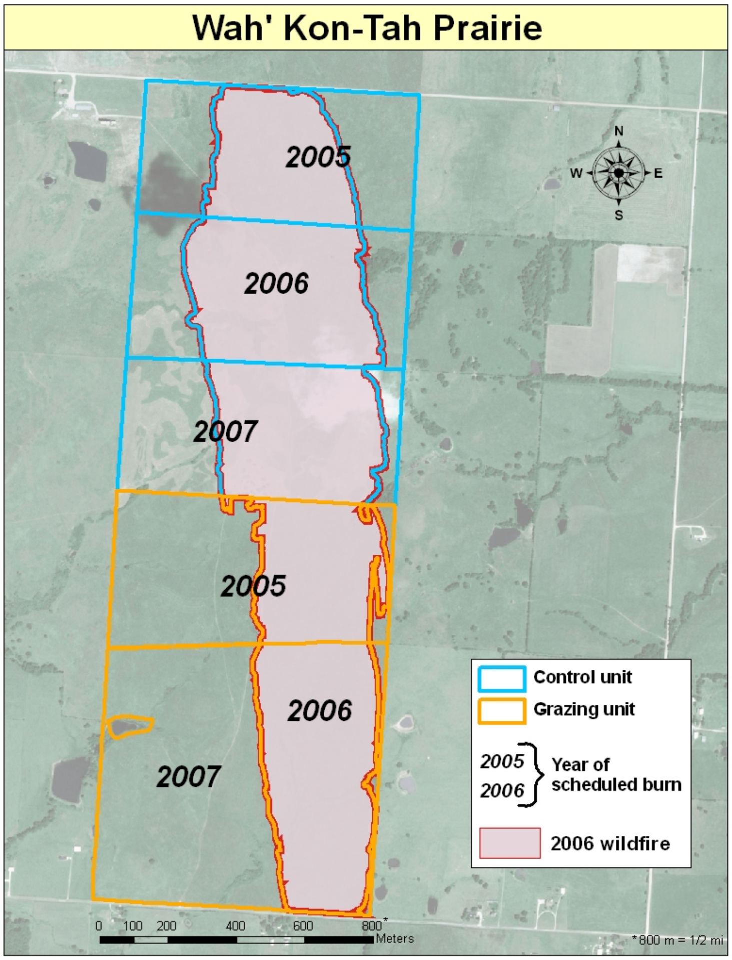


Figure 2. Wah' Kon-Tah Prairie patch-burn grazing unit and control unit with boundary of 233-acre area burned by arson-set wildfire on March 1, 2006.

Patch-burn grazing treatments and monitoring began in 2005. We determined starting weights of mixed-breed 9- to 14-mo-old yearling cattle within seven days prior to stocking in mid-April and ending weights within three days of when cattle were removed in mid-August each year during 2005, 2006, and 2007. We mapped locations of cattle at least twice per week through early August each grazing season. Observations ceased when cattlemen began supplemental feeding to condition animals to gather at specific points to facilitate round-up in mid-August.

We measured vegetation height and density (i.e., vegetation structure) beginning the last week of May and concluded sampling by mid-June each year from 2005 through 2008. We conducted breeding bird surveys from late May through mid-July 2006 and 2007, and we sampled vegetation composition and coverage in July each year from 2005 through 2008.

Sampling Methods

Animal performance and economics.— We weighed cattle individually by using portable electronic scales with a digital indicator or the cattleman's permanent electronic scales (Figure 3). To develop frame scores for later analyses, we read hip heights to the nearest 1 inch as cattle were weighed. Starting weights were determined on the same scales as ending weights for each group of animals.

Figure 3. Weighing yearling cattle for the Taberville Prairie site by using portable electronic scales. Cattle were transported by truck to the grazing unit immediately following weighing.

Grazing Distribution.—Locations of grazing animals were determined by using ground-based surveys. Observers approached grazing units by vehicle in an inconspicuous manner and recorded locations of all readily visible individuals in the unit on an aerial photograph. Observers then searched for missing animals by driving to locations that provided a vantage point of previously obscured areas of the unit. Finally, the observer searched the area on foot until ≥95% of the total number of head in the unit had been located. For each mapped location, the observer recorded the activity of the animal as grazing or loafing. Locations marked on the aerial photos were digitized in ArcMap 9.2™ (ESRI 2008, Redlands, California 92373) and the date of observation and the activity of the animal (grazing or loafing) were recorded in corresponding attribute tables.

Vegetation structure.—We excluded the Hi Lonesome site from vegetation structure sampling and bird surveys because we suspected that ongoing woody vegetation control efforts at the site would have confounded our vegetation structure and resulting bird use information. We measured vegetation structure at the four remaining sites by using a 200 × 10-cm vertical cover board divided into 10 × 10-cm strata (Figure 4). Sampling locations were established systematically on a 50-m grid created by using Hawthorn's Tools for ArcMap 9.2. Across all four sites, we established 2,391 sampling points in control and grazing units. Pairs of observers traversed both control and grazing units on foot and located sampling points by using a Wide Area Augmenation System (WAAS) enabled hand-held Global Positioning System (GPS) receiver. At each sampling point, observers recorded litter depth to the nearest 1 cm and estimated percentage of each stratum that was obscured by live or residual vegetation. Observers read cover boards from a distance of 5 m and from a height of 1 m above ground. To categorize estimated obstruction, observers coded estimated percentages to pre-defined cover classes (Table 2). Observers omitted sampling at points that fell within stock ponds or impenetrable cover types such as dense blackberry (*Rubus* spp.) thickets >1.5m in height.

Figure 4. Observers estimating percent obstruction of 200 × 10-cm coverboard from a distance of 5 m and height of 1 m.

Table 2. Cover classes assigned to estimated percent coverage of coverboard strata and mid-points of ranges used for statistical analyses.

% cover	Cover class	Mid-point
0	0	0.0
≤ 1	1	0.5
2 - 5	2	3.5
6 - 10	3	8.0
11 - 20	4	15.5
21 - 30	5	25.5
31 – 40	6	35.5
41 – 50	7	45.5
51 – 60	8	55.5
61 – 70	9	65.5
71 – 80	10	75.5
81 – 90	11	85.5
91 – 99	12	95.0
100	13	100.0

Grassland Birds.—Densities of breeding birds were determined by using distance sampling techniques wherein we counted birds encountered along transects. Distance sampling is based on determining a detection function. We used program DISTANCE to compute the probability of detection (p) for the avian species associated with our grassland community (Buckland et al. 2001). The detection function compensated for the fact that detectability decreases with increasing distance from the observer (Rosenstock et al. 2002). Distance sampling also allowed us to model detection probability by observer, study site, treatment and other habitat characteristics. We established two permanent survey transects in each burn-year patch in the grazing unit and in each patch in the control unit at four of the five sites by marking the beginning and end points with fiberglass fence posts. To help observers to maintain the correct azimuth as they walked transects, additional posts were added along the transects when the end point could not be seen from the starting point due to terrain. Bird surveys were not conducted at Hi Lonesome due to additional management efforts that affect vegetation structure. We conducted 12 line transect surveys in two consecutive years. Two sites were sampled simultaneously each morning with one observer in the control unit while another observer surveyed the treatment unit. Four observers conducted surveys each year beginning at sunrise and ending by 1000 hrs. Birds encountered along transects were identified by sight or sound. For each individual bird encountered, observers recorded the species, and distance from the transect line using laser range finders.

Vegetation composition.—We monitored changes in vegetation composition in 9 pairs of permanent sampling plots per site. Each 10 $\times$ 10-m plot employed a nested design (Figure 5), and we established a pair of these sampling plots at each of three randomly selected locations within each patch of the grazing unit. We arranged plots such that members of the pair shared slope and aspect, fell on approximately the same contour, and appeared to encompass similar vegetation communities. One plot of each pair was selected to serve as a control to isolate the effects of grazing. We determined which plot would serve as the control by the flip of a coin, and constructed a grazing exclosure around that plot by using t-posts and woven-wire fencing. We retained a 1-m buffer between the exclosure fence and the sample plot boundary. Plots within pairs were separated by a 15-m buffer to ensure that cattle paths that developed around exclosure fences did not influence vegetation in the unfenced treatment plot.

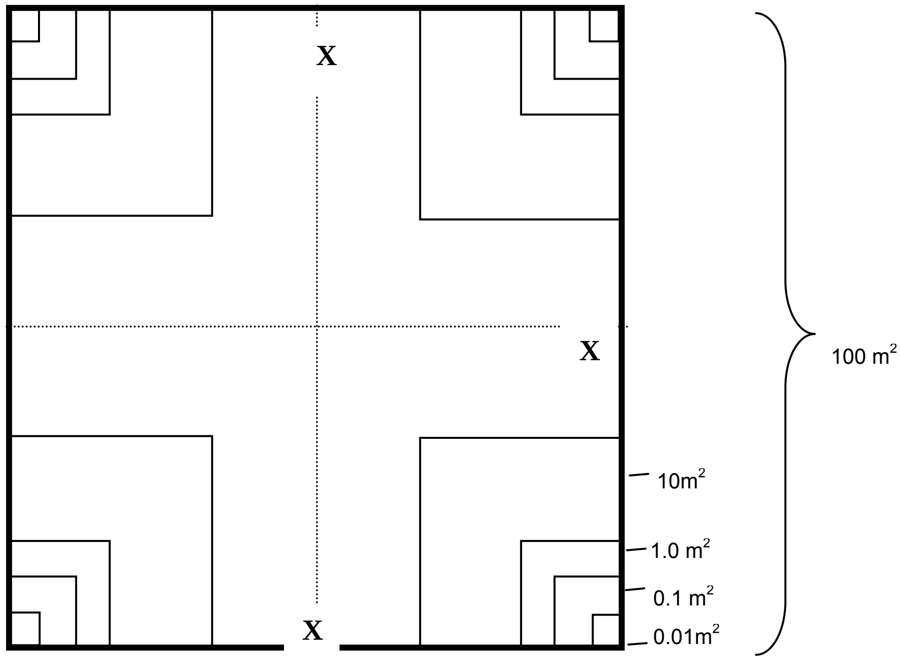


Figure 5. Nested sampling unit for measuring plant species composition.

Analyses

Animal performance and economics.— We calculated average daily gain (lbs/head/day) for each animal. Average daily gain (ADG) estimates for each site were calculated as the grand mean of the invidual average daily gains. Gain per acre was calculated for each site by dividing the total of the individual gains by the total acres used to determine stocking rates. We compared potential economic returns of patch-burn grazing on un-fertilized tallgrass prairie to that for yearling cattle under management intensive grazing (MIG) with a tall fescue (*Schedonorus phoenix*) forage base. We used the most recently available input costs for our comparison and calculated returns over a 3-yr period. We used animal performance results from our evaluation for patch-burn grazing on tallgrass prairie and published estimates from the University of Missouri for MIG-managed tall fescue to compare potential costs and benefits using hypothetical scenarios for 160 acres of available forage. Input costs were categorized as either initial costs required to establish necessary infrastructure or annual operating costs. To identify initial costs, we assumed that perimeter fencing, one watering point, and the forage base were in place for both the patch-burn grazing and MIG scenario. No additional infrastructure would be required for patch-burn grazing. For the MIG scenario, we estimated the costs of installing three additional watering sources to reduce animal travel distance to less than 800 ft as recommended by the University of Missouri. We also estimated the cost of an additional 1 mile of permanent barbed-wire fencing and 5 miles of electric fencing required to create paddocks for MIG. We estimated the annual cost of fence maintenance and labor costs for both grazing systems, the cost of annual nitrogen inputs for MIG, and the cost of contracting prescribed fire for patch-burn grazing. We assumed a 120-d grazing period for each grazing system-forage type combination and that cattle were sold at the end of the grazing period regardless of body weights.

Grazing distribution.—Cattle observation data were summarized by determining the proportion of observations that occurred in the most recent burn each treatment year of the study. For 2007, we compared densities of cattle observations in the most recently burned patch to that of patches burned in previous years.

Vegetation structure.—Because exploratory analyses suggested that variation in vegetation structure was driven primarily by obstruction at lower strata and estimates of maximum height, we restricted most comparisons to these variables. Prior to analyses, we converted cover class categories to percentages by using the corresponding mid-point of the range (Table 2). To examine effects of patch-burn grazing on vegetation height, density, and litter depth, we estimated mean maximum height, mean percent obstruction at 0-10 cm and 11-20 cm above ground, and average litter depth for patches within grazing units and controls for each year. To demonstrate changes in these variables over time, we selected a single class of burn-year patches (i.e., all patches that were burned in 2006) and estimated values for the above variables for the year prior to prescribed fire, the year the prescribed fire was applied, and each of the two years following prescribed burning. These sampling occassions were denoted as -1, 0, 1, and 2 yrs post-burn, respectively. Data summaries were completed in SAS 9.1.

Grassland birds.—To determine PBG effects on bird diversity and abundance we referenced the bird survey results to the patch or unit they were located in to show their response to burning, grazing or the combination of burning and grazing. We tested for differences in species richness among burning and grazing treatment combinations by using analysis of variance (ANOVA) in SAS (SAS Institute 2000). We examined differences in species richness and abundance by study site, treatment, years since burning, and treatment plus years since burning. We estimated avian abundance with program DISTANCE (version 5.0; Thomas et al. 2005).

We chose to analyze data for Dickcissel and Henslow's Sparrows for three reasons. One, they were the two largest datasets respectively, and two; both species are associated with dense stands of tallgrass prairies. We expected both species to show preference for the taller, thicker grasslands found in the control units and have lower abundance estimates in the grazed areas and even lower numbers in the grazed and burned patches. And three, Henslow's Sparrows are also listed as a species of concern, and the Dickcissel is a species of management concern in Missouri (MDC 2008).

To get a picture of how PBG affects other species we chose to evaluate Eastern Meadowlarks and Grasshopper Sparrows. These species are associated with short to medium height grasslands and their sample sizes were adequate for evaluating patch level abundances. The Eastern Meadowlark is common in Missouri but the Grasshopper Sparrow is designated a species of management concern (MDC 2008).

Vegetation composition.— Plant species richness and the Frequency Quality Index (FQI) were the indicators observed to understand how the plant community responds to a fire-grazing interaction. The FQI describes the plant community by weighting species by degree of conservatism at a site. FQI was calculated as $FQI = C/N * N^{0.5}$ where C is the sum of coefficient of conservatism values and N is the total number of natives for each plot. Each plant is assigned a coefficient based on its specificity and fidelity to a particular habitat type where 10 is highly conservative and 0 is ubiquitous (Ladd 2004). Introduced plants do not receive a value and, therefore, do not factor into the calculation. Greater FQI values indicate greater numbers of highly conservative plants (species that disappear quickly with degradation). The total number of species and FQI for each plot was determined, and comparisons were analyzed using an analysis of variance (ANOVA) for differences between grazed and non-grazed plots. Data summaries were completed in SAS 9.1.

RESULTS

Animal performance and economics

Averaged daily gains (ADG) of yearling cattle ranged from 1.0 to 2.1 lbs/hd·d^{-1} among sites and years (Figure 6). Gain per acre varied from a low of 34 to about 88 lbs/acre (Table 3).

