Responses of grassland birds and butterflies to control of sericea lespedeza with fire and grazing

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Abstract

Sericea lespedeza (*Lespedeza cuneata*) is an invasive forb that reduces native grass and forb abundance in tall-grass prairie by up to 92%. Controlling invasions is difficult because traditional land management tools used in the Flint Hills, broad spectrum herbicides, spring prescribed fire, and cattle grazing, are ineffective against sericea. Recent research has demonstrated, however, that mid- and late summer prescribed fire and spring fire with early season grazing by steers followed by late season grazing by sheep are effective at reducing sericea whole plant mass, number of seeds produced, and seed mass. Field results were from two separate experiments conducted in tall-grass prairie study sites in the Flint Hills. On a Geary County, Kansas, study site, the utility of 1) spring fire (control), 2) mid-summer fire, and 3) late summer fire on sericea control were compared. On a Woodson County, Kansas, study site, the utility of 1) spring fire with early season steer grazing followed by rest (control) and 2) spring fire with early season steer grazing and late season sheep grazing on sericea control were compared.

At the same study sites, I measured responses by the native wildlife community to use of summer fire and sheep grazing, relative to their controls, to manage sericea lespedeza. Specifically, my objectives were to compare grassland songbird density, grassland songbird nest survival, and grassland butterfly species composition and density among treatments at both study sites. I also related patterns in the vegetation community of each treatment for each study site to respective patterns in grassland bird and butterfly communities. Within study sites, density, nest density, and nest success of grassland bird communities responded similarly to treatments and controls, with the exception that densities of Grasshopper Sparrows (*Ammodramus savanarrum*) were 3.4- and 2.2-fold greater in mid- and late summer fire plots than spring fire plots,

respectively, in the Geary County study site. Species compositions of butterfly communities were similar across treatments within experiments, but grassland specialist species comprised only 8.6 and 1.2% of all butterfly observations in the Geary County and Woodson County experiments, respectively. Grassland specialist butterfly species may benefit from summer fire, as their nectar sources were more abundant in Summer Fire plots than Spring Fire plots. Overall, within each experiment, grassland bird and butterfly communities were similar across treatments, suggesting that treatments did not negatively affect grassland songbird and butterfly communities.

I additionally demonstrated that Dickcissel (*Spiza americana*) nest sites contain a lower proportion of sericea than random points, the first evidence that the invasion is detrimental to grassland songbird species. Lacking control, the continued sericea invasion will out compete cumulatively more forb plants resulting in declining quality of grassland bird nesting habitat on the landscape. Controlling sericea lespedeza invasions will allow native forb species to increase in abundance and improve the condition of grasslands for native wildlife and livestock producers. Therefore, I advocate use of summer fire or spring fire with a combination of cattle and sheep grazing to control sericea lespedeza with the long-term goal of tall-grass prairie restoration.

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Dedication

To my mother, Laura P. Bonneville, for sharing with me her gentle appreciation for bats, flowers, and butterflies.

And to my nephew, Owen E. Loiacono, for his fits of laughter along the Rock Creek Trail.

And, to heterogeneity!

Chapter 1 - Introduction

Vast expanses of grassland once covered approximately 162 million ha of the North American Great Plains, but that extent was drastically reduced upon European settlement and expansion west (Samson and Knopf 1994). During the 1800s, European settlers converted ~80 million ha of grassland into settlements and agricultural land, effectively halving the total amount of grassland and fragmenting that which remained (Samson et al. 2004). In the past century, habitat loss and fragmentation has continued and even accelerated due to row-crop agricultural intensification, improvement in irrigation technology, and expansion of urban and residential areas. As a result, North American grasslands, encompassing tall-grass, short-grass, and mixed-grass prairies, have been reduced in area by >90% and are now considered one of the most endangered ecosystems on Earth (Samson and Knopf 1994). The tall-grass prairie is the most imperiled of the three North American grassland ecotypes, only covering ~4% of its pre-European settlement extent (Samson and Knopf 1994).

Compounding the negative effects of a reduction in tall-grass prairie area, much of the remaining prairie is highly fragmented. This fragmentation, in conjunction with altered and homogenized fire and grazing regimes and introduced non-native plants, results in a degraded prairie system, as evidenced by a reduced capacity to support native species (e.g., Collins 2000, Herkert et al. 2003, Wilgers et al. 2006, Jonas and Joern 2007). Insect pollinators, for example, are experiencing global population declines that are attributed to a combination of global climate change and habitat loss, fragmentation, and degradation (Knops et al. 1999, Ricketts et al. 2008, Winfree et al. 2009, Potts et al. 2010). The Regal Fritillary (*Speyeria idalia*) is a grassland-obligate butterfly species that has been assigned status as a threatened and endangered species at a state-level across most of its current range (Selby 2007). The species' only remaining population stronghold is in Kansas, where native tall-grass prairie remains intact (Selby 2007). Loss of native prairie similarly has resulted in prairie skippers (Lepidoptera:Hesperidae) being considered more endangered than the tall-grass prairie itself and caused grassland birds to experience the steepest population declines of any guild of North American birds (Herkert 1994, Herkert et al. 1996, Schlict and Orwig 1998, Herkert et al. 2003, Brennan and Kuvlesky 2005). Specifically, between 2003 and 2013, Dickcissel (*Spiza americana*) populations in Kansas declined an estimated 2% and Grasshopper Sparrow (*Ammodramus savanarrum*) populations decreased an estimated 3.7% (Sauer et al. 2014).

Although loss and fragmentation of remaining grasslands are factors most strongly implicated in the declines of wildlife populations, the spread of invasive species has the potential to exacerbate these negative effects (Gibbons et al. 2000, Gurevitch and Padilla 2004, Stout and Morales 2009). For instance, grassland birds have specific nesting requirements, which may include vegetation height, amount of litter, and type of vegetative substrate, all of which could be disrupted by establishment by non-native plant species. If fewer nesting sites are available on the landscape, grassland birds will experience reduced recruitment, causing population declines. Similarly, for a pollinator specialist, a reduced abundance of a particular plant species may result in starvation or an inability to complete an insect's life cycle. For a generalist insect pollinator, dominance of the plant community by one species may lead to an inadequate supply of nectaring sources during certain times of the year. An altered plant community that affects the invertebrate community could have consequences for higher trophic levels; for example, reduced survival or recruitment of grassland birds.

The dominant native vegetation in tall-grass prairies include four species of grass (big bluestem [*Andropogon gerardii*], indiangrass [*Sorghastrum nutans*], little bluestem

[*Schizachrium scoparium*], and switchgrass [*Panicum virgatum*]), and numerous forb species. Sericea lespedeza (*Lespedeza cuneata*, hereafter sericea) is one of seven invasive forbs considered noxious weeds in Kansas (Natural Resources Conservation Service 2016). The species is widespread throughout the eastern half of the United States, has invaded ~15% of the tall-grass prairie, and is continuing to expand its range at a rate of ~2% increase per year (Cummings et al. 2007). Sericea is an herbaceous, warm season, perennial forb that was intentionally introduced to the United States from central and eastern Asia for erosion control, as a forage species, and for wildlife cover (Eddy and Moore 1998). The species is able to outcompete native grasses and forbs by depositing an extensive seed bank and producing phytochemicals that retard the growth of neighboring plants (Koger et al. 2002). The cumulative effect of the competitive ability of sericea is a reduction in abundance of tall-grass prairie native grasses and forbs by up to 92% (Eddy and Moore 1998). Areas of tall-grass prairie with large proportions of sericea support diminished invertebrate communities, which is presumed to be detrimental to native wildlife communities (Eddy and Moore 1998). Although scant literature exists regarding wildlife response to sericea invasions, this topic is receiving increased attention. Brooke et al. (2016) offered the first quantitative evidence of an effect of sericea on grassland wildlife by demonstrating that northern bobwhite (*Colinus virginianus*) place nests disproportionately in areas treated with herbicide to control sericea. Dominance of tall-grass prairie by sericea is also problematic for livestock producers because the plant species has high concentrations of condensed tannins, making it unpalatable to and indigestible by cattle. Thus, spread of sericea lespedeza is a major concern for land and wildlife managers, as well as livestock producers; and, identifying effective methods to control spread is a common goal.

Many methods of control have been attempted for sericea lespedeza, including biological control by lespedeza webworm, cutting and mowing, numerous broad-spectrum herbicides, fire applied at various times throughout the year, and livestock grazing (Altom et al. 1992, Ohlenbush et al. 2001, Koger et al. 2002, Vermeire et al. 2002, Eddy et al. 2003, Brandon et al. 2004, Farris 2006, Cummings et al. 2007, Wong et al. 2012, Mantz et al. 2013, Alexander et al. 2016, Lemmon et al. 2016). Application of broad-spectrum herbicides, in some circumstances, is effective at controlling sericea invasions. Of herbicides tested, triclopyr, fluroxypyr, and metsulfuron are the most effective at reducing sericea lespedeza stem density, biomass, and seedling density (Altom et al. 1992, Koger et al. 2002, Cummings et al. 2007). All herbicides, however, require repeated application, becoming expensive for control, and have the potential to reduce the abundance of native, beneficial broad-leafed forbs (Koger et al. 2002, Cummings et al. 2007). Problems associated with using herbicides to eradicate unwanted plant species are exacerbated in the Flint Hills ecoregion. The Flint Hills is a region of tall-grass prairie that extends from north-eastern Kansas to north-central Oklahoma. In general, the tall-grass prairie has deep, fertile soils and flat terrain that facilitate row-crop agriculture, but the Flint Hills ecoregion is an exception to this generality. This area is characterized by rolling hills with shallow soils and limestone outcrops, which preclude cultivation of the land for row-crop agriculture (Anderson and Fly 1955). Consequently, the largest contiguous area of remaining tall-grass prairie is located in the Flint Hills (Reichman 1987). Although a stronghold for native tall-grass species, features of the ecoregion that spared land from the plow are the same ones that make herbicide application particularly challenging. The rocky, hilly landscape of the Flint Hills makes tractor spraying impractical, thus aerial spraying is the most efficient method for applying herbicides. Unfortunately, rocky outcrops and the robust canopy shield some plants from application, leaving islands of the invasive species from where the invasion continues to spread, ultimately rendering the treatment incomplete.