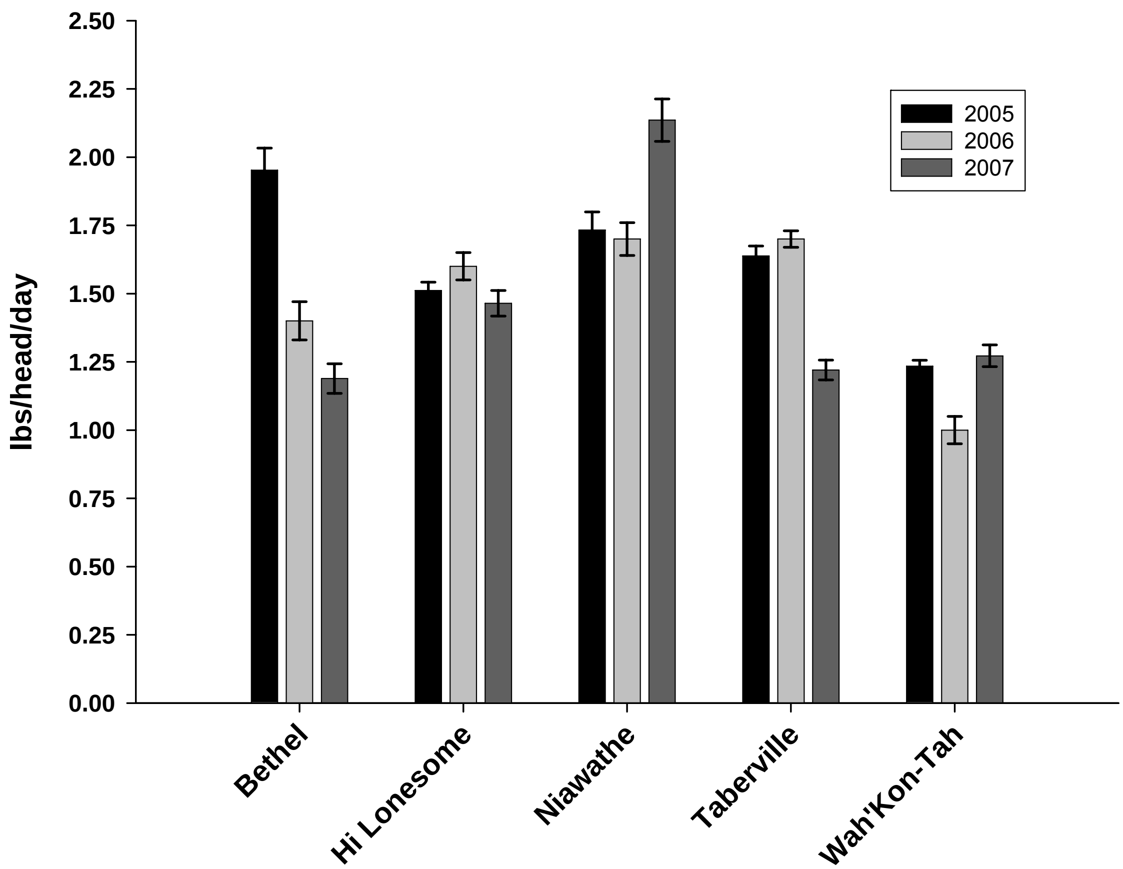


Figure 6. Average daily gains of unsuplemented yearling cattle stocked at 5.5 acres/AU for 120 d on five patch-burn grazed tallgrass prairie remnants in west-central Missouri 2005-2007.

Table 3. Average daily gains and gain per acre for yearling cattle on patch-burn grazing units in west-central and southwestern Missouri from 2005 through 2007.

Site	Acres[a]	Year	N [b]	Daily gain $\bar{x}$ lbs (2 SE)	Gain per acre(lbs)[c]
		2005	48	2.0 (0.16)	88.1
Bethel	131.9	2006	34	1.4 (0.14)	37.4
		2007	44	1.2 (0.11)	46.4
		2005	91	1.5 (0.06)	64.3
Hi Lonesome	257.1	2006	100	1.6 (0.10)	75.9
		2007	81	1.5 (0.09)	59.1
		2005	57	1.7 (0.14)	69.6
Niawathe	173.3	2006	49	1.7 (0.12)	60.4
		2007	53	2.1 (0.16)	81.6
		2005	100	1.6 (0.08)	86.0
Taberville	240.0	2006	71	1.7 (0.06)	56.2
		2007	82	1.2 (0.07)	52.1
		2005	115	1.2 (0.04)	74.0
Wah' Kon-Tah	239.7	2006	66	1.0 (0.10)	34.0
		2007	85	1.3 (0.08)	54.1
		2005	411	1.6 (0.04)	75.4
All	1042.0	2006	320	1.5 (0.04)	53.8
		2007	345	1.4 (0.06)	58.5

[a] Total acres of available forage used to determine stocking rate (excludes wooded areas with closed tree canopy, pond exclosures, etc.)
[b] Number of head for which beginning and ending weights were recorded; not same as total herd size
[c] Gain per acre based on total forage acres

The costs to establish infrastructure necessary to conduct management-intensive grazing (MIG) were greater than that required for patch-burn grazing (Table 4). However, despite much higher initial costs and annual input costs, MIG yielded greater economic returns in the second and third years of operation that off-set these expenditures (Table 5).

Table 4. Estimated costs of inputs that differ between that required to implement and maintain a patch-burn grazing (PBG) system on a 160-acre tallgrass prairie and management intensive grazing (MIG) system on a 160-acre tall fescue pasture for a 3-yr period.

			Grazing System – Forage Base			
			MIG – tall fescue		PBG – tallgrass prairie	
Input type	Item	Unit cost	Units required	Extended cost	Units Required	Extended cost
One-time	5-strand barbed wire fence (includes installation)	$6,000/mi	1	$6,000	0	$0
	Single strand polyethylene electric fence	$710/mi	5	$3,550	0	$0
	Stock tanks	$200/ea	3	$600	0	$0
	Labor (installation of water and electric fence)	$10/hr	40	$400	0	$0
Annual	N fertilizer	$500/ton	8	$4,000	0	$0
	Prescribed fire	$20/ac	0	$0	53	$1,060
	Labor (moving cattle and electric fence)	$10/hr	240	$2400	0	$0
	Fence repairs (yrs 2-3)	$200/mi	3	$600	2	$400
		Total year 1 costs	$16,950		$1,060	
		Total year 2 costs	$7,000		$1,460	
		Total year 3 costs	$7,000		$1,460	
		Grand total	$30,950		$3,980	

Table 5. Profit comparison for a patch-burn grazing (PBG) system on a 160-acre tallgrass prairie and management intensive grazing (MIG) system on a 160-acre tall fescue pasture using input costs shown in Table 4 and assuming a 120-d grazing season.

	Year of Operation					
	Year 1			Years 2 and 3		
	MIG – tall fescue E+	MIG – tall fescue E-	PBG – tallgrass prairie	MIG – tall fescue E+	MIG – tall fescue E-	PBG – tallgrass prairie
Stocking rate (hd/A)	1.5	1.5	0.46	1.5	1.5	0.46
ADG (lb/hd/day)	1.0	1.6	1.5	1.0	1.6	1.5
Purchase weight (lb/hd)	400	400	400	400	400	400
Purchase price/cwt($/cwt)	$125	$125	$125	$125	$125	$125
Purchase cost/head($/hd)	$500	$500	$500	$500	$500	$500
Variable costs/head($/hd)	$30	$30	$30	$30	$30	$30
Operating interest($/hd)	$25	$25	$25	$25	$25	$25
Total cost/head ($/hd)	$555	$555	$555	$555	$555	$555
Sale weight (lb/hd)	$520	$592	$544	$520	$592	$544
Sale price/cwt ($/cwt)	$112	$112	$112	$112	$112	$112
Gross revenue/head($/hd)	$582	$663	$609	$582	$663	$609
Net revenue/head ($/hd)	$27	$108	$54	$27	$108	$54
Net revenue/acre ($/A)	$41	$162	$25	$41	$162	$25
Input costs (fence, water, labor, contracting; $/A)	$106	$106	$7	$44	$44	$9
Fixed costs ($/A)	$12	$12	$12	$12	$12	$12
Profit/acre ($/A)	($77)	$44	$6	($15)	$106	$4
Profit on 160-acre unit	($12,294)	$7,060	$1,014	($2,344)	$17,010	$614

Grazing distribution
Across sites and years, the proportion of the observed locations of grazing cattle usually was greatest in the most recently burned patch in the unit. The percentage of observations in the most recent burn ranged from 32 to 84% and averaged 64% across sites and years (Figure 7).

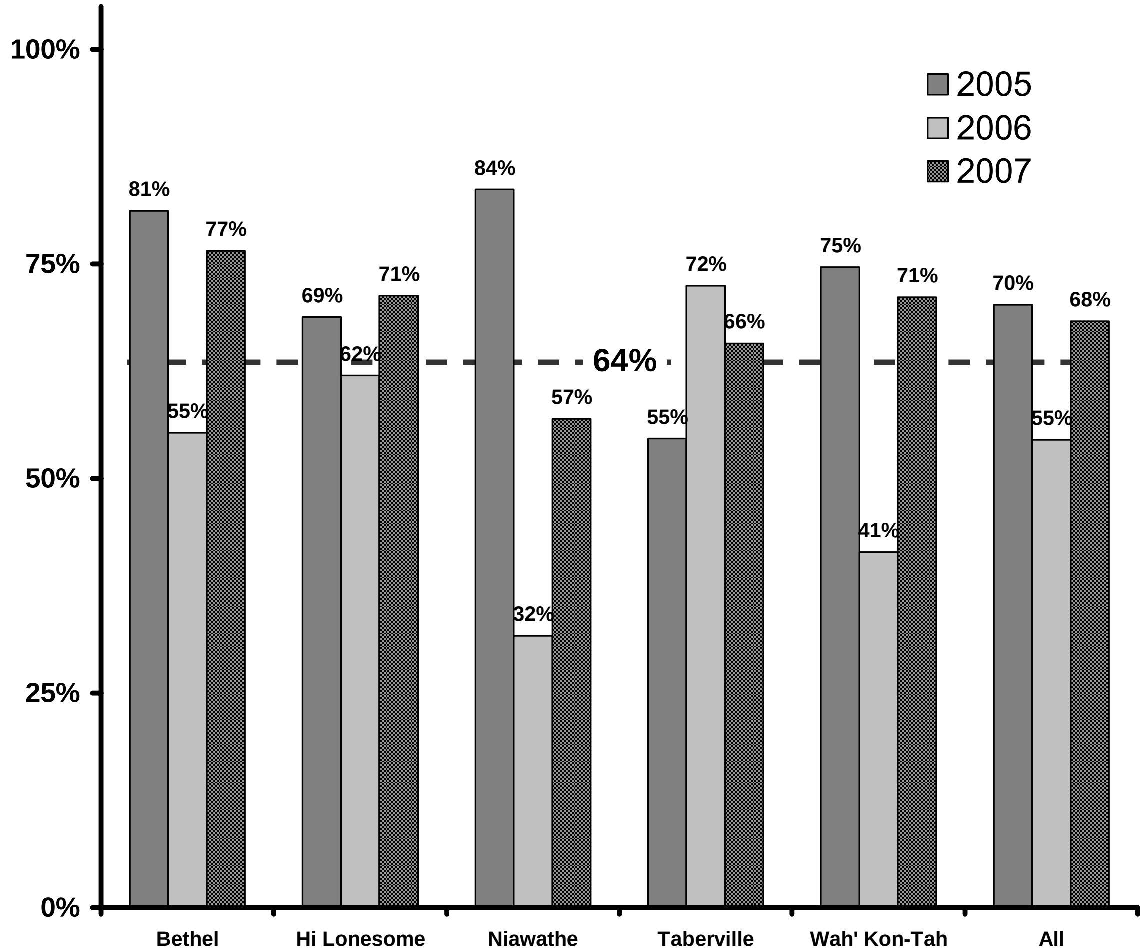


Figure 7. Proportion of observations of grazing yearling cattle within the most recently burned patch on five patch-burn grazed tallgrass prairie remnants in west-central and southwestern Missouri from 2005 through 2007. Reference line at 64% represents average across sites and years. Patches that burned due to the arson fire at Wah' Kon-Tah were omitted for clarity.

In only two cases did the proportion of observations in the most recent burn decline to <50%. In 2005, cattle had a choice between the one-third of the area that was burned, and the two-thirds of the management unit that was not burned. About 74% of the cattle observations in 2005 were made while animals were grazing and 70% of those were in the burned patch. In 2006, cattle chose among patches burned the previous year, patches burned in spring 2006, and unburned patches that each comprised about one-third of the grazing management unit. At Wah' Kon-Tah, a fourth option was available to cattle because of a wildfire that reburned a portion of the 2005 burn patch. Cattle spent less time grazing in the patch burned the current year in 2006. Cattle were observed grazing 72% of the time, and about 55% of the grazing observations were recorded in the patch burned in spring 2006. In 2007, yearling cattle again showed strong preference for the most recently burned patch. About 68% of the observations of grazing cattle occurred in the patch burned that spring. The density of observations of grazing cattle in the most recent burn was over three times greater than that observed in the previous year's burn patches in 2007 (Figure 8).

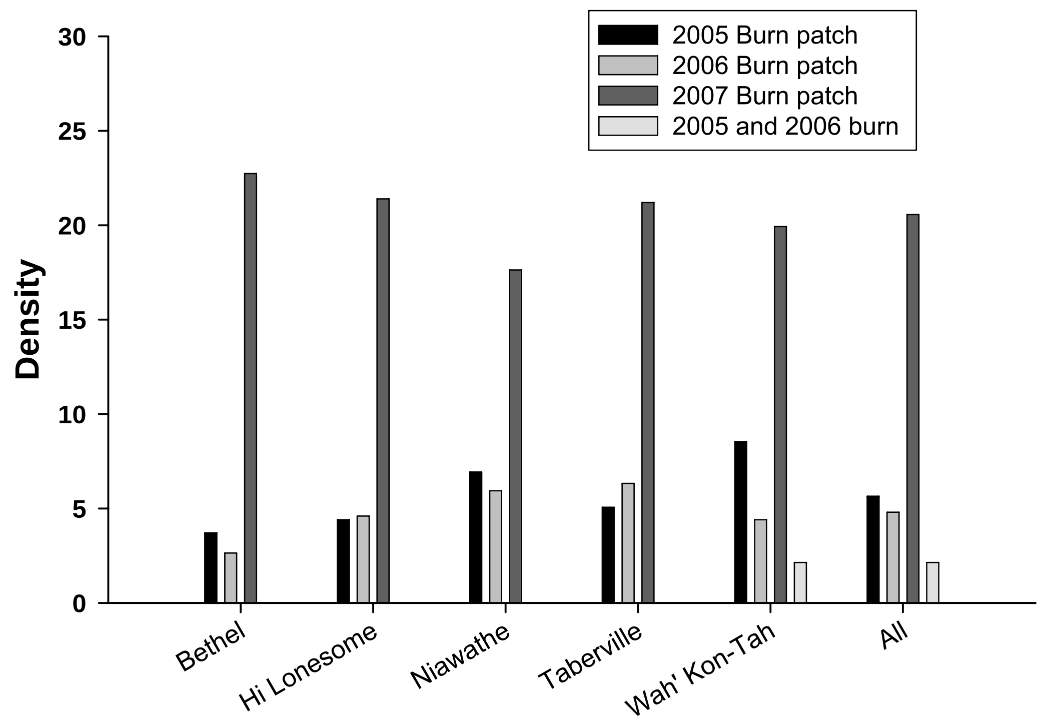


Figure 8. Density of observations (number of observations/acre) for each burn year patch for yearling cattle grazing on five patch-burn grazed prairie remnants in Missouri in 2007.

Vegetation structure

Cattle grazing created greater heterogeneity in litter depth, and height and density of grassland cover, than spring prescribed fire alone. In 2005, vegetation structure was measured at 1,136 points in control units and 1,255 points in grazing management units. Mean percent obstruction within the first 20 cm above ground and maximum height of vegetation were greater in control units than in grazing units (Figure 9). However, heterogeneity of percent obstruction and maximum height were greater in grazed units (Figure 10). These results were driven by effects at the patch level within units and were attributable to cattle focusing grazing activities in the burned portion of the grazing unit. Mean percent obstruction in the first 20 cm above ground was similar among the burned and unburned portions of the control unit and the unburned portion of the grazing unit. Obstruction in the first 20 cm was significantly greater than in the burned patches within grazing units where cattle grazed the majority of the time (Figure 11). Maximum vegetation height responded similarly. Variation in measures of obstruction and vegetation height was greater in burned portions of grazing units than in control units or unburned portions of grazing units. Variation in percent obstruction and vegetation height in unburned portions of grazing units generally was intermediate between burned patches within the grazing units and control unit patches (Figure 12). At the Taberville site, mowing treatments within the grazing unit had been conducted in 2004 prior initiation of patch-burn grazing. Cattle distributions demonstrated greatest preference for the burned patch similar to that at other sites, but revealed that cattle may have a secondary preference for mowed portions of unburned patches over unmowed portions. These patterns were reflected in maximum vegetation height for this site. Some of the observed gradient in vegetation structure within mowed portions was likely due to the mowing treatment itself and some was undoubtedly attributable to the preferential grazing, but the relative contribution of each cannot be det

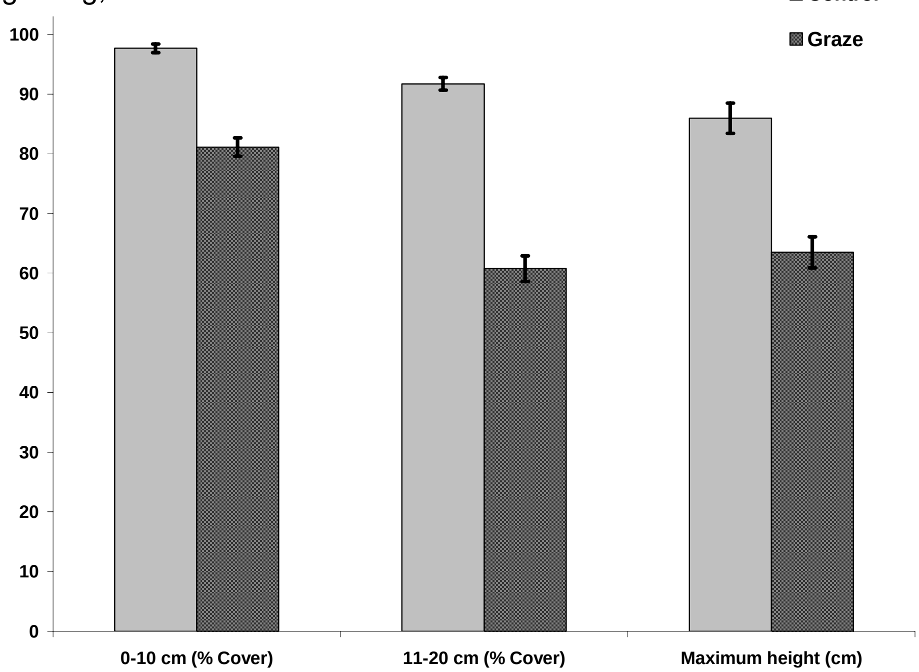


Figure 9. Mean percent obstruction (±2 SE) and mean maximum vegetation height (±2 SE) in four control and patch-burn grazing units in which one third of each unit was burned in spring, 2005.

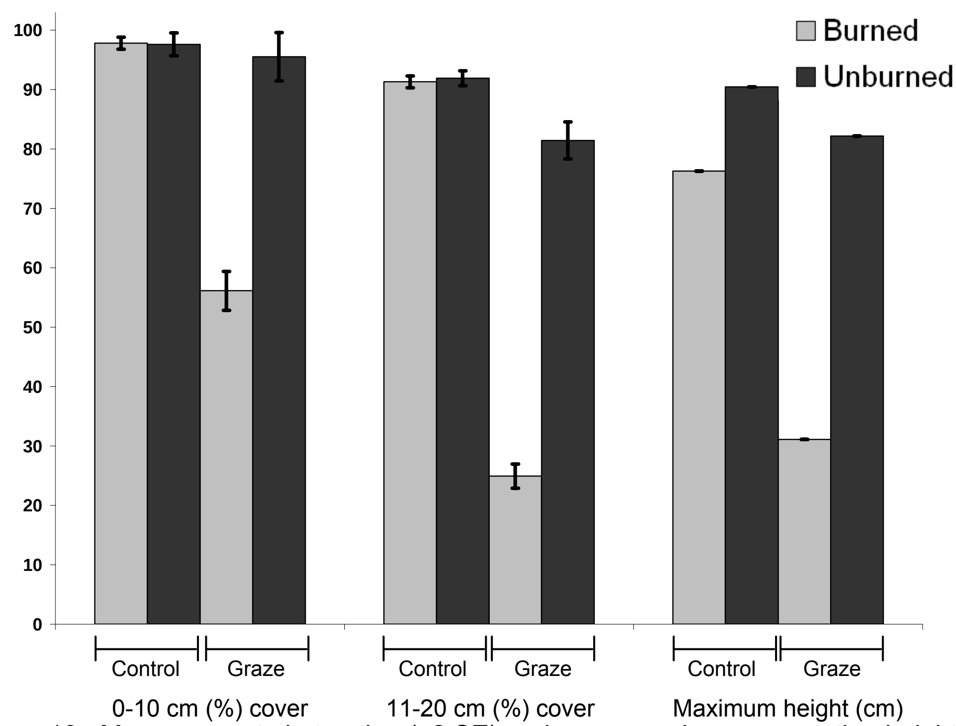


Figure 10. Mean percent obstruction (±2 SE) and mean maximum vegetation height (±2 SE) in burned and unburned patches in control units and patch-burn grazing units measured during June, 2005.

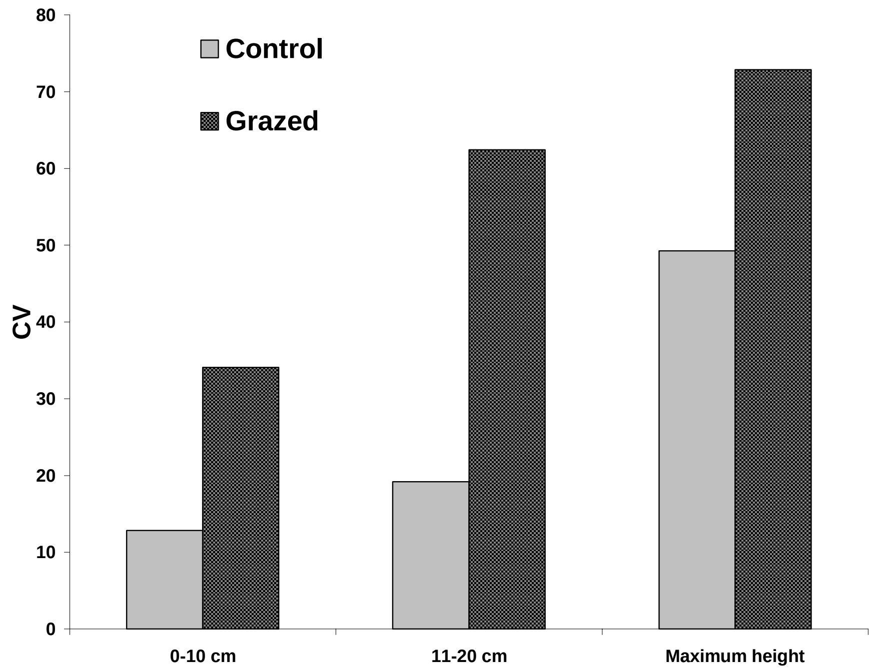


Figure 11. Hetereogeneity of mean percent obstruction at 0-10 cm above ground, 11-20 cm above ground and mean maximum height of vegetation in four spring-burned only and four patch-burn grazed management units in June, 2005.

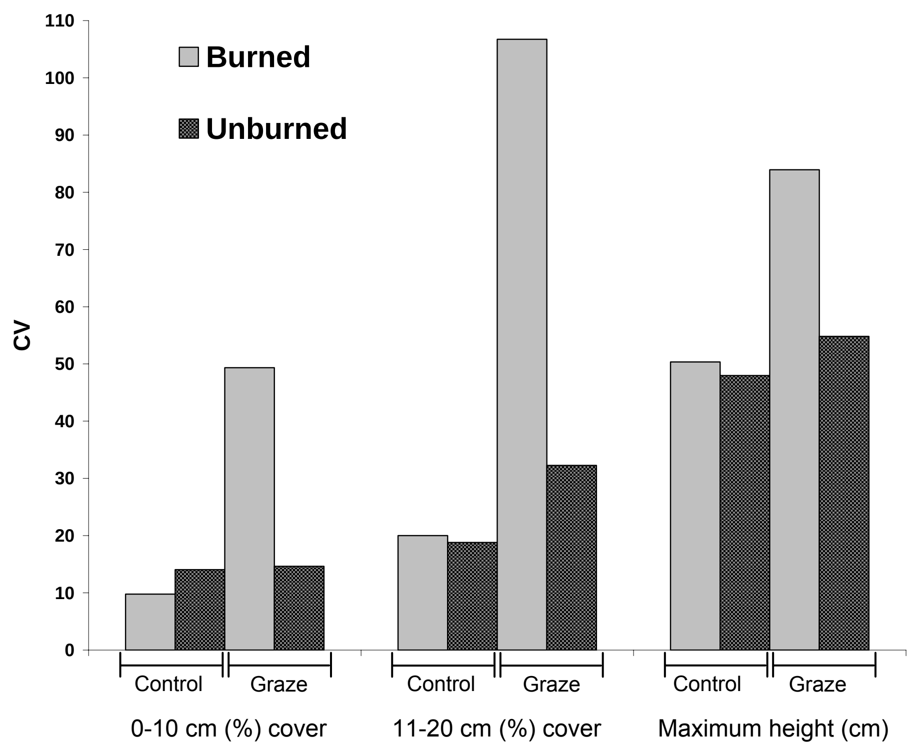


Figure 12. Hetereogeneity of mean percent obstruction at 0-10 cm above ground, 11-20 cm above ground and mean maximum height of vegetation in burned and unburned patches in four spring-burned only and four patch-burn grazed management units in June, 2005.

In 2006, we measured vegetation structure at 1,129 points in control units and 1,245 points in grazing management units. After two years of management with PBG, structural diversity of grazed grasslands had increased dramatically, whereas control units that received only spring burning were characterized by relatively uniform vegetation structure and overall vegetation height. Mean percent obstruction within the first 20 cm above ground and maximum height of vegetation were again greater in control units than in grazing management units (Figures 13 and 14), and heterogeneity of percent obstruction and maximum height were greater in grazed units (Figure 15).

In the patch that was burned in 2005, evidence of the intensive grazing that occurred that year were still evident. Mean obstruction in the first 10 cm above ground in the 2005 burn patches within grazing units exceeded 95%—only slightly lower than that in ungrazed controls. However, mean obstruction at 11-20 cm above ground and maximum vegetation height was still less in grazing unit patches burned in 2005 than that in control unit patches. Variation in obstruction and vegetation height was greater in the grazing unit patch burned in spring 2006 than in control unit patches, and greater than that in other patches in the grazing units. Variation in obstruction within the first 20 cm above ground was greater in all grazing unit patches than in controls. Variation in maximum vegetation height in the grazing unit patch that was burned in 2005 and the patch that has not yet been burned was similar to that in control unit patches (Figure 15). These results suggest that influences of grazing were strongest in the patch burned the current year despite the lower fidelity to burn patches observed in 2006 compared to 2005.

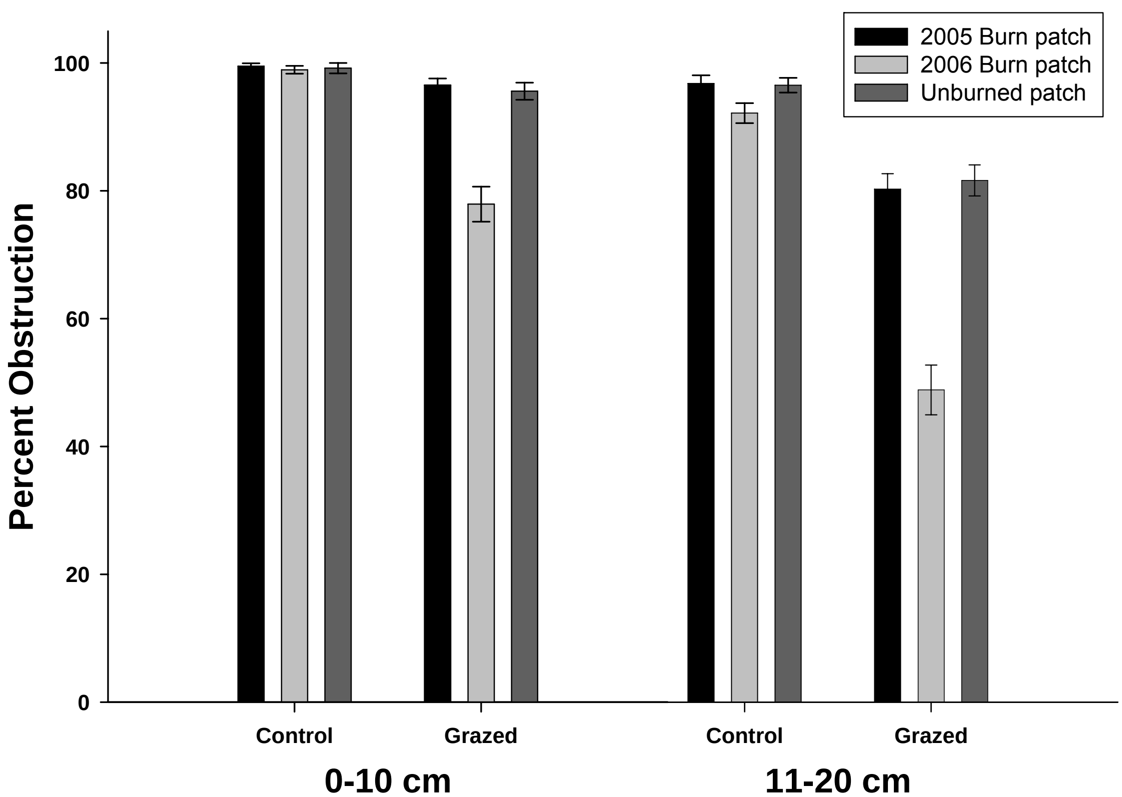


Figure 13. Mean visual obstruction (±2 SE) at 0-10 and 11-20 cm above ground in spring-burned controls and adjacent patch-burn grazed management units on four tallgrass prairie remnants in west-central and southwestern Missouri during June 2006.

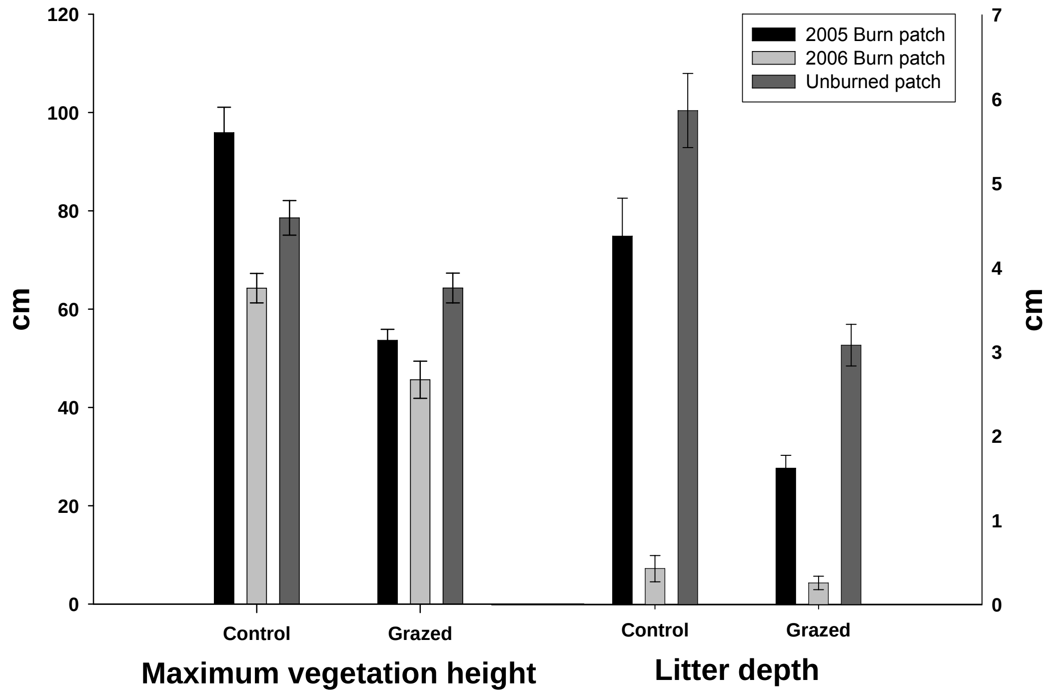


Figure 14. Maximum height of vegetation (cm) and litter depth (cm) in spring-burned control units and adjacent patch-burn grazed management units on four study sites in west-central and southwestern Missouri during June 2006.

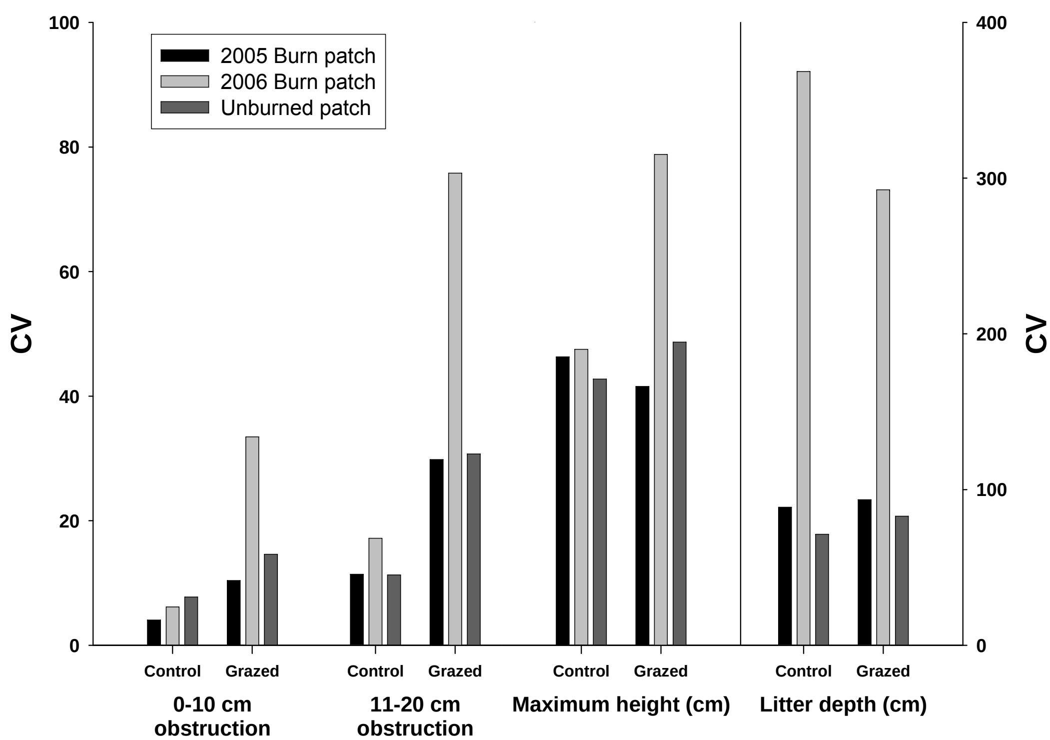


Figure 15. Coefficients of variation in mean percent obstruction, maximum height of vegetation, and litter depth in spring-burned control units and adjacent patch-burn grazed management units on four prairie remnants in west-central and southwestern Missouri during June 2006.