Landowners in the Flint Hills recognize that there is value in using methods other than, or in addition to, herbicides for managing grazing pastures. Grazing by large ungulates, periodic fire, and drought promote the growth of native flora and suppress growth of woody vegetation, acting in concert to maintain the tall-grass prairie ecosystem. Fortunately, the utility of grazing and fire can be harnessed to the benefit of the land and livestock production. Prescribed fire is a useful tool for livestock producers because removing the aboveground biomass increases the availability of mineral nitrogen, making the forage more nutritious to livestock and increasing their rate of weight-gain (Woolfolk et al. 1975, Hobbs and Schimel 1984, Hobbs and Swift 1985, Svejcar 1989). In the Flint Hills, prescribed fire is traditionally applied in the spring because this timing is considered most productive for promoting growth of warm-season grasses typical of tall-grass prairie and suppressing woody encroachment; however there is little to no empirical support for this claim (Towne and Owensby 1984). In fact, Towne and Craine (2014) demonstrated that woody cover is not affected differently by prescribed fires applied in November, February, or April. Moreover, Spring Fire will not effectively prevent the encroachment of warm season plant species, such as sericea lespedeza, which produces seeds and flowers in August and September. Multiple researchers have reported that fires applied in the early growing season (i.e., March and April) and dormant season (i.e., November to February) do not reduce sericea cover, and can even promote the growth of the species (Ohlenbusch 2007, Wong et al. 2012, Brooke et al. 2015).

Cattle grazing is a major income source in the Flint Hills and it is practical and common for land owners to use grazing as a method to maintain nutrient-rich forage while simultaneously producing livestock. Cattle grazing is effective at controlling or containing some invasions of some exotic plants by rendering seeds inviable as they pass through the gut, but is not effective at managing a sericea invasion (DiTomaso 2000). Thus, the declining quality of grazing pastures as a consequence of sericea invasions has large economic consequences for the Flint Hills livestock production community. Fortunately, there is evidence that altering these traditional fire and grazing regimes based on annual spring fire and cattle grazing to specifically target sericea lespedeza can be effective at controlling the invasion (Cummings et al. 2007, Alexander et al. 2016, Lemmon et al. 2016). Specifically, prescribed fire applied late in the growing season, in August or September, reduces the number of seeds produced per sericea lespedeza plant and whole plant mass of plants that persist by >95% (Alexander et al. 2016). Grazing by sheep, which are tannin tolerant, in addition to cattle similarly reduces the number of seeds produced per plant by >85% and reduces mass of persisting sericea plants by >70% (Lemmon et al. 2016). Alternative fire and grazing practices are promising avenues for controlling a problematic invasion, but given the precarious position of the tall-grass prairie ecosystem, it is important to understand the effects these management techniques have on the native wildlife communities.

To that end, I characterized the grassland nesting bird and butterfly communities at two separate study areas in Kansas: 1) sericea lespedeza-invaded pastures exposed to Spring Fire, Mid-Summer Fire and Late Summer Fire and 2) sericea-lespedeza-invaded pastures exposed to spring fire and either cattle grazing or cattle grazing followed by sheep grazing. The objectives for my field investigation were to: 1) characterize grassland bird communities in all treatments; 2) estimate reproductive output and daily nest survival of grassland nesting songbirds in all treatments; 3) characterize butterfly communities in all treatments; 4) characterize the vegetation communities among treatments; and 5) relate differences in bird and butterfly communities among treatments to differences in land cover and floral composition among treatments. The ultimate goal for my research project was to provide information that can be used to decide whether using summer prescribed fire or sheep grazing in tall-grass prairie to control sericea lespedeza are ecologically responsible practices in the Flint Hills.

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Chapter 2 - Grassland Bird and Butterfly Response to Seasonal Use of Prescribed Fire

Introduction

North American grasslands, including short-grass, mixed-grass, and tall-grass prairies, evolved with recurrent fire (Anderson 1990). Fire staves off woody encroachment, promotes grass and forb growth, and attracts large grazers, so not only is the ecosystem tolerant of fire, it is dependent on it (Willms et al. 1980, Towne and Owensby 1984, Towne and Craine 2014). Prior to European settlement in the North American Great Plains, fires were ignited by lightning strikes and Native Americans, but fire is now largely suppressed in grasslands (Anderson 1990). An exception to this generality occurs in the Flint Hills ecoregion, which extends from north-eastern Kansas to north-central Oklahoma (Figure 2.1). This ecoregion contains the largest remaining tract of intact tall-grass prairie, an ecosystem that is losing area through conversion to row-crop agriculture. The tall-grass prairie in the Flint Hills has been spared the plow because of its shallow soils and limestone outcrops, which make it more conducive to cattle grazing than row-crop agriculture (Anderson and Fly 1955). In the Flint Hills, land owners utilize prescribed fire in maintaining healthy native prairie and on these pastures have established a prolific and profitable cattle ranching industry (Reinking 2005).

Land owners in the Flint Hills have traditionally applied prescribed fire in the spring. This seasonal timing is considered optimal for promoting native grass and forb growth with the greatest nutritive quality for livestock and preventing encroachment of woody plant species (Towne and Owenbsy 1994). While there is a great deal of anecdotal evidence to support these claims, there is little empirical evidence to draw on, especially in terms of the purported utility of spring fire to suppress woody growth. Included in the limited peer-reviewed literature on the subject is a study conducted by Towne and Craine (2014) who reported that fires applied in April, November, and February are equally effective at suppressing woody growth in tall-grass prairie.

Intuitively, the most effective timing of fire for promoting growth of desired plant species and preventing growth of undesired species will depend on the plant species composition in the area being burned and phenology of those species. To promote growth of desired warm-season grass species for cattle production, it is recommended to apply fire early in the growing season, typically early spring in the Flint Hills, to decompose the aboveground biomass and release nutrients that can be used for new growth (Ohlenbusch and Hartnett 2000). Reducing growth of undesired plant species is achieved by applying fire later in the growing season, when plants are producing seeds and flowers and nutrient reserves are at the lowest point of the season (Ohlenbusch and Hartnett 2000).

Sericea lespedeza (*Lespedeza cuneata*) is an invasive plant that cannot be effectively controlled by herbicides but using prescribed fire may be a viable option for control (Cummings et al. 2007, Alexander et al. 2016). The species is most vulnerable to fire in August and September because it flowers and sets seed in late summer; hence, fire applied in the spring is ineffective at controlling the invasion (Ohlenbusch and Hartnett 2000). In fact, prescribed fire applied in August and September has been demonstrated to reduce sericea whole plant mass, number of seeds produced, and seed mass compared to fires applied in the spring (Figure 2.2; Alexander et al. 2016). These results are encouraging for land owners and managers in the Flint Hills; however, before promoting the use of summer fire to control sericea lespedeza, it is important to understand how this management strategy affects native wildlife communities in tall-grass prairie ecosystems. Remaining tall-grass prairie is ~4% of what historically existed, thus it is our responsibility as land stewards to make all efforts to maintain the remaining tall-grass prairie in an ecological state that promotes the persistence of native wildlife species (Samson and Knopf 1994).

In a study concurrent with Alexander et al. (2016) who focused on performance of sericea lespedeza, I surveyed grassland songbird and prairie butterfly communities in plots of tall-grass prairie exposed to prescribed fire in April, August, and September. Specifically, I compared grassland songbird density among fire treatments, estimated songbird nest survival in each treatment, and evaluated prairie butterfly density and species composition among treatments. I also investigated the influence of plant species composition and structure on avian and butterfly community density and species composition.

Methods

Study Site

The study site consisted of 50 ha of sericea lespedeza invaded tall-grass prairie in Geary County, Kansas, within the north-central portion of the Flint Hills (39°02’04.00”N; 96°42’04.21”W; Figure 2.1). The entire study area was comprised of Benfield-Florence complex-type soils with 5 to 30% slope (Web Soil Survey 2016). Historical mean daily high temperature from March through September in nearby Manhattan, Kansas, ranges from 13.9 to 33.1° C. In 2015 and 2016 from March through September, daily high temperatures ranged from 15.5 to 32.2° C and 17.9 to 32.7° C, respectively (www.usclimatedata.com). Historically, total precipitation in Geary County, Kansas, from March to September averages 647 mm. From March to September 2015 and 2016 total precipitation was 571 mm and 771 mm, respectively (climate.k-state.edu).

For this study, the site was divided along watershed boundaries into nine fire-management units (5 ± 2.6 ha), each randomly assigned to one of three treatments: mid-April fire (Spring; control), early August fire (Mid-Summer), or early September fire (Late Summer; Figure 2.1). Each treatment was applied annually from 2014 to 2016. Domestic livestock grazing occurred on the site occasionally during the fall and winter months of the study period.