In 2007, Vegetation structure was measured at 1,129 points in control units and 1,245 points in grazing management units. After a complete 3-yr burn rotation under patch-burn grazing, structural diversity of grazed grasslands had increased dramatically, whereas control units that received only spring burning were characterized by relatively uniform vegetation structure and overall vegetation height. Mean percent obstruction within the first 20 cm above ground was greater in control units than in grazing units (Figure 16). Maximum vegetation height and litter depth also were greater in control units (Figure 17). Heterogeneity of percent obstruction, maximum height, and litter depth generally were greater in grazing units (Figure 18). Although mean obstruction and maximum height were generally lower in all patches in the grazing unit than in controls, results of comparisons between grazing units and controls were driven primarily by structural measurements recorded in the 2007 burn patch where cattle focused grazing activities.

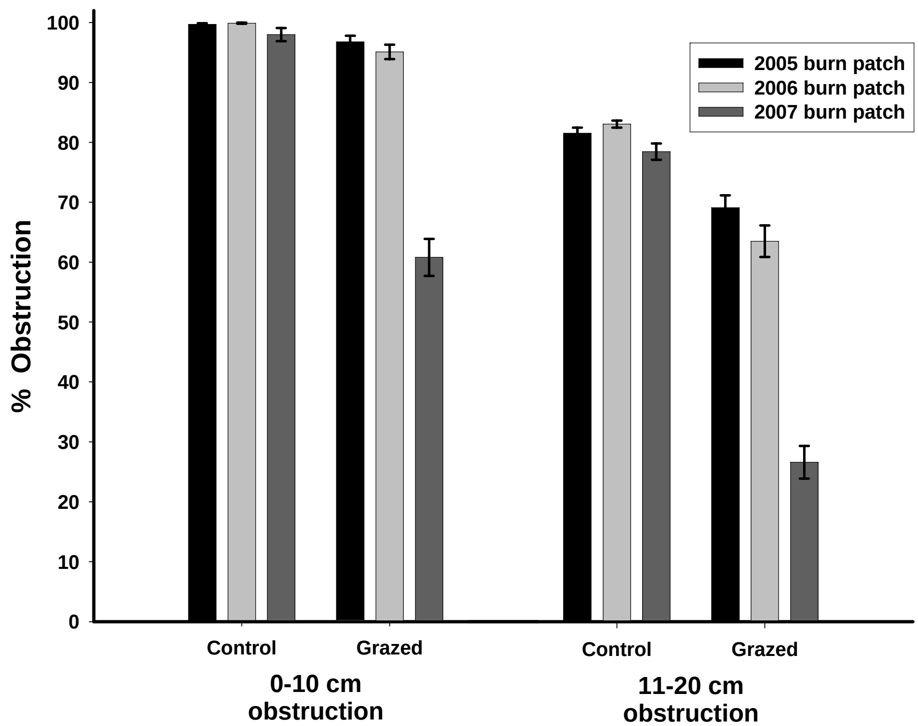


Figure 16. Mean visual obstruction (%) at 0-10 and 11-20 cm above ground in four spring-burned only controls and four adjacent patch-burn grazed management units during June 2007.

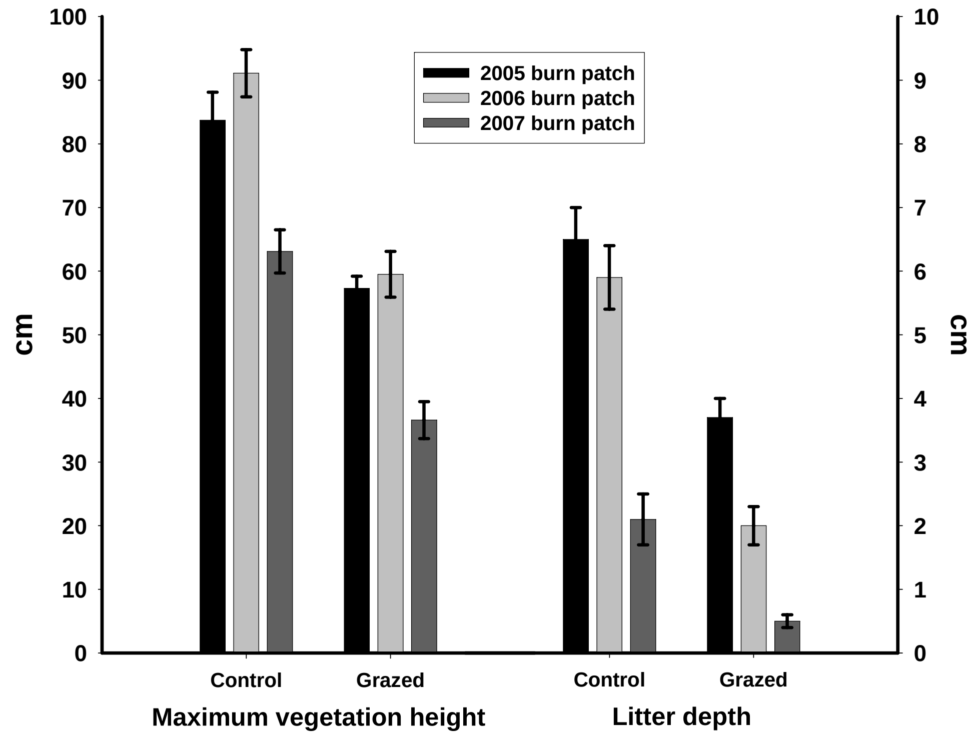


Figure 17. Maximum height of vegetation (cm) and litter depth (cm) in four spring-burned only controls and four adjacent patch-burn grazed management units during June 2007.

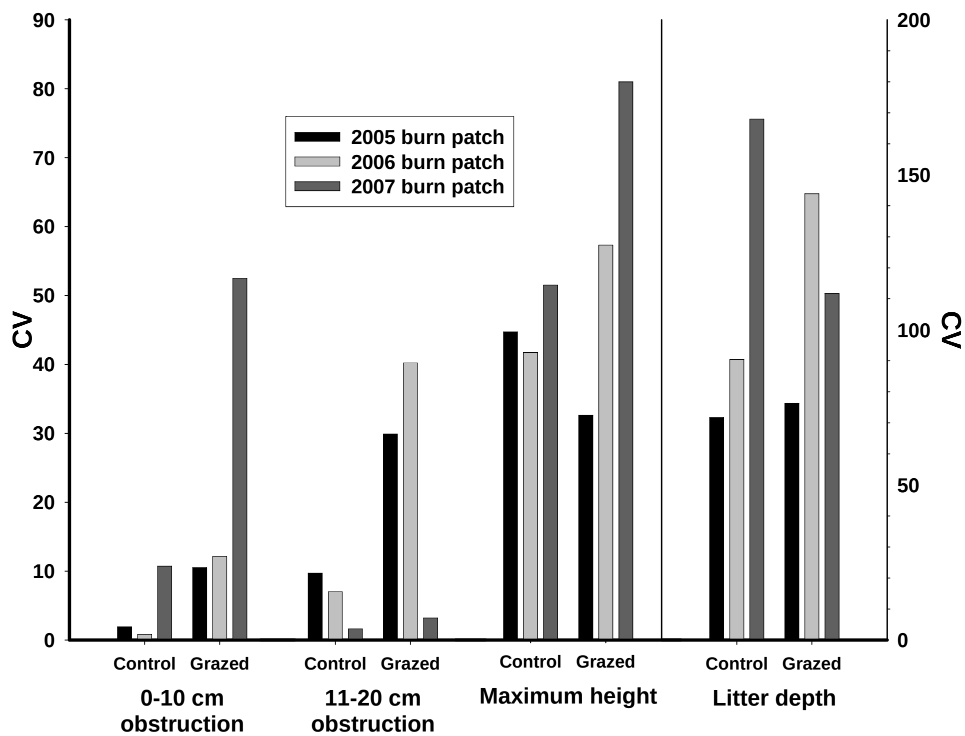


Figure 18. Coefficients of variation in mean percent obstruction, maximum height of vegetation, and litter depth in four spring-burned only controls and four adjacent patch-burn grazed management units during June 2007.

In 2008, about 9 months after the end of grazing treatmens, we measured vegetation structure at 1,132 points in control units and 1,249 points in grazing management units. After less than one year with no disturbance, differences in obstruction at ground level between the control and grazing units were nearly eliminated (Figure 19).

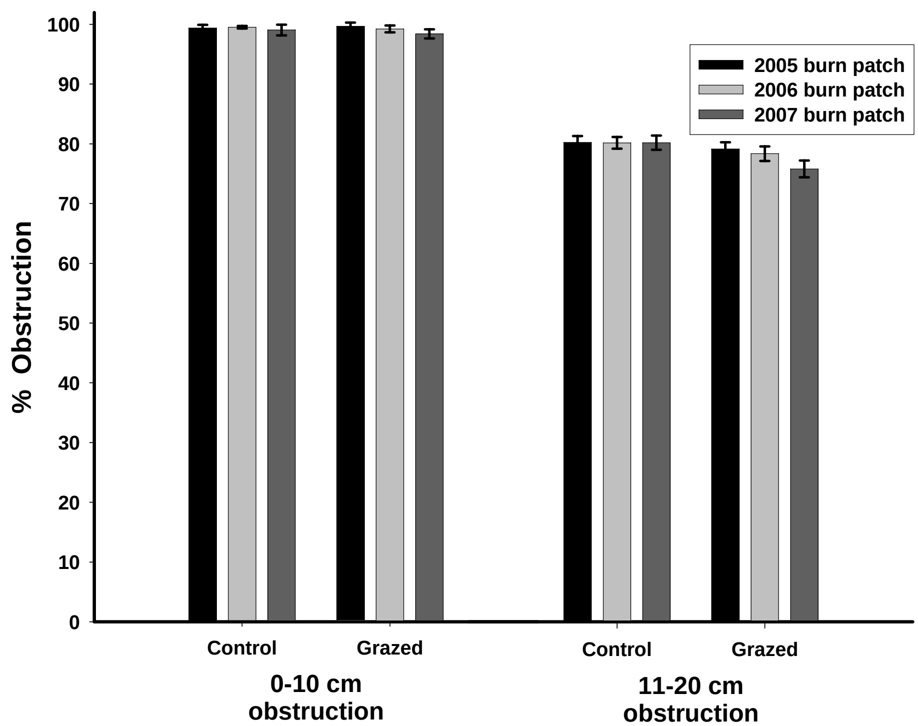


Figure 19. Mean visual obstruction (%) at 0-10 and 11-20 cm above ground in four spring-burned control units and four adjacent patch-burn grazed management units during June 2008.

Small differences in vegetation height remained. Maximum vegetation height averaged 91 cm across all patches in the control units but only 72 cm in grazing management units (Figure 20). As expected following burning and intensive grazing, litter accumulation in the 2007 burn patches within the grazing management units was minimal (Figure 20). In the 2007 burn patches in the control unit, mean litter depth in 2007 (the year of the burn) was 2.1 cm. Average litter depth in those control unit patches had increased to 8.9 cm just 14 months following the prescribed fire. Conversely, average litter depth in the 2007 burn patches in the grazing units was 0.5 cm in 2007 and, because cattle consumed plant material that would have become litter, mean litter depth had increased to only 1.7 cm by 2008. Coefficients of variation in mean obstruction at ground level and maximum height were similar between grazing units and control units. Variation in litter depth, however, remained much higher in the grazing unit patch that was burned in spring 2007 compared to other patches in the grazing unit or control unit patches (Figure 21).

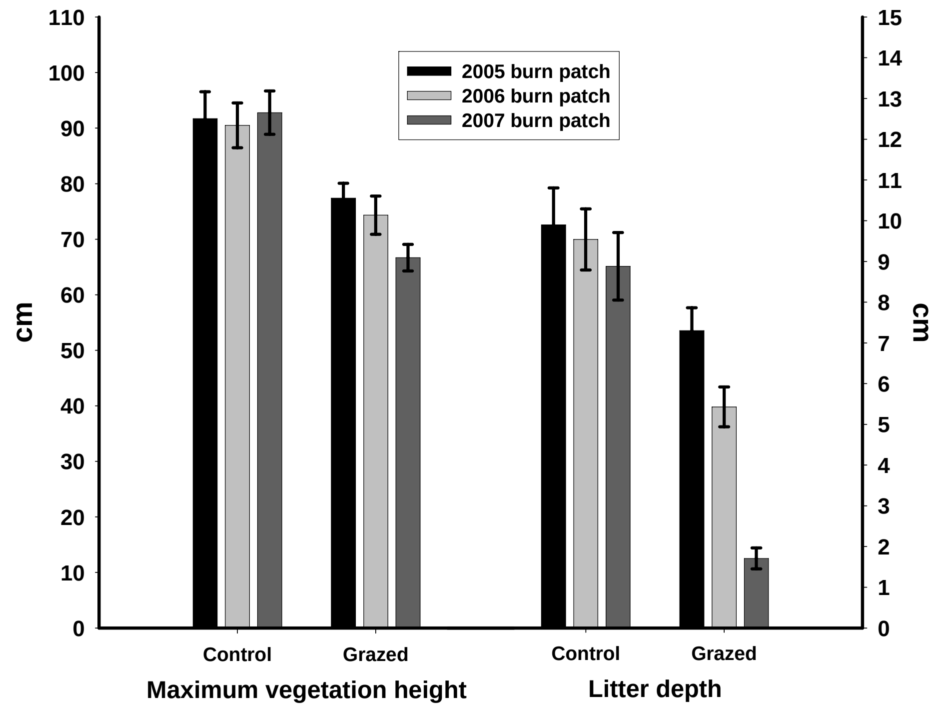


Figure 20. Maximum height of vegetation (cm) and litter depth (cm) in four spring-burned control units and four adjacent patch-burn grazed management units during June 2008.

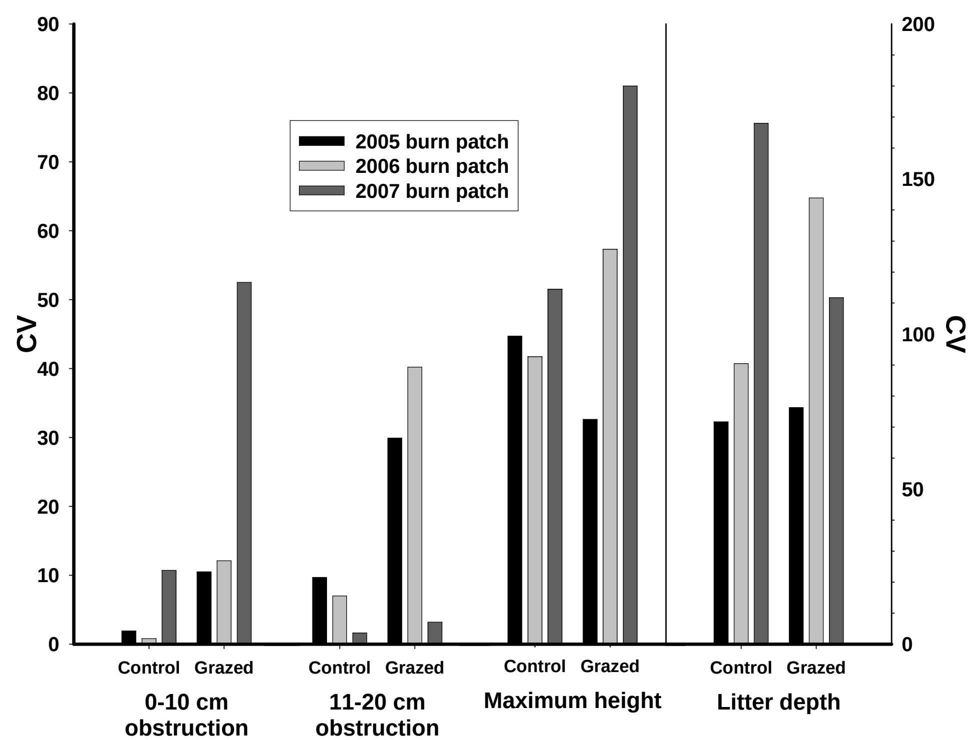


Figure 21. Coefficients of variation in mean percent obstruction, maximum height of vegetation, and litter depth in four spring-burned only controls and four adjacent patch-burn grazed management units during June 2007.

To understand temporal variation in vegetation structure, we summarized results for the 2006 burn year patches separately. We summarized obstruction data, vegetation height and litter depth for these patches one year prior to burning, the year they were burned, and for two years after they were burned. Mean percent obstruction at ground level averaged nearly 100% each year in the control units (Figure 22).

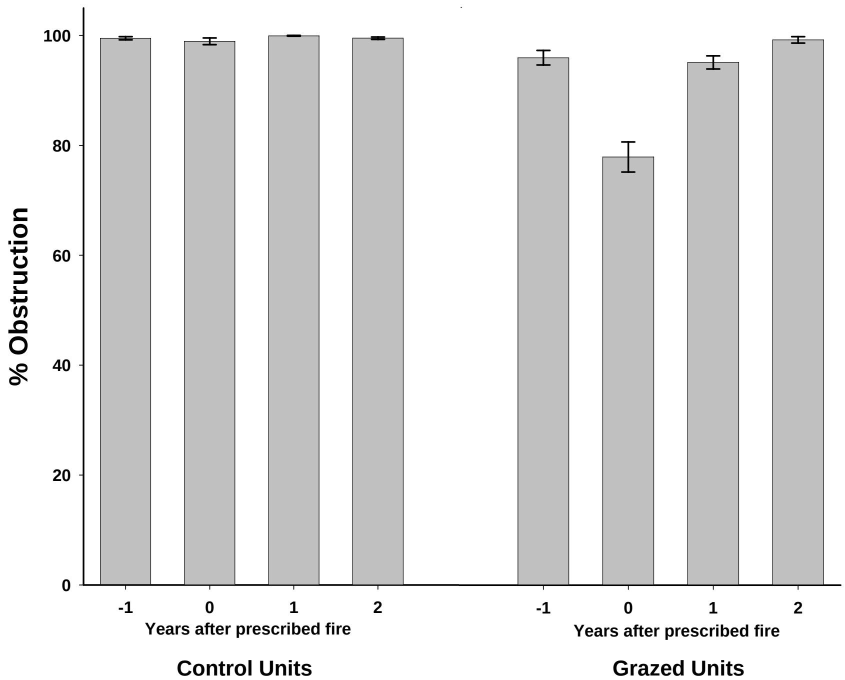


Figure 22. Mean percent obstruction (±2 SE) at 0-10 cm above ground 1 yr prior to burning, the year of the burn, 1 yr post burning, and 2 yrs post burning in spring-burned control unit patches and patch-burn grazing unit patches which were burned in spring 2006.

Assuming an average burn date of 30 March, obstruction at ground level had recovered to pre-burn condition within 8 wks following burning. Conversely, obstruction at ground level in patch-burn grazing units was slightly lower than in control units prior to burning, averaged less than 80% the year of the burn, and returned to pre-burn condition 1 and 2 yrs following prescribe fire. Similar trends were noted for obstruction at 11-20 cm above ground, litter depth, and maximum height (Figures 23, 24 and 25).

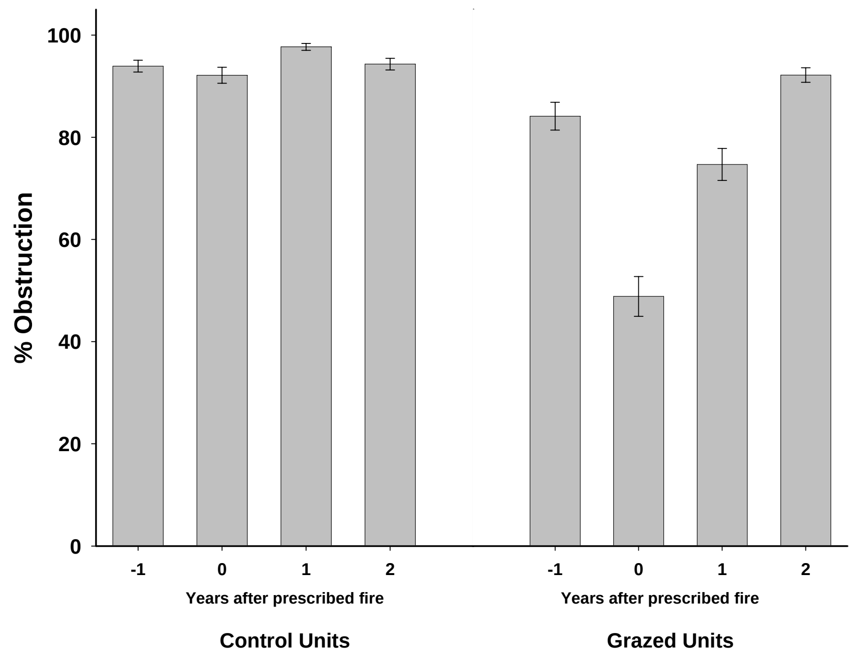


Figure 23. Mean percent obstruction (±2 SE) at 11-20 cm above ground 1 yr prior to burning, the year of the burn, 1 yr post burning, and 2 yrs post burning in spring-burned control unit patches and patch-burn grazing unit patches which were burned in spring 2006.

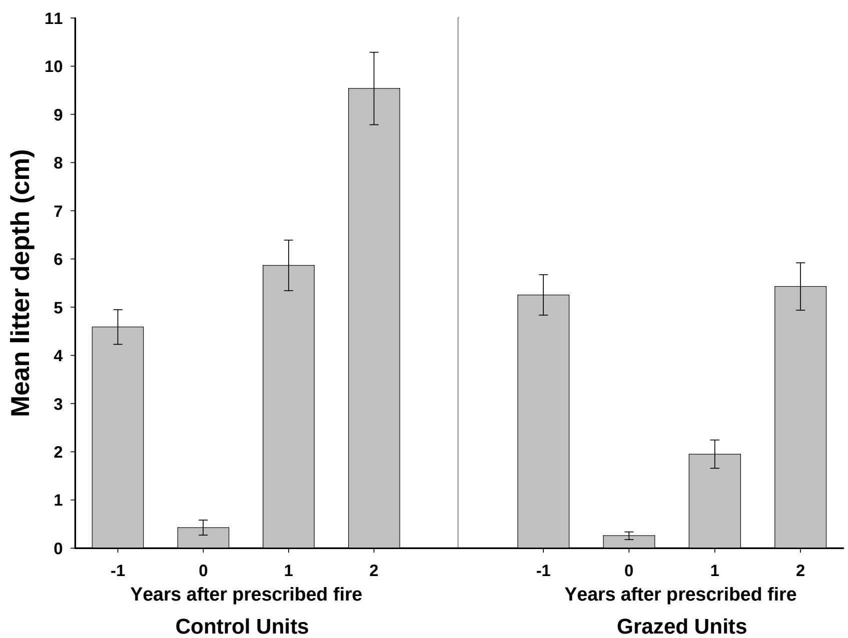


Figure 24. Mean litter depth (±2 SE) 1 yr prior to burning, the year of the burn, 1 yr post burning, and 2 yrs post burning in spring-burned control unit patches and patch-burn grazing unit patches which were burned in spring 2006.

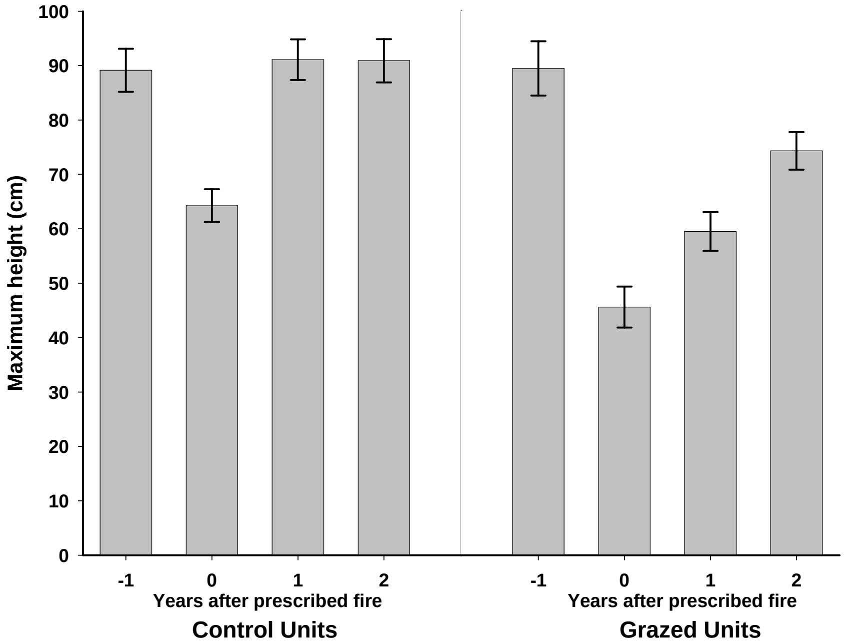


Figure 25. Response of vegetation height to spring fire (control units) and patch-burn grazing over 4 years. Measurements were recorded in patches that were burned in 2006. Years after fire -1, 0, and 1 were grazing treatment years; units received no disturbance in 2008.

Grassland Birds

Species richness.—Species richness was greater on patch burn graze units ($\bar{x}$ = 20.2 +/- SD 2.77) than control units ($\bar{x}$ = 17.5 +/- SD 3.09; P = 0.02) (Table 6). Fourteen species occurred uniquely on PBG units (Table 7), the Upland Sandpiper, Horned Lark, Greater Prairie Chicken, Scissor-Tailed Flycatcher and Eastern Bluebird occurred frequently on PBG sites, but only rarely (<3 observations) on control units (Table 8). Of these species, the Upland Sandpiper, Horned Lark, Greater Prairie Chicken and Scissor-Tailed Flycatcher are true grassland species. The Greater Prairie Chicken is listed as a state endangered species and the Upland Sandpiper and Scissor-Tailed Flycatcher are species of management concern (MDC 2008). Seven species occurred uniquely or predominantly (< 3 detections on PBG) on control units (Table 9) of these, none were true grassland species.

Table 6. Species richness by treatment.

Treatment	Mean (sd)
Control	17.46 (3.1)
Grazing	20.17 (2.8)

Table 7. Species that occurred only in grazing units.

American Crow
American Robin
Black Capped chickadee
Blue Grosbeak
Eastern Bluebird
Great Blue Heron
Green Heron
Horned Lark
Killdeer
Northern Flicker
Orchard Oriole
Turkey Vulture
Upland Sandpiper
Wood Thrush

Table 8. Species that occurred frequently in the grazing units but occurred less than three times in the control unit.

Upland Sandpiper
Horned Lark
Greater Prairie Chicken
Scissor-Tailed Flycatcher
Eastern Bluebird

Table 9. Species that occurred only in the control units.

Baltimore Oriole
Carolina Wren
Cedar Waxwing
Downy Woodpecker
Eastern Tufted Titmouse
Eastern Peewee

The ANOVA output showed significant differences between study sites ($P = 0.03$), no significant difference between years since burning ($P = 0.46$) and no significant difference with the treatment plus years since burning interaction ($P = 0.49$). This seems to suggest that it's not an individual patch within the PBG units that accounts for greater species richness but the close spatial distribution of patches which were burned in different years.

The Greater Prairie Chicken occurred frequently in the Year 0 and Year 2 grazing patches and once in the Year 0 control patch. The prairie chicken was never detected in the other control patches. The Upland Sandpiper and Horned lark were detected in all three grazing patches but were never found in the control units. The Scissor-Tailed Flycatcher occurred frequently in the

Year 0 and Year 2 grazing patches and once in the Year 1 control patch but was never found in the other control patches.

Density and Abundance.---Dickcissel and Henslow's Sparrow estimated abundance was higher in the control units while the Eastern Meadowlark and Grasshopper Sparrow were more abundant in the grazing units (Figure 26). This result is consistent with the literature and our predictions for the Dickcissel and Henslow's Sparrow as they prefer taller grasslands with fewer disturbances. For the Eastern Meadowlark and Grasshopper Sparrow this result is also consistent with the literature and our predictions for these two species as they prefer short to intermediate height grasslands.