Breeding Grassland Birds

Estimates of avian density were obtained by conducting fixed-radius point-count surveys with distance sampling (Buckland et al. 2001). I conducted point-count surveys from mid-May to early June 2015 and 2016. In 2015, I surveyed 18 50-m radius stations and one 100-m radius station nine times. In 2016, I surveyed 21 50-m radius stations eight times. Two four- to five-day survey bouts were conducted with approximately one week between bouts. The point-count period began with a two-minute acclimation period, followed by five minutes of survey in which two independent observers recorded the species of each bird detected by sight or sound within the survey area. The distance from the observer to each bird was measured with a Leica Rangemaster CRF 1000-R rangefinder. Following each five minute survey, the two observers compared detections and arrived at a consensus regarding the number of individuals of each species within the survey area and the distance from the point-count center to each individual. Point counts were conducted between first light and 10:45 hours on mornings with no precipitation, winds ≤32 kph, and good visibility. Each morning, among the point-count stations, a random start point was generated with subsequent order depending on the nearest neighbor point-count location.

I located nests of grassland nesting songbirds via rope-dragging, following females to their nests, and serendipitous flushing from late May to late July in 2015 and 2016. Upon locating a nest, I recorded nest location in Universal Transverse Mercator (UTM) units using a handheld Global Positioning System (GPS) device. I marked each nest with flagging 5 m north and south of the nest. I recorded nest contents (number of eggs and the presence and number of parasitic Brown-headed Cowbird [*Molothrus ater*] eggs or chicks) and candled eggs to estimate the number of days since the start of incubation. I monitored each nest every two to three days until it was determined to have failed or the chicks to have fledged (defined as chicks leaving the nest).

Butterflies

I surveyed the butterfly (Order Lepidoptera) community using a modified Pollard walk method (Pollard 1977). Surveys were conducted along permanent 100-m transects between 09:00 and 18:00 hours on days with no precipitation, winds ≤24 kph, and good visibility. Each of the nine plots in the study site contained one permanent 100-m transect and I surveyed each transect mid-month from June to September in 2015 and May to September in 2016. All butterflies detected within 5 m of either side of each transect and within 15-m above ground were recorded and identified to species or lowest possible taxonomic level. Orange, Clouded, and Dainty Sulphur butterfly species (*Colias eurytheme*, *C. philodice*, and *Nathalis iole*) were difficult to distinguish without capture and combined as Sulphur species. Likewise, due to difficulty of distinguishing without capture, Spring and Summer Azures (*Celastrina ladon* and *Celastrina neglecta*) were combined as Azure species and all species within the Grass Skipper subfamily (Family Hesperiidae, subfamily Hesperiinae) were combined as Grass Skipper species.

Plant Community and Land Cover Measurements

I measured canopy land-cover at each monitored grassland songbird nest and a paired unused point 5 m away from the nest. Measurements were made one day post-fledging or anticipated fledge date if the nest had failed. Between early June and late July 2015 and 2016, I estimated the proportional canopy cover of grass, forbs, shrubs, bare ground, and litter within a 1-m^2 Daubenmire frame. In 2016, proportional canopy coverage of sericea lespedeza was also estimated. Proportions were placed into six classes (0.0-0.05, 0.06-0.25, 0.26-0.50, 0.51-0.75, 0.76-0.95, and 0.95-1.0) and the midpoint of each class was used for analyses (Daubenmire 1959). I recorded litter depth to the nearest cm at the northwest corner of the Daubenmire frame. I measured height of 100% visual obstruction using a Robel pole to the nearest decimeter at a distance of 4-m and 1-m above the ground at all four cardinal directions from the nest or paired unused point (Robel et al. 1970).

Once per year between early June and late July 2015 and 2016, I recorded basal land-cover measurements and forb and shrub species composition along the permanent 100-m transect within each plot. I recorded occurrence of grass, forb/shrub, litter, or bare ground at each 1-m mark. If a forb or shrub was detected, it was identified to species. I estimated percent composition of grass, forb/shrub, litter, and bare ground by dividing the number of points at which each was recorded by the total number of points on the transect.

Statistical Analyses

I estimated avian detection probabilities and densities using Program Distance (version 6.2 Release 1; Thomas et al. 2010). Detection probabilities and densities were separately estimated for Dickcissel (*Spiza americana*), Grasshopper Sparrow (*Ammodramus savanarrum*), and Eastern Meadowlark (*Sturnella neglecta*), the focal grassland nesting birds, and Brown-headed Cowbird (*Molothrus ater*), a brood parasite. I pooled observations from 2015 and 2016 to increase sample size with the assumption that responses to treatments were consistent between years. Because most point-count surveys had a fixed radius of 50 m, observations were right-truncated at 50 m, which allowed calculation of more precise detection probabilities. Detection functions were calculated using the program's default settings, a half-normal key function and a cosine series expansion. Densities were post-stratified by species and I compared rankings of a model using treatment as a covariate to a model without any covariates. Models were ranked using Akaike's Information Criterion, corrected for a small sample size (AIC_c; Burnham and Anderson 2002). For each species, I tested for differences in avian density among treatments using a chi-square test in Program CONTRAST (version 2.0; Hines and Sauer 1989).

For songbird species for which I monitored >15 nests, I estimated daily nest survival using the Nest Survival option in Program MARK (version 6.2; White and Burnham 1999, Dinsmore et al. 2002). Because I was primarily interested in fire treatment effects, I pooled nests found in 2015 and 2016 to increase sample size. I tested four competing models: a null model (null), a model considering fire treatment type (treatment), a model considering each day separately (day), and a model considering the interaction between treatment and day (treatment*day). Models were ranked using AIC_c. Model averaging was performed using the Model Averaging tool in Program MARK. Period survival estimates for Dickcissel nests within each stage were calculated by exponentiating daily nest survival estimates by 12 in the incubation stage (nest initiation to hatching) and 9 in the nesting stage (hatching to fledging), which are the numbers of days a typical Dickcissel nest is exposed within each stage (Winter 1999). Standard errors for period survival estimates were calculated using the Delta method. For songbird species for which I monitored >15 nests, I calculated apparent nest survival by dividing the number of successful nests (fledged ≥1 chick) by the number of nests I monitored.

I estimated songbird nest density by dividing the number of nests found in each plot in both years by the area of each plot and averaging among treatments. I tested for differences in parasitism rates and nest density among treatments using an analysis of variance (ANOVA). I estimated butterfly density by tallying the number of butterflies recorded within each 15,000-m^3 survey area for all months combined and averaging within treatments. I tested for differences in butterfly density among treatments and between years using a chi-square test in Program CONTRAST. To test for differences in nectar source abundance among treatments, I used an ANOVA on $\log_e(x+1)$ transformed counts of nectar forbs. I estimated species diversity for the butterfly and forb/shrub communities using Shannon's Diversity Index and divided species diversity by log-species richness to estimate species evenness.

I compared canopy cover measurements between years, between nests and random points, and among treatments (pooling measurements at nests and random points) using Wilks' lambda multivariate analysis of variance (MANOVA) tests in Program R (version 3.1.1; R Development Core Team 2010) and subsequent ANOVA and Tukey HSD tests following a significant MANOVA to univariately separate treatments for each dependent variable. Proportional canopy coverage of grass, forbs, litter, and bare ground, litter depth, and visual obstruction reading (VOR) were included as dependent variables for the canopy coverage MANOVA. Differences in proportional canopy coverage of sericea lespedeza between point use (i.e., nest or random) or among treatments in 2016 were tested using an ANOVA. Proportional coverage of grass, sericea lespedeza, forbs other than sericea lespedeza, litter, and bare ground were included as dependent variables for the basal coverage MANOVA. I tested treatment, year, and the interaction of treatment and year as independent variables in MANOVA for both canopy and basal coverage models. Likewise, I tested for differences in average vegetation metrics between nest sites and random points, year, and the interaction between point use and year as independent variables in MANOVA. Proportional land cover measurements were arcsin-transformed prior to analysis to meet the assumption of normality. I set $\alpha = 0.05$ for all statistical tests.

Results

Breeding Grassland Birds

A total of 22 bird species were detected within 50-m radius survey areas from 339 point-count surveys (Table 2.1). Detection probabilities at point-count center ranged from 0.55 to 1.00 for the four focal species (Dickcissel, Grasshopper Sparrow, Eastern Meadowlark, and Brown-headed Cowbird) indicating that nearly all individuals of these species were reliably detected within 50 m of the observers (Table 2.2). Female songbirds were less conspicuous than singing male songbirds and less likely to be detected. Density estimates are therefore conservative and reflect a minimum density estimate. Minimum densities for the focal species ranged from 0.4 to 3 birds/ha. For Dickcissels, there was a tendency for higher densities in Spring Fire plots than Mid- and Late Summer Fire plots ($\chi^2_2 = 0.71$, $P = 0.70$). Densities of Eastern Meadowlarks ($\chi^2_2 = 0.12$, $P = 0.94$), and Brown-headed Cowbirds ($\chi^2_2 = 0.56$, $P = 0.76$) did not differ among fire treatments, whereas Grasshopper Sparrow densities were two to three times greater in Mid-Summer Fire ($\chi^2_1 = 5.34$, $P = 0.02$) and Late Summer Fire ($\chi^2_1 = 2.34$, $P = 0.13$) treatments compared to Spring Fire treatments (Figure 2.3). In comparing a density model considering fire treatment to a null model, the treatment model outperformed the null model by >1900 AIC_c units, with 100% of the weight.