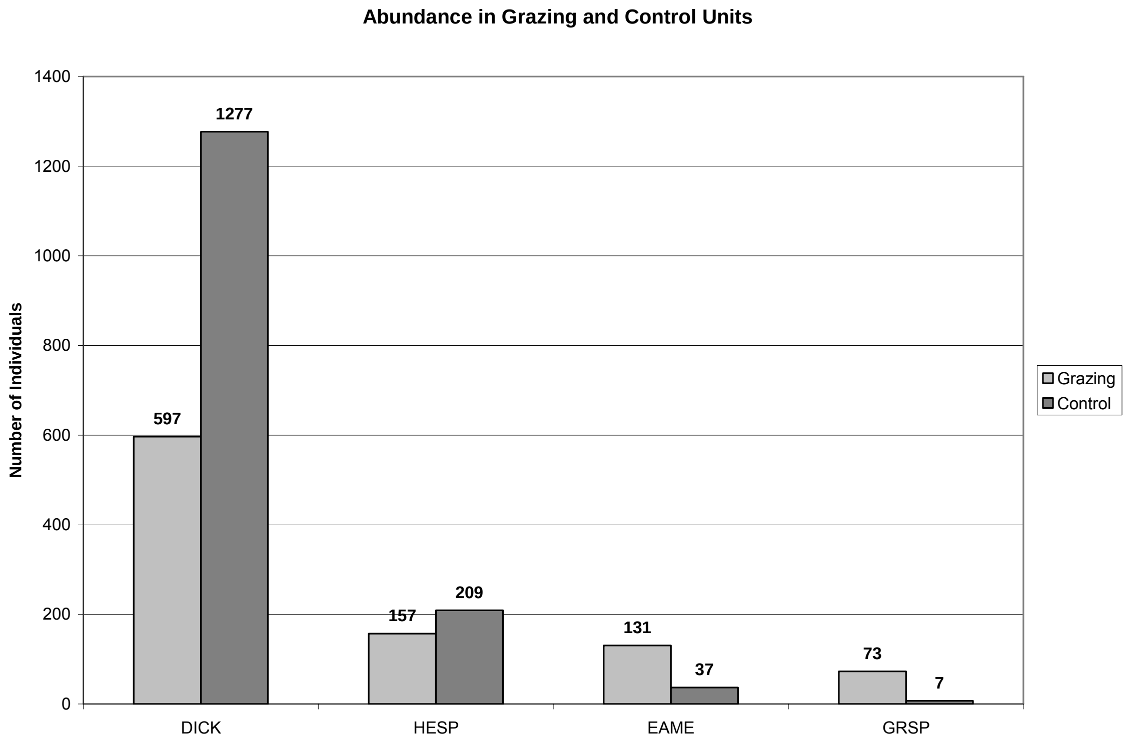
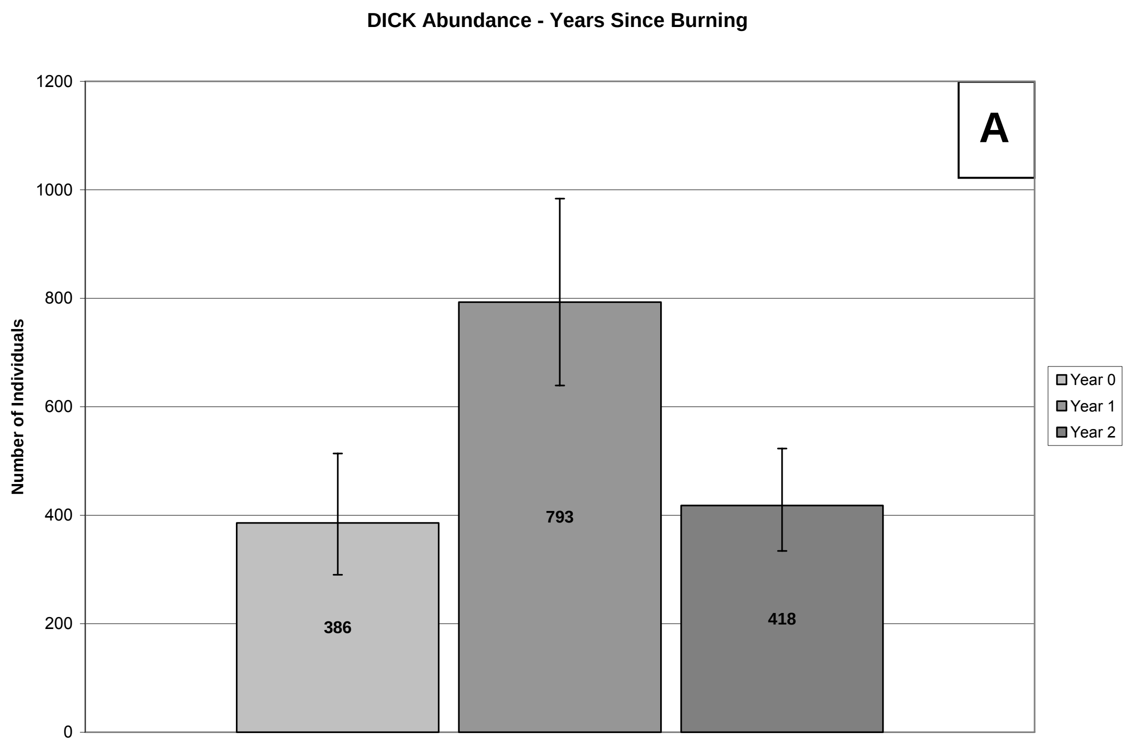
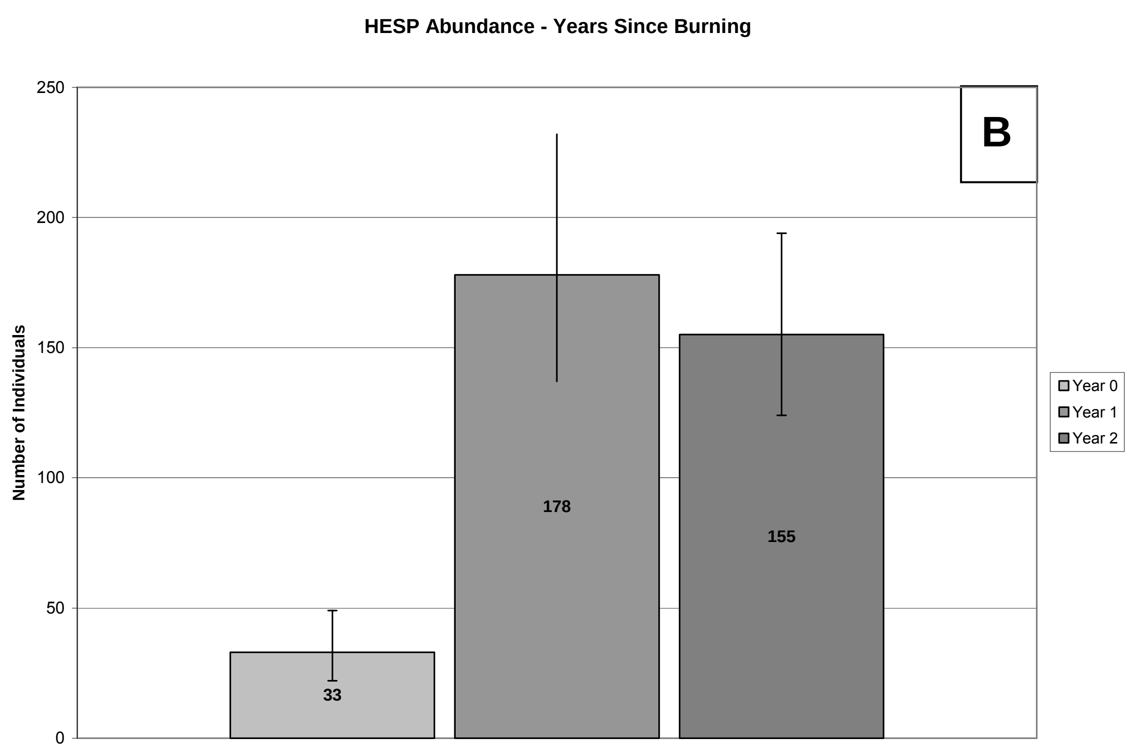


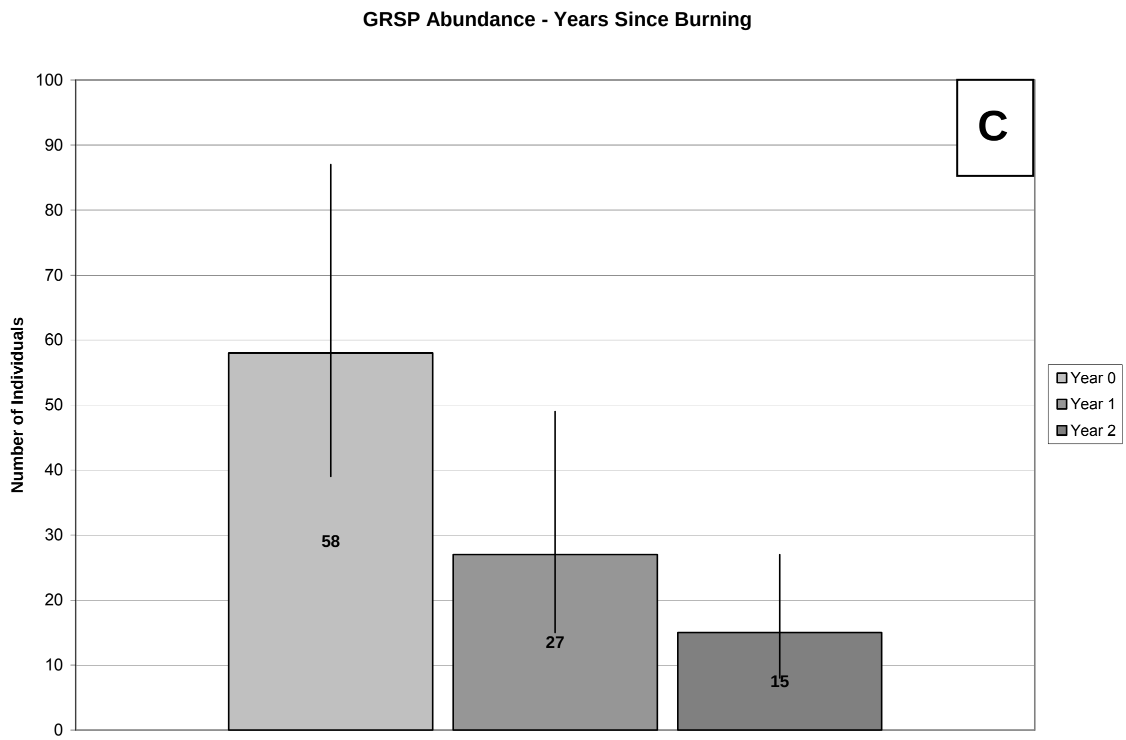
Figure 26. Abundance estimates (number of individuals) for selected species.

To evaluate density at the patch level, estimated abundance was evaluated by years since burning with Year 0 denoting the patches that were burned the spring immediately preceding the survey, and Year 1 or 2 being one or two years of growth since they were last burned. For the Dickcissel, estimated abundance was lowest in the Year 0 patches with N = 386, and highest in Year 1 with N = 793 (Figure 27). The Henslow's Sparrow was rare in the Year 0 patches with N = 33 and highest in the Year 1 patches with N = 178 (Figure 27b). It was no surprise that estimated abundance for both of these species would be lowest in Year 0 but it is interesting that estimated abundance was highest in Year 1 and not Year 2. It appears that two years after burning the habitat is less attractive to these species, too dense, or that is unable to support densities higher than the Year 1 patches.

Eastern Meadowlark estimated abundance (Figure 27c) was lowest in the Year 0 patches with N = 46 and highest in Year 2 with N = 78. We predicted that meadowlarks would vary in their response to years since burning. We would have expected Year 1 to have the highest estimated abundance because of the Eastern Meadowlark's affinity for intermediate height grasslands. However, the data shows a positive response to years since burning with lowest estimated


DICK Abundance - Years Since Burning
A
Number of Individuals
1200
1000
800
600
400
200
0
386
793
418
Year 0
Year 1
Year 2


HESP Abundance - Years Since Burning
B
Number of Individuals
250
200
150
100
50
0
33
178
155
Year 0
Year 1
Year 2



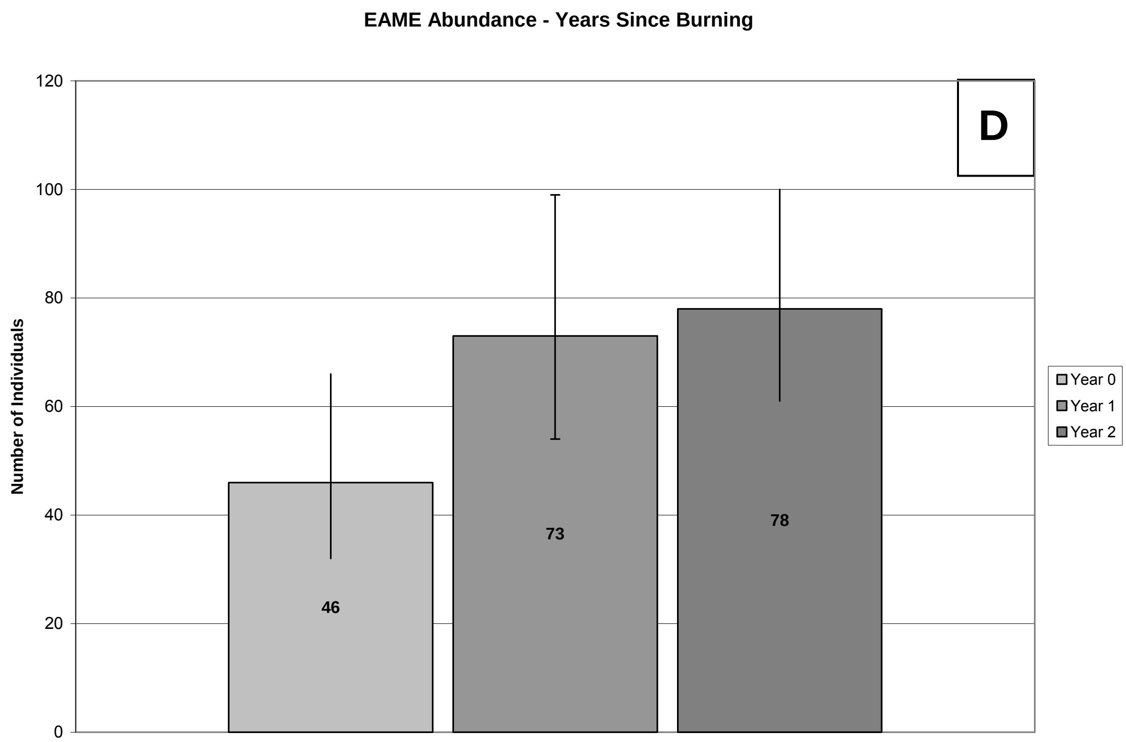


Figure 27a-d. Abundance and 95% confidence intervals broken out by Years Since Burning.

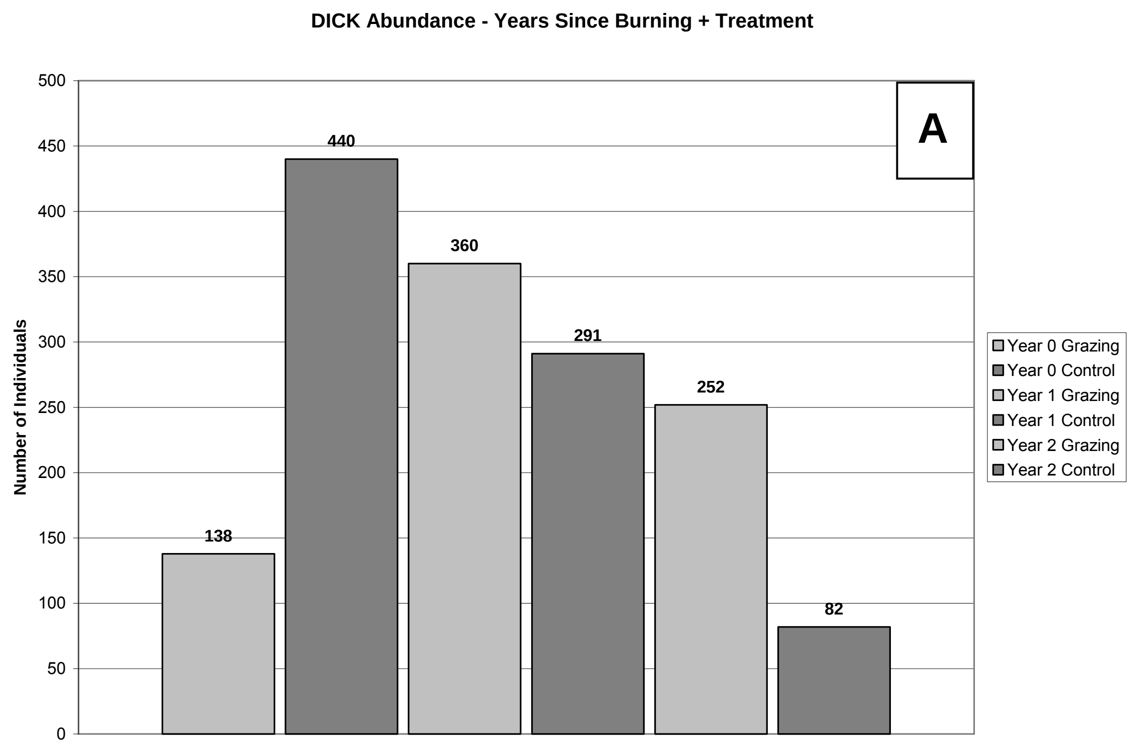
abundance at Year 0 and highest at Year 2. It is worth noting that estimated abundance for year 1 was N = 73, almost equal to Year 2.

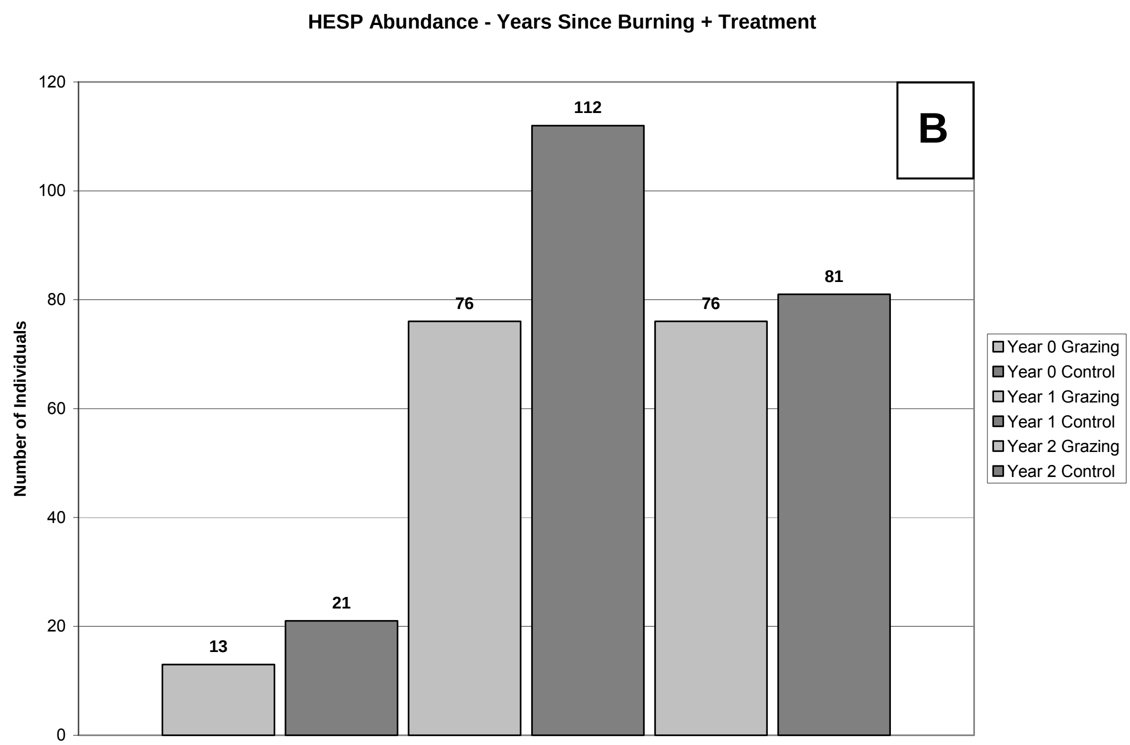
For Grasshopper Sparrows estimated abundance was found to be greatest in Year 0 with N = 58 and lowest in Year 2 with N = 15 (Figure 27d). This response is exactly as we expected given the Grasshopper Sparrow's preference for short grasslands. Their estimated abundance drops off dramatically with time and by Year 2 there are only 25% as many birds as estimated in Year 0.

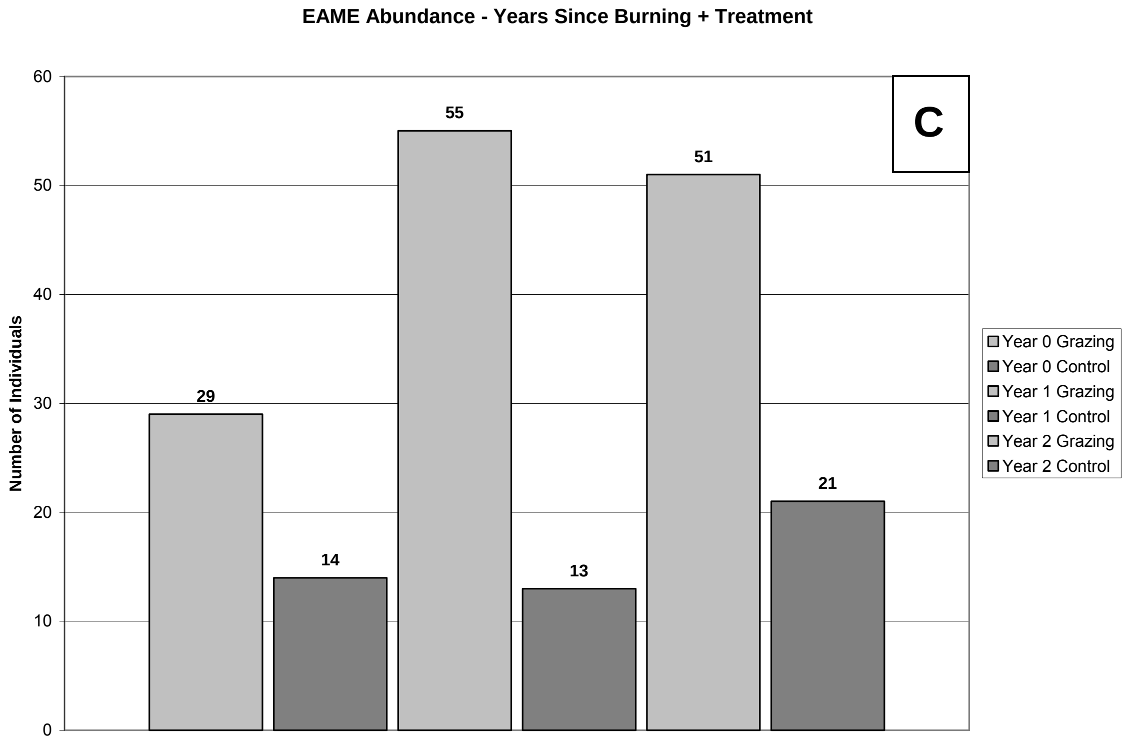
When the data was analyzed by years since burning and by treatment, the highest Dickcissel estimated abundance was in the Year 0 control with N = 440. Estimated abundance in the control patches then declined with each passing year (Figure 28a) Year 1 abundance was N = 291 and Year 2 was N = 82. In the grazing patches, Dickcissel estimated abundance was highest in the Year 1 patches with N = 360, followed by Year 2 with N = 252 and the lowest estimated abundance was found in the Year 0 patches with N = 138. It was not expected that Dickcissel estimated abundance would decrease with time in the control unit. What we know about this species habitat preferences and what other studies have found would predict the opposite response. We believe that the vigorous growth of the grasslands following fire resulted in very good habitat within the year of burning but this continued growth quickly resulted in habitat that became too dense or thick for even the Dickcissel. In the grazing unit there were also some unexpected responses. Estimated abundance was lowest in the Year 0 patch, as expected, but highest in Year 1, not Year 2. The combination of burning and grazing resulted in the lowest estimated abundance of any patch in the grazing unit but was still higher that estimated abundance in the Year 2 control patch. So it would appear the combination of burning and grazing within the same year is preferable to habitat two years following burning with no grazing. We expected Dickcissel estimated abundance to be highest in Year 2 as the grasslands would have time to recover from the burning and grazing, this was not the case. Their estimated abundance was highest in Year 1 and then declined in Year 2. It's worth noting that their estimated abundance in Year 2 of the grazing unit is three times higher than that of Year 2 in the control unit. This would suggest that the addition of grazing animals extends the impact of the fire for an additional year creating more attractive habitat.

In the control patches, Henslow's Sparrow estimated abundance was lowest in the Year 0 patches (Figure 28b) with N =21, highest in Year 1 with N = 112 and in the Year 2 patches N = 81. In the grazing patches Henslow's estimated abundance was again lowest in the Year 0 patches with N = 13 and both Year 2 and 3 had equal abundance with N = 76.
Eastern Meadowlark estimated abundance was lower (Figure 28c) in all three control patches than in the grazing patches with Year 0 and Year 1 patches nearly the same, N = 14, and N = 13 respectively, and highest in Year 2 with N = 21. In the grazing patches, estimated abundance was lowest in Year 0 with N = 29, highest in Year 1 with N = 55, and in Year 2, N =51.

Like the meadowlark, Grasshopper Sparrow estimated abundance was also lower (Figure 28d) in all three control patches with N = 6 in year = 0, N = 7 in Year 1 and N = 3 in Year 2. In the grazing patches, estimated abundance was at its highest in Year 0 with 46 individuals. Year 1 patches had an estimated abundance of N = 21 and estimated abundance was lowest in Year 2 with N = 12.


DICK Abundance - Years Since Burning + Treatment
A
Number of Individuals
500
450
400
350
300
250
200
150
100
50
0
138
440
360
291
252
82
Year 0 Grazing
Year 0 Control
Year 1 Grazing
Year 1 Control
Year 2 Grazing
Year 2 Control


HESP Abundance - Years Since Burning + Treatment
B
Number of Individuals
120
100
80
60
40
20
0
13
21
76
112
76
81
Year 0 Grazing
Year 0 Control
Year 1 Grazing
Year 1 Control
Year 2 Grazing
Year 2 Control



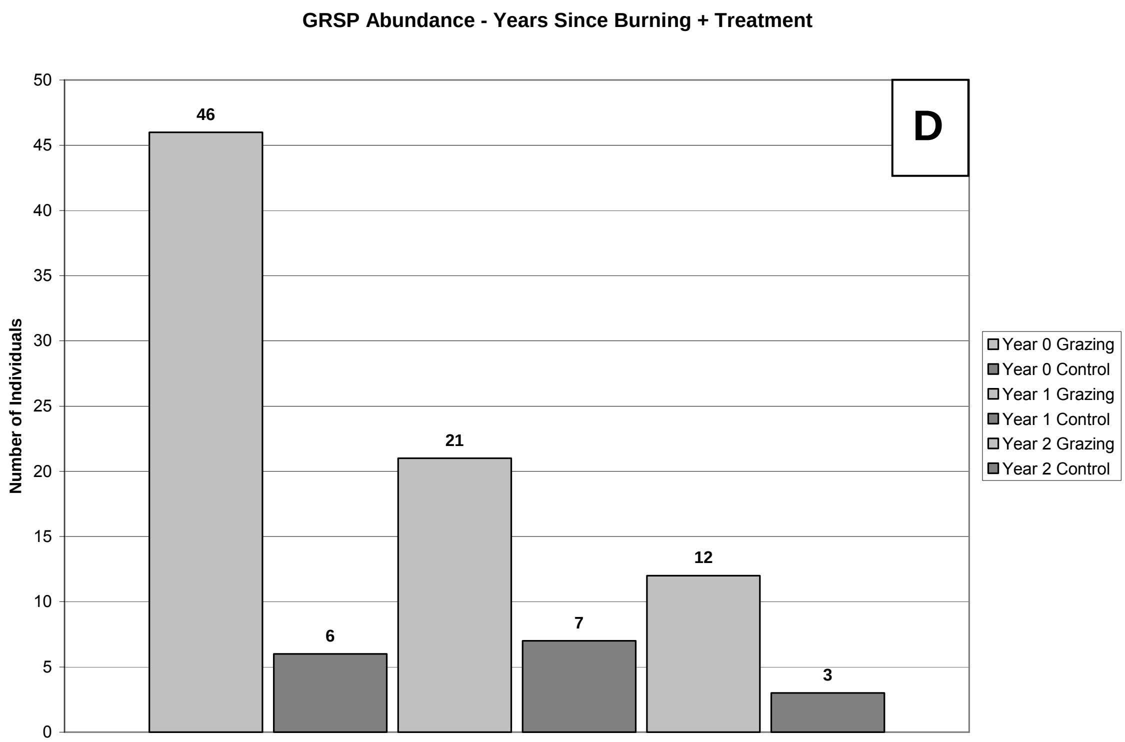


Figure 28a-d. Abundance for each species by Years Since Burning and Treatment using the best supported model from Table 4.

Vegetation composition

Plant species richness for each study site is shown in Table 10 (also see species list in Appendix 1). Sampling was conducted in paired plots with each pair consisting of a grazed plot and an exclosure. Species richness and FQI were assumed to be the same for both plots within each pair because of their close proximity. Results are summarized as the difference in species richness and FQI of grazed and non-grazed plots. Therefore, if grazing had no effect, a difference between grazed plots and exclosures would not exist. A positive difference would indicate a positive impact to species richness or FQI following grazing, whereas a negative difference would indicate a negative response to grazing.

Table 10. Total Species Richness for All Study Plots by Site (2005-2008).

	Number of species observed	
Site	Exclosures	Grazed Plots
Bethel	203	210
Hi Lonesome	206	216
Niawathe	222	217
Taberville	204	202
Wah' Kon-Tah	212	213
All sites	374	387

Significant differences in species richness and FQI were not detected ($P > 0.5$) among patches within each sampling year. There were also found to be no interactions of patch and year despite some fluctuations in total number of species and in FQI (Figures 29 and 30). The 2005 and 2006 burn patches showed an initial decline in species richness and FQI the first year following fire. Such declines were anticipated, however these attributes quickly recovered to pre-burn levels by the second year following fire. The response of the 2007 burn patch did not indicate a drop species richness or FQI during the first year following fire. This could be attributed to the presence of cattle for two years prior to burning that particular patch. Although cattle grazing were focused in other patches of the study site previous to 2007, some light grazing and trampling may have occurred in the 2007 burn patch that reduced the initial impacts of heavy grazing following fire. While these responses are considered notable, it is important to remain cognizant of the fact that they are not significant. Data collected during 2008 indicates that there were no negative impacts to species richness or FQI following a 3-year burn/grazing rotation and 1 year of rest.

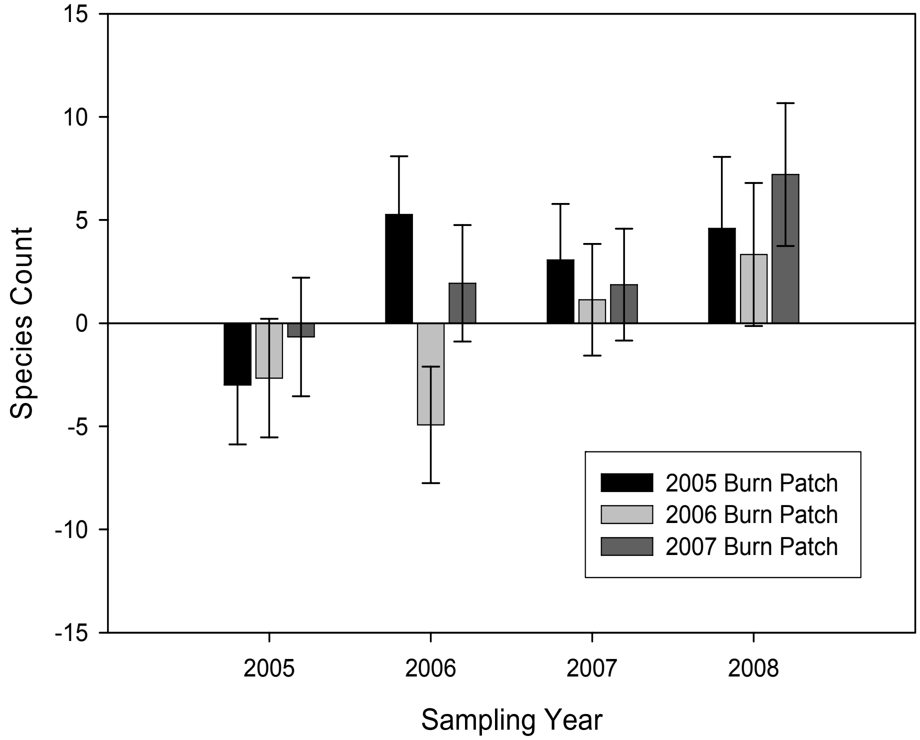


Figure 29. Average difference in species richness between paired Peet plots (grazed plots - exclosures). A positive value indicates a greater number of species in grazed plots. A negative value indicates a greater number of species in exclosures. Bars indicate standard error.

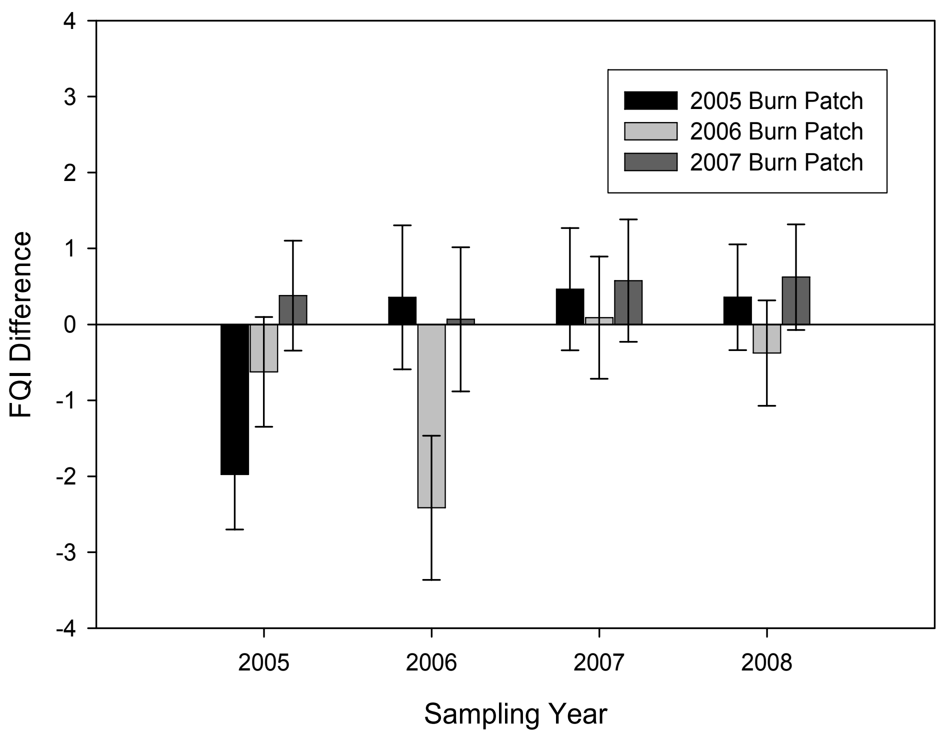


Figure 30. Average difference in FQI between paired Peet plots (grazed plots – exclosures). A positive value indicates a greater FQI in grazed plots. A negative value indicates a greater FQI in exclosures. Bars indicate standard error.

DISCUSSION

Animal performance and economics

Though useful for comparative purposes, our hypothetical scenarios for patch-burn grazing and management-intensive grazing may lack realism in some respects. Our assumptions and analyses have not yet been independently reviewed by agricultural economists and will likely be refined at a later date. It is unlikley that cattle would be sold at the end of the 120-d grazing period as their body weights are well under that preferred for animals bound for the feed lot. It is also unlikely that the rates of gain presented for tall fescue were observed over the same range of dates as that for tallgrass prairie in our study. Nonetheless, the comparison remains informative.

Our comparison of patch-burn grazing to management-intensive grazing illustrates the difficulty of generating profits by backgrounding steers on endophyte-infected (E+) tall fescue pastures. Our results also show the lower returns of patch-burn grazing with much lower stocking rates versus grazing endophyte friendly (E-) tall fescue. Backgrounding steers on low endophyte, endophyte-free (E-), or strains of tall fescue innoculated with novel endphytes (E++) that do not produce alkaloid toxins can be profitable, but these forages require greater attention to management than the more disturbance-tolerant E+ pastures. Low endophyte cultivars are less drought tolerant and more susceptible to overgrazing than high endophyte cultivars. Endophyte infected tall fescue inhibits pathogenic fungi, parasitic nematodes, and the beneficial mycorrhizal fungi giving it a competitive advantage over low endophyte or endophyte free fescue. As a result, E- pastures may not be able to sustain the stocking rates assumed for our comparison without being susceptible to reinvasion by E+ fescue.