I monitored 25 (21 Dickcissel and 4 Eastern Meadowlark) and 48 nests (40 Dickcissel, 6 Eastern Meadowlark, and 2 Grasshopper Sparrow) in 2015 and 2016, respectively (Table 2.3). A complete census of songbird nests was not possible, therefore nest density estimates are conservative and reflect minimum nest density. There was no interaction between treatment and year on nest density of all species combined ($F_{2,12}$ = 0.22, P = 0.81) and nest density did not differ among treatments, ranging from 0 to 2.2 nests/ha ($F_{2,15}$ = 0.17, P = 0.85; Figure 2.4A). Average number of host eggs/nest was 3.3 eggs/nest (range 1-5; SE = 0.15) for Dickcissel and 4.1 eggs/nest (range 1-5; SE = 0.37) for Eastern Meadowlark. Both Grasshopper Sparrow nests contained four eggs. Of all nests monitored, 46.0% were parasitized by Brown-headed Cowbirds and, of parasitized nests, an average of 1.74 (range 1-4; SE = 0.15) Brown-headed Cowbird eggs were observed in the nest. Across the two years, only five parasitized nests contained Brown-headed Cowbird nestlings, with an average of 1.4 Brown-headed Cowbirds/nest (range 1-2, SE = 0.24). One nest successfully fledged two Brown-headed Cowbirds; in this nest there were no host (Dickcissel) nestlings that survived to fledging, though one hatched. Parasitism rates did not differ across treatments ($F_{2,15}$ = 0.34, P = 0.67; Figure 2.4B).

Both of the monitored Grasshopper Sparrow nests hatched but neither fledged. Apparent nest success for Grasshopper Sparrows in the incubation and nestling stages, therefore, was 100% and 0%, respectively. Of the 11 Eastern Meadowlark nests monitored, seven hatched and, of those, two fledged. Resulting nest survival during the incubation and nestling stages, was 64% and 29%, respectively. Nest survival rates during incubation and nestling stages were estimated for Dickcissels, which comprised 82% of all nests monitored (Table 2.3). The treatment model was the top ranked model for Dickcissel nests during the incubation stage, with 57.9% of the weight (Table 2.4). The null model, however, held 42.1% of the weight and had a ΔAIC_c of 0.63. These two models were considered competitive and model averaged to obtain daily nest survival estimates (Table 2.5). Estimated period survival during incubation was lowest in in Mid-Summer Fire plots (0.1136 ± 0.0488), intermediate in Late Summer Fire plots (0.1605 ± 0.0783), and greatest in Spring Fire plots (0.2507 ± 0.0803).

As was the case for the incubation stage, null and treatment models both ranked highly for the nestling stage (Table 2.4). The null and treatment models held 74 and 26% of the weight, respectively, differing in AIC_c values by 2.09. Model-averaged period survival estimates for the nestling stage were lowest in Late Summer Fire plots (0.2475 ± 0.1197), intermediate in Mid-Summer fire plots (0.2940 ± 0.1476), and greatest in Spring Fire plots (0.3402 ± 0.1177; Table 2.5).

Butterflies

A total of 684 individual butterflies within 23 taxa were detected during surveys (Table 2.6). Species evenness in Spring Fire, Mid-Summer Fire, and Late Summer Fire plots was 0.305, 0.684, and 0.631, respectively. Following guild classifications of Moranz et al. (2012), three of the species identified were grassland specialists (Regal Fritillary [*Speyeria idalia*], Great Spangled Fritillary [*S. cybele*], and Common Wood-nymph [*Cercyonis pegala*]) and the remaining 18 were generalists, as were the species complexes included within the Sulphur species group and Azure species group. The Grass Skipper group potentially included both generalist and grassland specialist species. Eastern Tailed-blues (*Cupido comyntas*) and Sulphur species were most common along transects, comprising 58.3% and 14.8% of all butterfly detections, respectively (Table 2.6). Common Wood-nymphs and Regal Fritillaries were ranked third and seventh in terms of abundance, comprising 6.1 and 2.2% of all detections, respectively. Only two Great Spangled Fritillaries were detected along transects, constituting 0.3% of all butterfly detections.

In 2015, densities of the overall butterfly community ranged from 40 to 61 butterflies/ha and were similar among treatments (χ^2_2 = 1.62, P = 0.45; Figure 2.5A). In contrast, in 2016, differences of butterfly densities in Spring Fire plots compared to Mid- and Late Summer Fire plots increased by several orders of magnitude, ranging from 5 to 187 butterflies/ha. Butterfly densities in Spring Fire plots were 3.1-fold greater than in Late Summer Fire plots ($\chi^2_1 = 3.24$, $P = 0.07$) and 35-fold greater in Spring Fire plots than Mid-Summer Fire plots ($\chi^2_1 = 5.45$, $P = 0.02$; Figure 2.5B). In both 2015 and 2016, densities of grassland specialist butterflies were similar among treatments, ranging from 3 to 12 butterflies/ha in 2015 and 3 to 8 butterflies/ha in 2016 (2015: $\chi^2_2 = 1.92$, $P = 0.38$; 2016: $\chi^2_2 = 0.35$, $P = 0.84$; Figure 2.5C, D).

Plant Community and Land Cover

Using canopy coverage measurements taken at nests and random points pooled within treatments, A MANOVA test for differences revealed no significant interaction between treatment and year ($F_{16,270} = 1.57$, $P = 0.08$). With measurements pooled between years, there was a significant treatment effect ($F_{18,174} = 2.20$, $P = 0.005$; Figure 2.6). Testing for differences in specific measurements among treatments using ANOVA tests followed by Tukey HSD revealed that proportional canopy coverage of litter was 2.8- and 1.6-fold greater in Late Summer Fire plots than Spring, and Mid-Summer Fire plots, respectively ($F_{2,145} = 5.92$; $P = 0.003$; Figure 2.6E). Height of tallest vegetation was 1.2-fold greater in Spring Fire plots than Late Summer Fire plots, whereas height of tallest vegetation in Mid-Summer Fire plots was intermediate to that in the other treatments and not significantly different than either ($F_{2,145} = 3.64$, $P = 0.03$; Figure 2.6H). Visual obstruction readings were 1.2- to 1.4-fold greater in Spring Fire plots than Mid-Summer and Late Summer Fire plots, respectively ($F_{2,145} = 5.88$, $P = 0.004$; Figure 2.6I). Proportional canopy coverage of sericea lespedeza, all forbs, grass, shrubs, or bare ground did not differ ($P > 0.05$) among treatments, nor did litter depth (Figure 2.6A-D, F, G). Basal coverage measurements differed among fire treatments ($F_{10,16} = 2.80$, $P = 0.03$) and between years ($F_{5,8} = 13.12$, $P = 0.001$), with no interaction ($F_{10,16} = 1.07$, $P = 0.44$; Figure 2.7).

Basal coverage by sericea was 5-fold greater in Spring Fire plots than in Late Summer Fire plots and a similar 2.5-fold increase in sericea in Spring Fire plots relative to Mid-Summer Fire plots was evident ($F_{2,15}$ = 4.78, P = 0.02; Figure 2.7B). Proportional basal coverage of litter was 4.9-fold greater in Mid-Summer Fire plots than Spring Fire plots and 4.4-fold greater in Late Summer Fire plots than Spring Fire plots, though the difference was marginally statistically significant ($F_{2,15}$ = 3.90, P = 0.04; Figure 2.7D). Proportional basal coverage of grass ($F_{2,15}$= 0.21, P = 0.81), forbs other than sericea ($F_{2,15}$ = 0.33, P = 0.73), and bare ground ($F_{2,15}$ = 2.92, P = 0.09) did not differ among treatments (Figure 2.7A, C, E).

A comparison of characteristics at Eastern Meadowlark nest sites compared to paired points revealed no interaction of point use (i.e., nest or unused) and year ($F_{7,12}$ = 0.68, P = 0.69) and no difference in characteristics between nest sites and paired points ($F_{7,14}$ = 1.54, P = 0.23; Table 2.7). A comparison of nest characteristics at Dickcissel nest sites compared to paired points revealed no interaction of use and year ($F_{8,111}$ = 1.29, P = 0.26), but there were differences between nest sites and paired points (Figure 2.8). At nest sites in both years, canopy coverage of grass ($F_{1,120}$ = 21.88, P < 0.001; Figure 2.8A) and bare ground ($F_{1,120}$ = 11.09, P = 0.001; Figure 2.8F) were lower whereas coverage of shrubs ($F_{1,120}$ = 21.15, P < 0.001; Figure 2.8D) and litter ($F_{1,120}$ = 3.96, P = 0.049; Figure 2.8E) were greater than at paired points. In 2016, canopy coverage of sericea was lower at nest sites than at paired points ($F_{1,78}$ = 4.88, P = 0.03; Figure 2.8C).

A total of 355 forbs and shrubs within 35 taxa were identified along transects in 2015 and 2016 (Table 2.8). Species evenness in Spring Fire, Mid-Summer Fire, and Late Summer Fire plots was 0.635, 0.763, and 0.861, respectively. Following guild classifications of Moranz (2010) and Moranz et al. (2012), three genera that were present (*Vernonia, Asclepias,* and *Sativa*) were potential nectar sources for grassland specialist species and detections of those genera constituted 17.2% of all forb and shrub detections (Table 2.7). In contrast, 18 of the plant genera that I recorded were in the same genera as species that are nectar sources for generalist butterfly species. I additionally observed eastern tailed-blues using sericea lespedeza as a nectar source. Including sericea lespedeza, 77.5% of all forb and shrub detections were species or genera potentially used by generalist butterfly species for nectar. There was not an interaction between treatment and year on abundance of generalist-serving nectar sources ($F_{2,12} = 0.16$, $P = 0.8$) but there was a marginally statistically significant treatment effect ($F_{2,15} = 3.13$, $P = 0.07$). Generalist-serving forb and shrub species were 2.0- and 2.4-fold more abundant in Spring Fire plots than in Mid- and Late-Summer Fire plots, respectively (Figure 2.9A). For specialist species-serving nectar sources, there was not an interaction between treatment and year ($F_{2,12} = 0.34$, $P = 0.72$), nor was there a treatment effect ($F_{2,15} = 1.93$, $P = 0.18$; Figure 2.9B). Although not statistically significant, mean abundance of specialist-serving nectar forbs and shubs was 3.2- and 2.7-greater in Mid- and Late Summer Fire plots, respectively, than in Spring Fire plots.