Our results may reflect the reasons why most Missouri cattlemen run cow-calf operations and few producers background calves on pastures that they themselves own. Because fixed per acre costs are assumed by the landowner, backgrounding steers on warm-season forages managed with patch-burn grazing may be profitable if cattlemen lease pasture for grazing. Though the details of their individual operations differed, the producers who provided cattle for our evaluation reported favorable profits when leasing pasture on public lands managed by the Missouri Department of Conservation.

Cool-season forages will outperform warm-season forages such as tallgrass prairie during the spring and fall, but adding a warm-season pasture may help avoid poor animal performance during the summer slump as cool-season forages such as tall fescue go dormant. Thus patch-burn grazing tallgrass prairie or a warm-season grass planting may complement an operation that currently utilizes only tall fescue forage.

Grazing distribution

Our results reiterate the attraction of grazing animals to recent burns (. More nutritious and palatable forage in burned areas is an adequate attractant that can be used to control grazing distribution. Using prescribed fire is more economical than installing fences and adding water sources. Fences also create collision hazards that must be avoided by the grassland birds that are often the target species for habitat management.

Because the attraction of yearling cattle to burns is predictably high, managers of warm-season grass or tallgrass prairies could consider using interior fences only to exclude cattle from areas in which they desire no disturbance, and opt instead to use fire to control which portions of their areas are grazed. The current practice of establishing a grazing unit with a temporary boundary fence, and moving that boundary fence to another area at the end of three years, may be unnecessary. The attraction of a recent burn (or burns) alone may be adequate to “confine” grazing animals to the area in which managers wish to control litter, decrease vegetation height, and increase heterogeneity of height and density. Areas far from the burned patches would largely be avoided. Strategic placement of other resources typically used to modify grazing distribution, such as water and mineral, could serve to enhance the attraction of a prescribed burn.

Vegetation structure

During the treatment years (2005 through 2007), heterogeneity of grazing units increased dramatically over that of spring-burned control units. Though heterogeneity of the entire units was increased, these results were driven primarily by the structure in the current year's burn. The most recently burned patch, where cattle grazing was most intense, showed the greatest variation in percent obstruction and vegetation height. We suggest that this variation was due to forage selection by grazing animals occurring at two spatial scales. First, within the grazing unit, cattle sought the most recently burned patch. Second, within those recent burns, grazing animals selected the most palatable forages with greater frequency, especially as the season progresses. This created a gradient of disturbance across the grazing unit wherein older burns or unburned areas received little disturburnce, low-quality forage within the burned unit received some disturbance, and the high-quality forages received the greatest disturbance. The observed vegetation height and density obviously corresponded to this gradient of disturbance.

Some effects of a 3-yr grazing rotation using patch-burn grazing persisted through the first year following removal of grazing, but some structural characteristics of the habitat quickly returned to pre-grazing conditions. Maximum vegetation height appeared to be reduced slightly for several years. Our observations also clearly demonstrate that the patch-burn grazing system controls litter accumulation for two or more growing seasons following a burn versus the shorter term effects of prescribed fire alone. Nine months following removal of prescribed fire and grazing, structural diversity began to decline. Heterogeneity of vegetation density as measured in our evaluation, however, declined quickly following the removal of grazing disturbance. Though the mechanisms driving our results are somewhat obvious, these observations have direct implications for grassland bird habitat management.

Grassland birds

Species Richness.—The greater species richness seen in the treatment units was due to the presence of species that prefer short, sparse grasslands with a bare ground component that could not be found in the control units. These species include; Upland Sandpiper, Horned Lark, Greater Prairie Chicken, Killdeer, and Scissor-Tailed Flycatcher. Detections of these species were rare in this study and occurred in low numbers even in the treatment units, however they were all but nonexistent (occurred <3 times) in the control units. Over two years of data we recorded one observation of a Greater Prairie Chicken in a control unit and one observation of a Scissor-Tailed Flycatcher in a control unit. The Northern Bobwhite was also rare in this study but occurred with two and a half times greater frequency in the grazing units. These are very important observations as the prairie chicken is a state endangered species, the Upland Sandpiper and the Scissor-Tailed Flycatcher are species of management concern in Missouri.

Density and Abundance.—First we wanted to determine whether density and abundance were higher in the treatment units (grazed units) or the control units. There were no surprises here as the Dickcissel and Henslow's Sparrow were both more abundant in the control units (Figure 26). These species are associated with taller grasslands and may be sensitive to disturbance by grazing animals. The Dickcissel was still the most detected species in the grazing units even though their abundance was almost 50% lower than the control units. Henslow's Sparrows were the second most detected species in both units. Although less abundant in the grazing units their numbers were only down 25%. Both the Eastern Meadowlark and the Grasshopper Sparrow were more abundant in the grazing units as predicted, with the meadowlark three and a half times more abundant in the grazing unit and the Grasshopper Sparrow over nine times more abundant. Clearly these species have benefited from the shorter grasslands created by patch burn grazing.

In Figures 27a-d we see species abundance at the patch level. Dickcissel and Henslow's Sparrow abundance was at its lowest in the patches most recently burned. This was expected for both species however, we thought that their abundance would continue to increase with time, and it did in year 1 but declined in year 2. It appears that one year post burning the habitat is favorable to both species but with an additional years growth the grassland becomes less suitable. This was more pronounced for the Dickcissel whose abundance decrease from year 1 to year 2 by 47%. The drop off was less severe for Henslow's Sparrow with a decline of 13%. Eastern Meadowlark abundance was at its lowest in the most recently burned patch and their abundance increased with time through year 2. This was expected for the meadowlark that is associated with medium height grasslands. Although their abundance was highest in year 2, it was only 6% higher than in year 1. It appears that fire will reduce meadowlark abundance, but only for the short term. The Grasshopper Sparrow was by far more abundant in the recently burned patches, more than twice that of the year 1 patches and almost four times that in the year 2 patches. This illustrates the strong affinity that this species has for short grasslands, even one year post burning their numbers decline dramatically and two years post burn their numbers decline even more.

By looking at years since burning plus treatment we can get a picture of how each species responds to the interaction between grazing and prescribed fire. Figures 28a-d show abundance for each of the four species at the patch level (years since burning) and in which treatment unit the patch lies. Looking at Figure 28a we get a more in depth look at Dickcissel response to fire and grazing. Remember in Figure 1 we saw their abundance was much greater in the control units but in Figure 28a we see that only in year 0 was their abundance higher in the control patches than in the grazing patches. In year 0, Dickcissel abundance is at its highest in the control patches and relatively low in the grazing patches. But in years 1 and 2 their abundance was higher in the grazing patches with the lowest patch abundance found in year 2 control patches. The grazing patches look similar to what we saw in Figure 27a, the years since burning graphs, with numbers lowest in year 0 and highest in year 1. The control patches show a linear decline from year 0 through year 2 with a dramatic drop in year 2. It appears that patches receiving the combination of recent spring fire and grazing are very unattractive to the Dickcissel but not as unattractive as burning a patch and then letting it sit idle for two years. Figure 27a shows us that they like patches one year post burn but in Figure 28a we see that abundance was greater in the year 1 grazing patches which is counter to what you might be lead to think after seeing Figure 1. In the year 2 patches abundance drops off quickly in the control patches but drops off less so in the grazed patches. It appears that the combination of one or two years of growth combined with grazing supports more birds than burning alone.

Figure 28b shows Henslow's Sparrow abundance and as predicted their abundance was greater in the control patches and much higher in the year 1 and year 2 patches versus the year 0 patches. Similar to the Dickcissel, the combination of recent fire and grazing was not attractive to the Henslow's Sparrow with the lowest abundance of both the grazing and control patches found in the most recently burned patches (year 0). Their abundance was greater in the year 1 control versus year 1 grazing and in the year 2 control patches. Consistent with what we saw in Figure 27b Henslow's Sparrow abundance was highest in the year 1 patches. Interestingly in the grazing patches year 1 and year 2 yielded the same estimated abundance value with the year 2 grazing patches being very close to the year 2 control patches. This would indicate that after two years of growth following a spring prescribed burn the habitat is not as attractive or cannot support this species in the numbers that one year post burn can.

Figure 28c shows Eastern Meadowlark abundance by years since burning and treatment. As predicted meadowlark abundance was substantially greater in the grazed patches but their response to years since burning was not as clear cut. In the control patches abundance was nearly equal in the year 0 and year 1 patches and highest in year 2. In the grazing patches abundance was lowest in year 0, highest in year 1 but year 2 estimated abundance was nearly equal to year 1. Although the combination of grazing and recent fire produced the lowest estimated abundance of any grazing patch, it was still double that of the year 0 control patch. Estimated abundance in year 1 grazing was four times that of year 2 control and year 2 grazing yielded estimates over twice that of the year 2 control patches.

Figure 28d shows Grasshopper Sparrow abundance by years since burning and treatment. As we predicted and as figures 1 and 2d show, Grasshopper Sparrow abundance was highest in the grazing patches and in the more recently burned patches. Abundance was highest in the year 0 grazing patches and nearly eight times that found in the year 0 controls. Abundance in the year 1 grazing patches was less than half that found in the year 0 grazing patches but still three times greater than that of the year 1 controls. Year 2 grazing patches produced the lowest abundance of any grazing patch but were still four times higher than the year 2 controls and higher than that of any control patch. Without grazing, Grasshopper Sparrows would be very rare regardless of the burning regime. This is a good indicator of how other short grass dependent species will respond to prairies that are managed with fire only.

The primary goal of grassland managers who championed the use of patch-burn grazing in Missouri was to increase habitat quality for species that required a variety of cover types to meet their life history needs. Species such as Greater Prairie Chicken, Upland Sandpiper, and Northern Bobwhite thrive in heterogeneous environments. All of these species require an interspersion of bare ground, short vegetation, and dense herbaceous cover. These structural requirements were immediately met with patch-burn grazing. In addition, each of these species requires brood-rearing habitats with abundant forbs that harbor high densities of invertebrates that are used as food by precocial young. Patch-burn grazing meets this requirement as intensively grazed patches respond to disturbance with a flush of early successional annual plants the year following the burn.

Grassland managers also sought to provide habitats for a variety of grassland passerines, which often have somewhat narrow habitat requirements during the breeding season. Henslow's Sparrows, for example, are often associated with tall, dense cover with a well-developed litter layer. In contrast, Grasshopper Sparrows prefer short, sparse vegetation for nesting. These, and other grassland bird species, often rely on conservation lands for habitat that is rarely available elsewhere. Because patch-burn grazing provides structurally different habitats in each patch, managers were able to meet the needs of a variety of species with very different requirements by using a single, low-cost technique. Of special note is the continued presence of Henslow's Sparrow in the grazing units, and that they were found using patches that were burned and intensively grazed the year before. This species is considered to require significant litter depth and standing residual vegetation (Herkert 2003). Given this apparent requirement, managers were concerned that grazing would cause their use of grazed units to decline dramatically.

Under patch-burn grazing, observed increases in the abundance of species that require short, sparse vegetation were greater than the declines observed for those species that require tall, dense vegetation. This suggests that managers can employ patch-burn grazing to create habitats for those species that depend on short sparse grasslands while still providing habitat for species generally associated with a lack of disturbance. If we desire to create habitat that increases species diversity and richness, and to bolster short-grass dependent species, it appears we must consider adding grazing to our prairie management plans.

Vegetation composition
Current data analysis shows that patch-burn grazing has had no significant impact on the vegetative community. However, only a few aspect s of vegetative composition have been investigated. As interest of land managers in patch-burn grazing increased, some botanists became concerned that populations of species that are intolerant of continued grazing would be reduced or eliminated by grazing. Among these species are compass plant (*Silphium laciniatum* L.), leadplant (*Amorpha canescens* Pursh), and pale purple coneflower (*Echinacea pallida* (Nutt.) Nutt.). Suffiecient data is now gathered to further study the impacts of specific speicies of interest subjected to patch-burn grazing. Results and implications of this data will be submitted to range and natural area management journals for publication.

DEMONSTRATION EFFORTS
During the course of this 4-yr evaluation, Missouri Department of Conservation staff conducted or participated in ≥12 meetings and workshops to share information on the practice of patch-burn grazing and provide updates on results of monitoring.

In 2005, we held two meetings during the field season to transfer information about the use of patch-burn grazing and progress of our monitoring efforts. A mid-season meeting was held in Clinton to update our collaborators and graziers on the progress of the project and to involve them in planning upcoming activities. We solicited observations and questions from Wildlife staff and producers to facilitate communication and information transfer. Max Alleger organized a patch-burn grazing workshop targeted at private landowners in the Cole Camp, MO area near the Hi Lonesome study site. We developed contacts outside of the Missouri network to aide our understanding of PBG, and the Patch-burn Grazing Working Group met in Missouri, Kansas, and Oklahoma. The meeting in Oklahoma included field trips to the patch burn studies in Stillwater and the Tall Grass Prairie Preserve. The group established a list serve through Kansas State University to facilitate communication.

In 2006, we attended the Patch-burn Grazing Working Group meeting in the Kansas Flint Hills and shared preliminary results from the first two years of the project. The Kansas meeting included field trips to public and private areas managed with patch-burn grazing including the Tallgrass Prairie National Preserve, Wayne Copp’s bison ranch, and Jane Koger’s Homestead Ranch.

Coordinators and team participants conducted several outreach events in 2007. In April, we conducted an internal workshop to inform local staff and administrators within MDC about patch-burn grazing and to discuss the potential influence of grazing on water quality in headwater prairie streams. In June, we met with local staff and professors and staff from Oklahoma State University and Iowa State University to show them our study sites and compare observations on how we are using the grazing technique and how the results compare with those they’re seeing on their study sites. In August, we held a patch-burn grazing workshop at Niawathe Prairie for Natural Resources Conservation Service, Missouri Department of Natural Resources, TNC, and MDC staff, as well as members of the Missouri Cattlemen’s Association.

In September, we hosted the Patch-burn Grazing Working Group meeting in Nevada, Missouri which included a field trip to Taberville Prairie. In October, we led an additional field discussion on patch-burn grazing for the Missouri Natural Areas Committee at the Taberville Prairie site. The Committee included representatives from USDA, the US Fish and Wildlife Service, and Missouri DNR.

In 2008, project coordinators and team members shared study results with Missouri Beef Tour participants in August at Bushwacker Lake Conservation Area in Barton and Vernon counties. Wes Spinks, who participated in our evaluation of this grazing system as a contract grazier, also provided his perpective onanimal performance under patch-burn grazing at the Tour. Project coordinators again presented study results at the annual Patch-burn Grazing Working Group meeting in Wood River, Nebraska. Project coordinators also shared project results related to prairie grouse conservation at the International Grouse Symposium in Yukon, Canada.

Collaborators also facilitated the preparation of an article on the benefits of patch-burn grazing for the Missouri Prairie Foundation's Prairie Journal, a four-color periodical produced quarterly to highlight prairie conservation efforts. Finally, MDC staff posted an animated clip on YouTube® that demonstrates the process of patch-burn grazing. To view the video, direct your internet browser to: **http://www.mdc.mo.gov/18952** .

At each outreach and demonstration events from 2005 through 2008, we shared information on the purpose and hypothesized benefits of patch-burn grazing as well as study results as they came available. We will continue information transfer efforts by producing peer-reviewed publications and presenting results at conferences and workshops. Project coordinators will share results of all study objectives during a workshop at the Missouri Natural Resources Conference in February, 2009.

ACKNOWLEDGMENTS
The project coordinators, collaborating scientists and team members thank Joe Coy, Ryan Craig, Sharron Gough, Katie Hall, Emily Horner, Kevin King, Louis Kleeman, Tom Kulowiec, Renee Larson, Sherry Leis, Mike Longhoefer, Mike McManus, Eric Merritt, Gary Robison, Mike Skinner, Jake Strozewski, Mike Wallendorf, Stasia Whitaker, Chris Wieberg, and Neal Young for assistance in study development, database management, coordination, and implementation. Josh Flinn, J.T. Layne, and Johnathan Slade conducted cattle observations, and dozens of other staff assisted with vegetation structure and composition sampling, as well as data entry. Chuck Daniel, Ronnie Davis, Tom Smith, and Wes Spinks provided insight and cattle, observations of grazing behavior, and their perspectives on patch-burn grazing management.

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