Discussion

Breeding Grassland Birds

Detection probabilities are not commonly reported in the literature, but my estimates were considerably greater than past estimates for Dickcissels, Eastern Meadowlarks, and Grasshopper Sparrows in tall-grass prairie (Jacobs et al. 2012, Hovick et al. 2014). My estimates of population densities for Dickcissels were greater, Grasshopper Sparrows were similar, and Eastern Meadowlarks were lower than estimates reported by Winter and Faaborg (1999) in Missouri tall-grass prairie. Although these density estimates suggest varying levels of habitat quality for these focal species, it is important to also consider demographic performance (Van

Horne 1983). Overall, daily nest survival rates I measured are consistent with those reported in the literature for Dickcissels, Grasshopper Sparrows, and Eastern Meadowlarks in tall-grass prairie (Churchwell et al. 2008, Frey et al. 2008, Sandercock et al. 2008, Conkling et al. 2015, Hovick and Miller 2016). Interestingly, the apparent nest densities for individual species reveal varying degrees of reliability of point-count data to indicate species-specific habitat quality.

Dickcissel

Dickcissels were present at large densities in all three treatments, Spring Fire, Mid-Summer Fire and Late Summer Fire, and had similar daily nest survival rates across treatments, indicating that, for this species, individual density was an appropriate indicator of nesting habitat quality. Dickcissels were ubiquitous at the study site, dominating point-count detections and nest samples. My finding that Dickcissel nests were placed in areas with significantly greater shrub and litter coverage and less bare ground and grass coverage than available at random is partially supported by previous studies on Dickcissel nesting habitat characteristics where a positive association of Dickcissel nests with shrubs and litter and a negative correlation with bare ground were found (Hughes et al. 1999, Jensen 1999, Winter 1999, Swengel and Swengel 2001, Churchwell 2005). My finding of a negative association with grass cover may be a result of selection for greater forb coverage, which has been reported by others (Frawley and Best 1991, Jensen 1999, Winter 1999).

In tall-grass prairie, Dickcissels are less abundant in areas managed with a combination of annual burns and livestock grazing than in areas with less intensive management, such as longer fire return intervals in combination with grazing, only annual fire, or only grazing (Rohrbaugh et al. 1999; Fuhlendorf et al. 2006; Powell 2006, 2008). The absence of grazing during the growing season on the study site considered here likely maintained litter and vegetation cover and height within a range available for Dickcissel nest sites, thus creating abundant high quality Dickcissel nesting habitat.

Eastern Meadowlark

Eastern Meadowlarks were relatively scarce on the study site, which may be due to the large territories that individuals of this species hold ($\geq$2 ha; Wiens 1969, 1971); however, densities did not approach this magnitude. Other factors deterring occupancy and nesting by Eastern Meadowlarks at this study site could be the lack of habitat features commonly associated with Eastern Meadowlark nests; for example, moderately tall and dense grass, standing dead grass, low forb to grass ratios, low shrub abundance, and shallow litter depth but enough coverage to conceal nests (Roseberry and Klimstra 1970, Wiens 1974, Rotenberry and Wiens 1980, Granfors et al. 1996, Rohrbaugh et al. 1999, Hubbard et al. 2006). These structural characteristics are created by fire return intervals of greater than one year and moderate intensity cattle grazing; a management regime that is inconsistent with the management employed on the study site considered here (Roseberry and Klimstra 1970, Wiens 1974, Skinner 1975, Rotenberry and Wiens 1980, Bock et al. 1993, Granfors et al. 1996, Rohrbaugh et al. 1999, Hubbard et al. 2006, Powell 2008). Structural heterogeneity, which is created by the fire-grazing interaction, is important for Eastern Meadowlarks, as the species requires litter depth and vegetation height sufficient to conceal nests, but place their nests in close proximity to areas with shorter and less dense vegetation, more suitable for foraging (Schroeder and Sousa 1982). My finding that vegetation characteristics at Eastern Meadowlark nests did not differ from those at paired points could be an indication that such heterogeneity was absent on the study site.

Density and nesting trends were similar across treatments and it appears that, as with Dickcissels, density was an appropriate indicator of nesting habitat quality for Eastern

Meadowlarks. However, because densities did not approach maximal levels for the species, I conclude that the study site contained moderately low abundance of high quality Eastern Meadowlark nesting habitat.

Grasshopper Sparrow

Unlike Dickcissels and Eastern Meadowlarks, I did observe an effect of fire treatment on Grasshopper Sparrow density in that Mid- and Late Summer Fire plots attracted a greater number of Grasshopper Sparrows than did Spring Fire plots. Visual obstruction was greater in Spring than Summer Fire plots, which was likely due to the growth-inducing effects of spring fire (Hulbert 1986). This outcome may help explain lower densities of Grasshopper Sparrows in Spring compared to Summer Fire plots, given that the species tends to occur in areas with low to moderate vegetation density and height, low to moderate levels of litter, and patches of bare ground (Blankespoor 1980, Rotenberry and Wiens 1980, Whitmore 1981, Arnold and Higgins 1986, Patterson and Best 1996, Jensen 1999, Sutter and Ritchison 2005, Hubbard et al. 2006, Powell 2006, Coppedge et al. 2008).

Also unlike Dickcissels and Eastern Meadowlarks, Grasshopper Sparrow density was not a reliable indicator of patch quality for the species. Although Grasshopper Sparrows were present at large densities during point-count surveys, they established relatively few nests on the study site, suggesting that the study site acted as an ecological sink. A discrepancy between Grasshopper Sparrow density and nesting is likely explained by changes in vegetative structure as the breeding season progressed. Point-count surveys were conducted early in the growing season, when vegetation was relatively short. Because no grazing occured during the growing season, vegetation became taller and denser later in the growing season, as can be seen by the 20 cm difference in average visual obstruction readings in early June compared to those from mid-

June to late July (Figure 2.10). Hubbard et al. (2006) measured characteristics at Grasshopper Sparrow nests on Fort Riley military installation in Riley, Clay, and Geary counties, Kansas and reported that Grasshopper Sparrow nest sites contained, on average, 12% bare ground, 3.6 cm litter depth, and 3.0 dm VOR. In the present study, percent bare ground ranged from 3.7% in Mid-Summer fire plots to 5.5% in Spring fire plots, less than half of what was documented at Grasshopper Sparrow nest sites by Hubbard et al. (2006). Litter depth ranged from 1.8 cm in Spring Fire plots to 3.1 cm in Late Summer Fire plots, also lower than what is typical for Grasshopper Sparrow nest sites. Additionally, average VOR was consistently greater on my study site than was reported by Hubbard et al. (2006), ranging from 3.3 dm in Late Summer Fire plots to 4.5 dm in Spring Fire plots. It is evident that Grasshopper Sparrow nesting habitat was limited, if not altogether absent on the study site from mid-June onward. This explanation is further supported by the fact that the two monitored Grasshopper Sparrow nests were located within the first two days of nest searching. Other researchers have pointed to moderate grazing as being important for creating Grasshopper Sparrow nesting habitat (Kantrud 1981, Whitmore 1981, Jensen 1999, Sutter and Ritchison 2005, Powell 2006, Coppedge et al. 2008, Powell 2008). Evidently, as with Eastern Meadowlarks, the lack of grazing during the growing season on the study site may have had a stronger influence on Grasshopper Sparrow nesting than the fire treatments.

Breeding Grassland Birds

In addition to demonstrating that the grassland songbird species considered here were unaffected or positively affected by summer fire, relative to spring fire, I have also demonstrated these species were negatively affected by sericea lespedeza. Canopy coverage by sericea lespedeza at Dickcissel nest sites was less than half of that at unused points but proportional canopy coverage by all forbs at nests was 26% greater at nests compared to paired unused points. Not only is this study one of the first to document any relationship between tall-grass prairie wildlife species and sericea lespedeza, my field study provides the first evidence that the invasion is detrimental to grassland songbird species. Without effective control, sericea will out compete cumulatively more forb plants resulting in declining quality of grassland bird nesting habitat on the landscape. Controlling sericea is important for the conservation of the tall-grass prairie ecosystem.

Butterflies

Native tall-grass prairie uninvaded by sericea lespedeza can still support a diverse butterfly community, including generalist, grassland specialist, and migrant species (Swengel 1998). Although >10% of all butterflies that I detected were grassland specialists, 99% of these individuals were of only two species: Common Wood-nymph and Regal Fritillary. Many grassland specialist butterfly species that have been recorded in Kansas tall-grass prairie were not detected (e.g., Gorgone Checkerspot [*Chlosyne gorgone*], Olympia Marble [*Euchloe olympia*], Henry's Elfin [*Callophrys henrici*]; Swengel 1998), which suggests that the study site was lacking resources, such as specific nectar sources, necessary for select grassland specialist species (Schultz and Dlugosch 1999, Rudolph 2006, Moranz 2010). The forb community was dominated by sericea lespedeza, which is evidence for a high competitive ability against native tall-grass prairie forb species and emphasizes the necessity of controlling the invasion for the benefit of grassland specialist butterfly species (Eddy and Moore 1998).

My observation of eastern tailed-blues using sericea lespedeza as a nectar source is not surprising given that this butterfly species, as well as many other generalist species, use other forb species within the genus *Lespedeza* as nectar sources (Brock and Kaufman 2003).

Generalist-serving forb species, including sericea, were at least twice as abundant in Spring Fire plots than Mid- and Late Summer Fire plots, which explains the doubling to quadrupling of butterfly densities in Spring Fire plots in 2016 that was primarily driven by eastern tailed-blues. Likewise, the doubling of grassland specialist species density in 2015 in Mid- and Late Summer Fire plots relative to Spring Fire plots is consistent with the doubling to tripling of specialist-serving forb abundance in Summer Fire plots. My results are supported by the results of many other studies that have found positive correlations between butterfly abundance and abundance of their nectar sources (e.g., Schultz and Dlugosch 1999, Rudolph 2006, Moranz 2010) Additionally, my data illustrate the importance of distinctly evaluating the abundance and richness of specialist butterfly species in assessing habitat quality. Interestingly, although relative abundance of nectar sources was consistent across years, patterns in butterfly density changed dramatically between years for the entire butterfly community and specialist species separately. Although nectar source abundance appears to have some influence on butterfly density, my results corroborate previous findings that other factors, such as abundance of host plants, are additionally influential (Moranz et al. 2012).

Maintaining forb communities with grassland specialist-serving species, thus controlling sericea lespedeza, is an obvious requisite for maintaining butterfly communities that include grassland specialist species. The use of fire to do so, however, is a contentious subject due to the uncertainty surrounding the effects of fire on different butterfly life stages and habitat guilds (e.g., Swengel 1996, 1998; Swengel and Swengel 2001; Vogel et al. 2010; Moranz et al. 2014). My study design did not address the effects of fire on the larval stage of butterflies but my results demonstrate that, relative to spring fire, summer fire is not detrimental to the adult butterfly community in tall-grass prairie. In addition, grassland specialist butterfly species may benefit from summer fire, as their nectar sources were more abundant in Summer Fire plots than Spring Fire plots. It is evident that sericea reduces habitat quality for grassland specialist butterfly species; therefore, controlling the invasion should be a priority and using summer fire to do so should be viewed favorably.

Management Implications

Fires applied in early August (i.e., Mid-Summer) and early September (i.e., Late Summer) are effective at controlling the sericea lespedeza invasion. Fires applied at these times are not detrimental to the grassland bird community nor to the butterfly community. Invasion of sericea lespedeza is reducing the availability of preferred grassland passerine nesting habitat on the landscape and reduces the availability of nectar and host plants for grassland specialist butterfly species, thus controlling the invasion is important for the native wildlife community in tall-grass prairie. Applying fire in August or September will reduce the abundance of sericea lespedeza and subsequent adoption of a patch-burn-grazing program will create structural heterogeneity and maintain biodiversity in tall-grass prairie.

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Figures and Tables

Figure 2.1 A) Outline of the continental United States of America with rectangle outlining placement of B) Kansas (green), the Flint Hills (gray), and Geary County (blue) with orange dot indicating C) the 50 ha study site where avian and butterfly densities were estimated from May to September 2015 and 2016. Black lines outline plots subjected to one of three fire treatments: Spring Fire (S), Mid-Summer Fire (M), or Late Summer Fire (L).

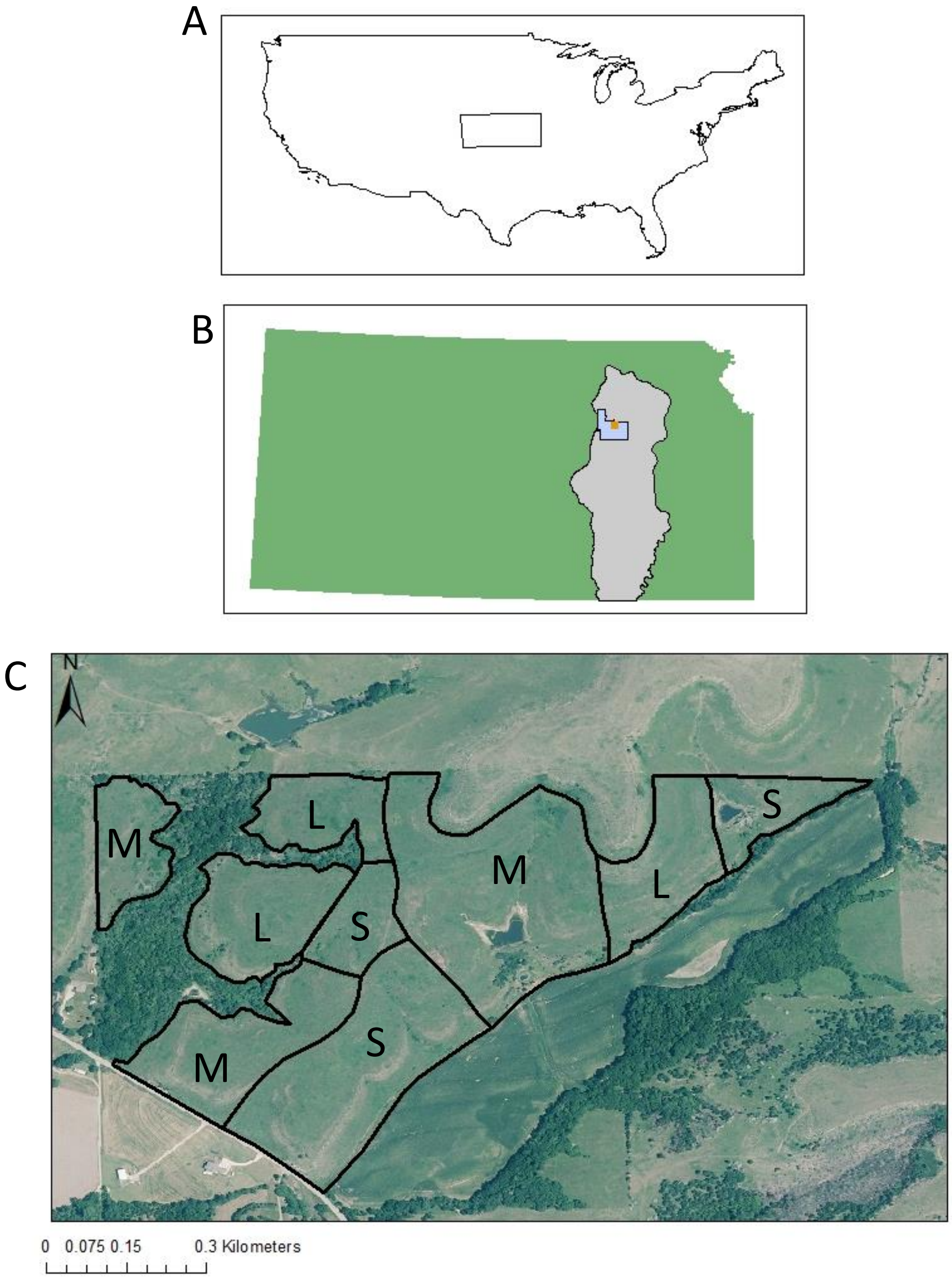
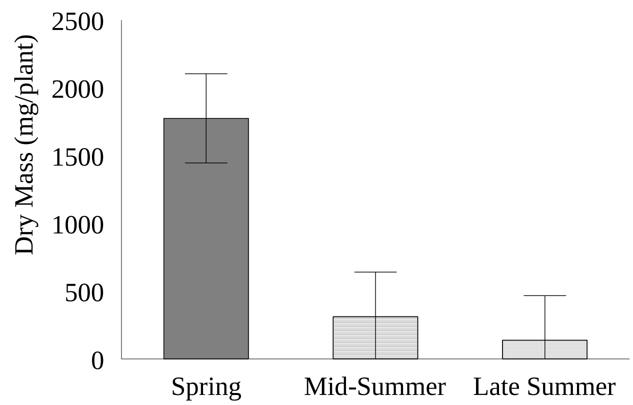
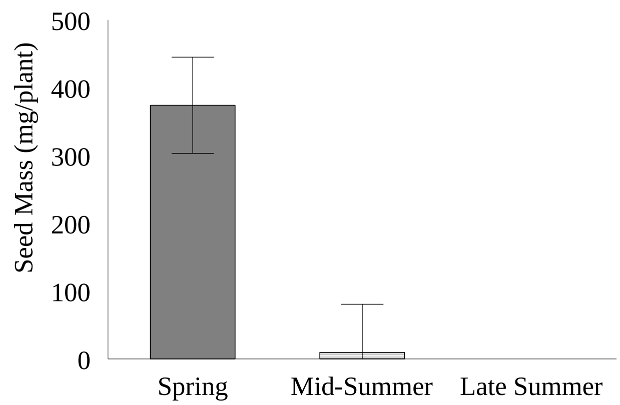


Figure 2.2 A) Average whole plant mass of sericea lespedeza (±SE), B) average seed mass of sericea lespedeza plants (±SE), and C) average number of seeds produced per sericea lespedeza plant (±SE) in 50 ha of tall-grass prairie in Geary County, Kansas. Measurements are averaged among three replicate plots within each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire). Fire treatments and data collection occurred in 2014. Data from Alexander et al. (2016).

A.



B.



C.

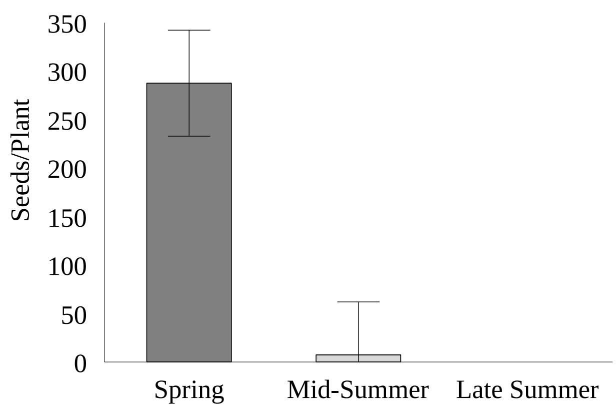


Figure 2.3 Mean bird densities ($\pm$ SE) estimated in Program Distance from 50 m radius point-count surveys conducted between mid-May and early June 2014 and 2016 in 50 ha of tall-grass prairie in Geary County, Kansas. Each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire) was applied to three replicate plots annually from 2013 to 2016. DICK = Dickcissel, GRSP = Grasshopper Sparrow, EAME = Eastern Meadowlark, BHCO = Brown-headed Cowbird. Lower case letters denote differences in density estimates ($P \leq 0.05$) among treatments for each species.

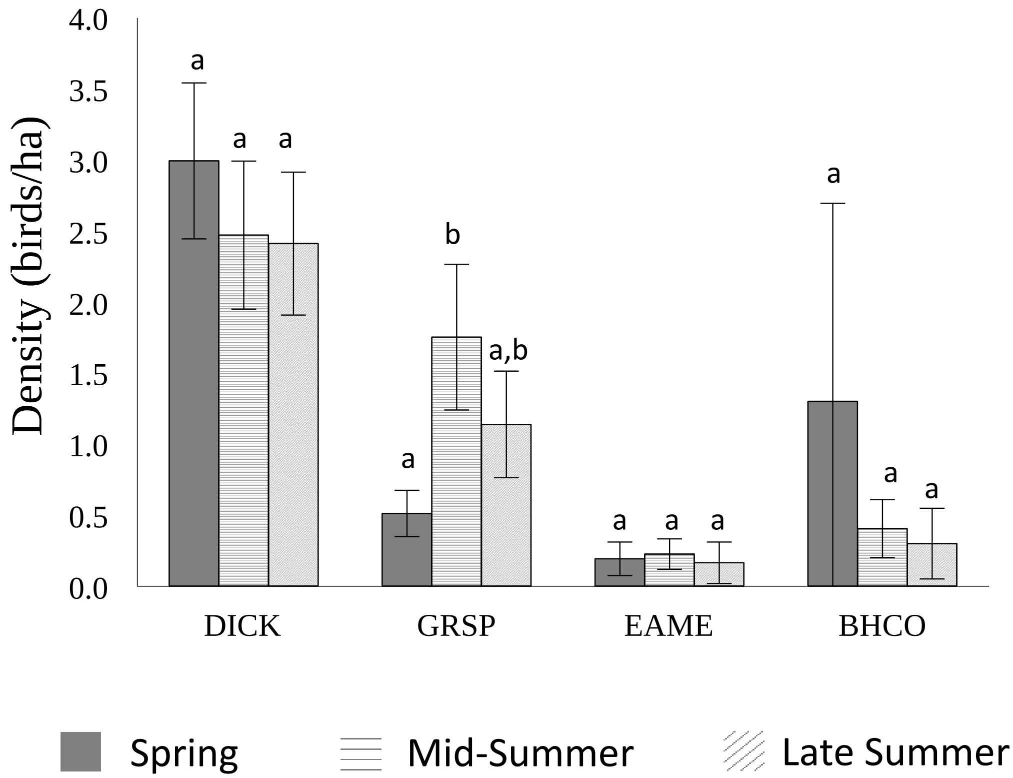
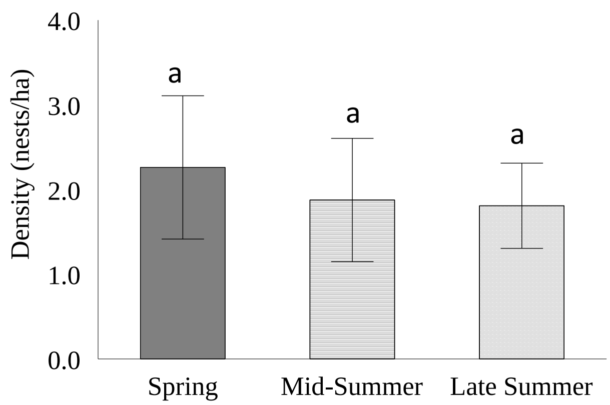


Figure 2.4 A) Average grassland nest density estimates for grassland songbirds (± SE) and B) average nest parasitism rates (± SE) by Brown-headed Cowbirds in tall-grass prairie in Geary County, Kansas. Nests were located from mid-May to mid-July 2015 and 2016. Measurements were averaged among three replicate plots within each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire). Fires were applied annually from 2014 to 2016. Treatment means with the same lower-case letter do not differ ($P \leq 0.05$).

A.



B.

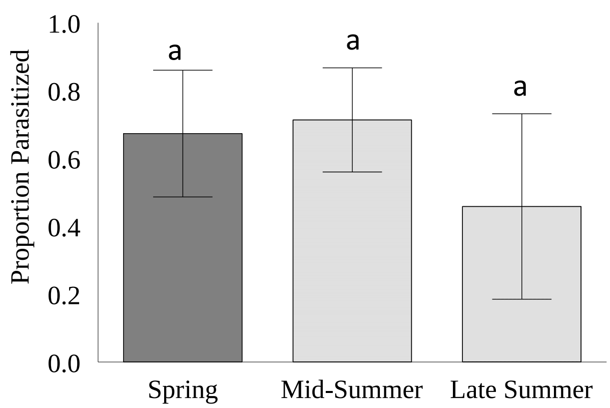


Figure 2.5 Average densities ($\pm$ SE) of A) and B) the entire butterfly community and, C) and D) only grassland specialist butterfly species during 2015 and 2016. Butterfly communities were surveyed along a 100-m transect within each of three replicate plots for each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire). Surveys were conducted once per month from June to September, 2015, and May to September, 2016, in 50 ha of tall-grass prairie in Geary County, Kansas. Fires were applied annually from 2014 to 2016. Treatment means with the same lower-case letter do not differ ($P \leq 0.05$).

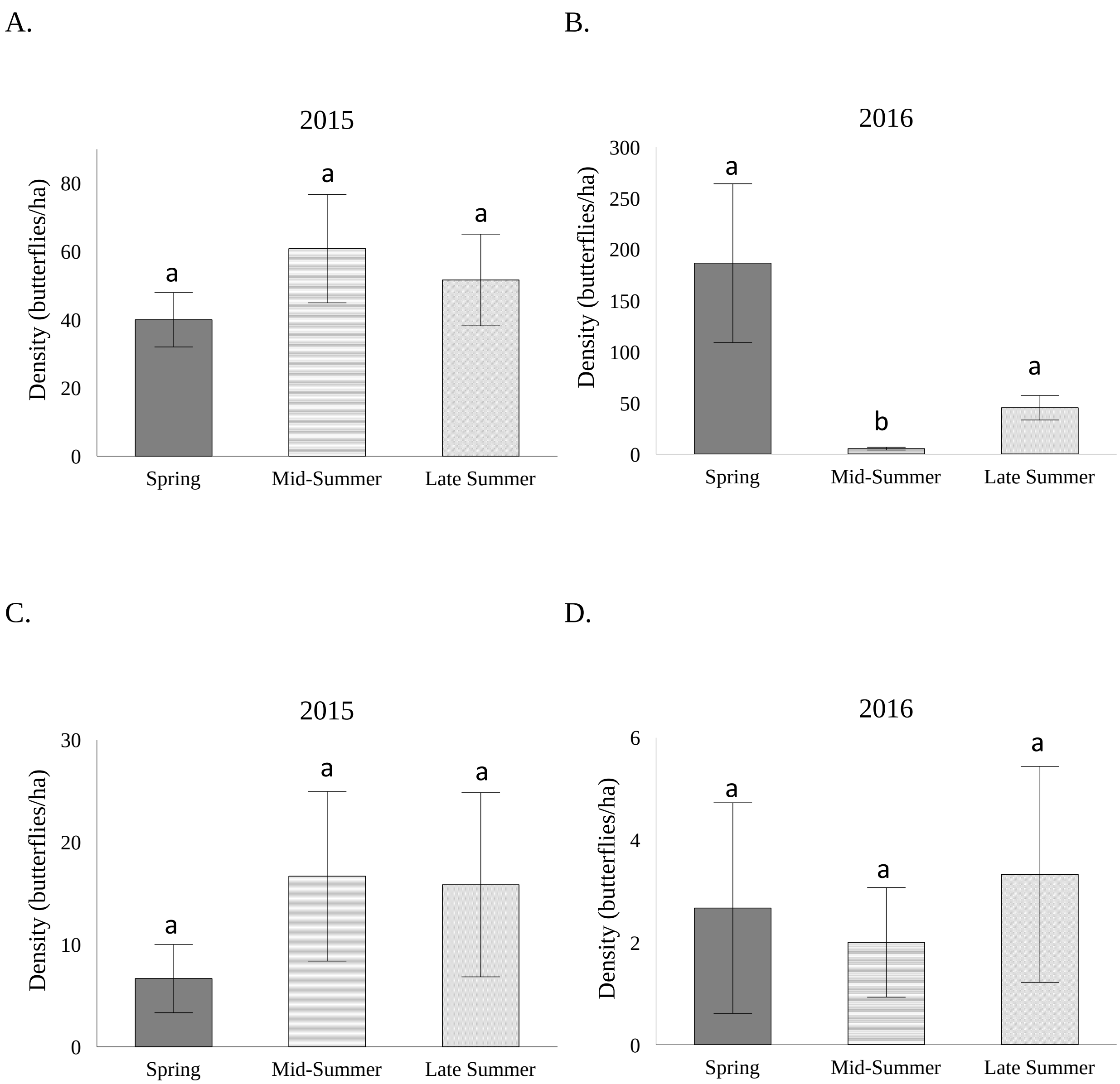
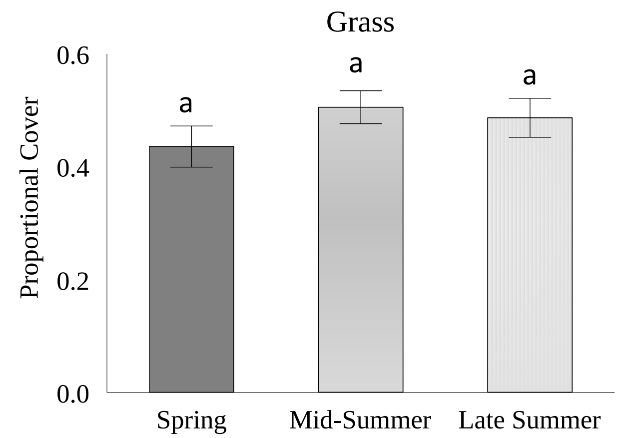
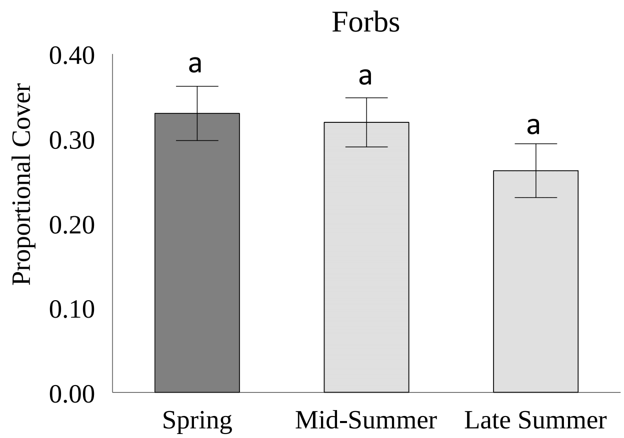


Figure 2.6 Proportional canopy cover (± SE; A-F) within a 1-m^2 Daubenmire frame, (G) litter depth (± SE), (H) height of tallest vegetation (± SE), and (I) and visual obstruction reading (± SE) as measured using a Robel pole in 50 ha of tall-grass prairie in Geary County, KS. Combined measurements taken between early June and late July 2015 and 2016 at grassland songbird nests and at nearby paired unused points averaged across three plots within each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire). Fires were applied annually from 2014 to 2016. Measurements taken in 2015 and 2016 were pooled except for proportional cover of sericea lespedeza, which was only measured in 2016. Treatment means with the same lower-case letter do not differ ($P \leq 0.05$).

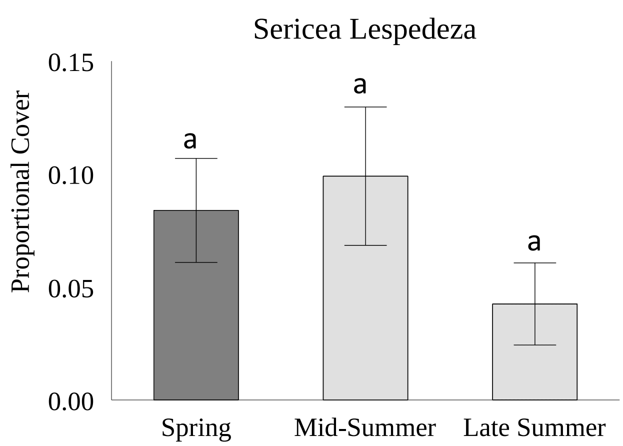
A.



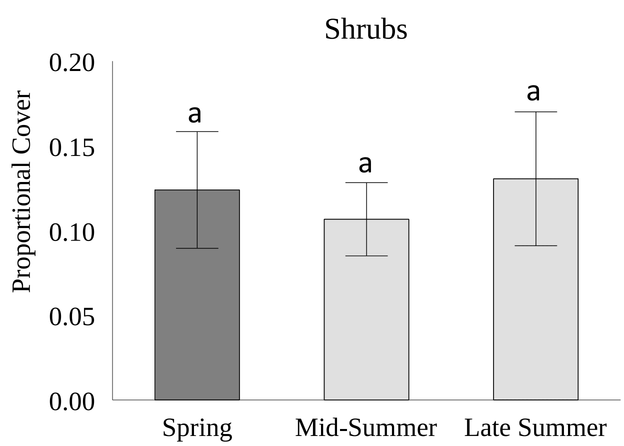
B.



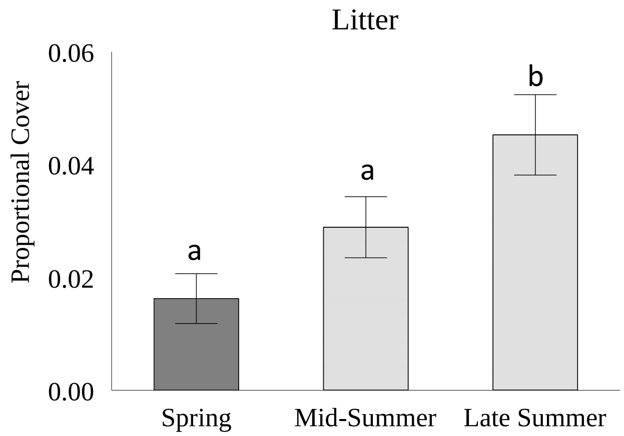
C.



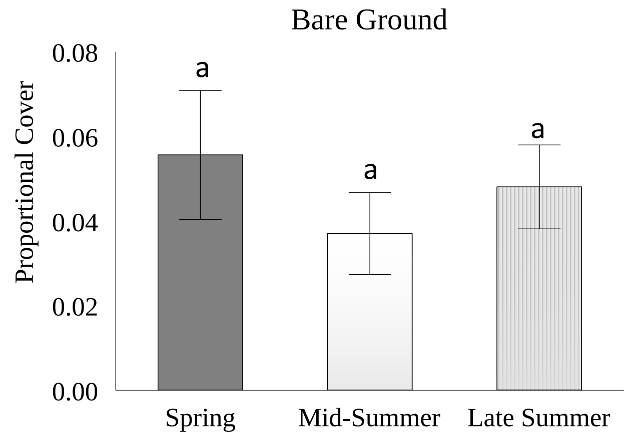
D.



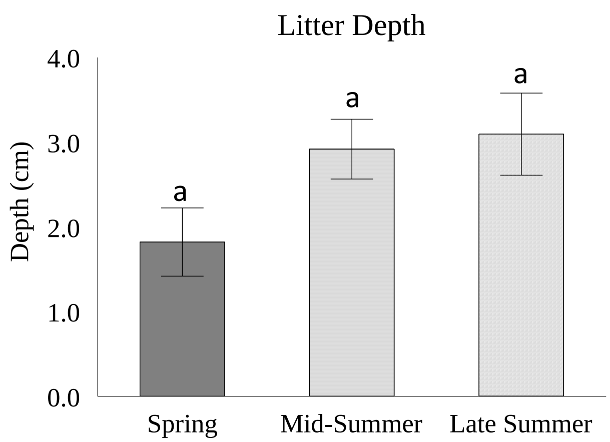
E.


Litter
Proportional Cover
0.06
0.04
0.02
0.00
a
a
b
Spring
Mid-Summer
Late Summer

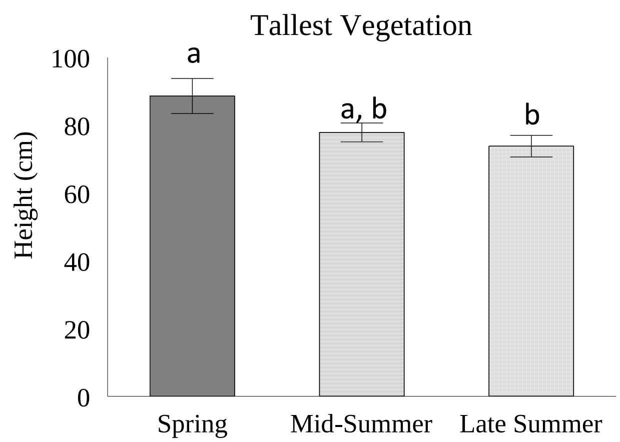
F.


Bare Ground
Proportional Cover
0.08
0.06
0.04
0.02
0.00
a
a
a
Spring
Mid-Summer
Late Summer

G.


Litter Depth
Depth (cm)
4.0
3.0
2.0
1.0
0.0
a
a
a
Spring
Mid-Summer
Late Summer

H.


Tallest Vegetation
Height (cm)
100
80
60
40
20
0
a
a, b
b
Spring
Mid-Summer
Late Summer

I.

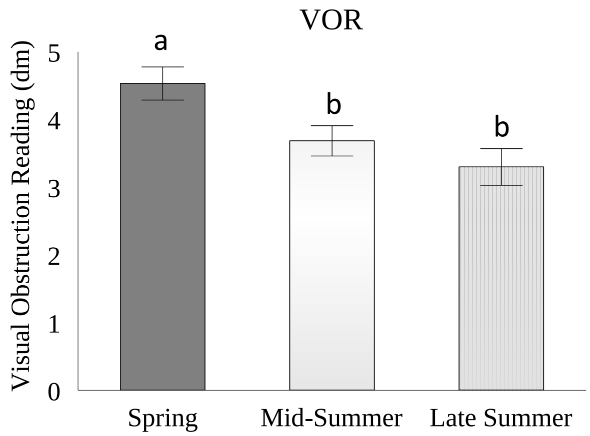
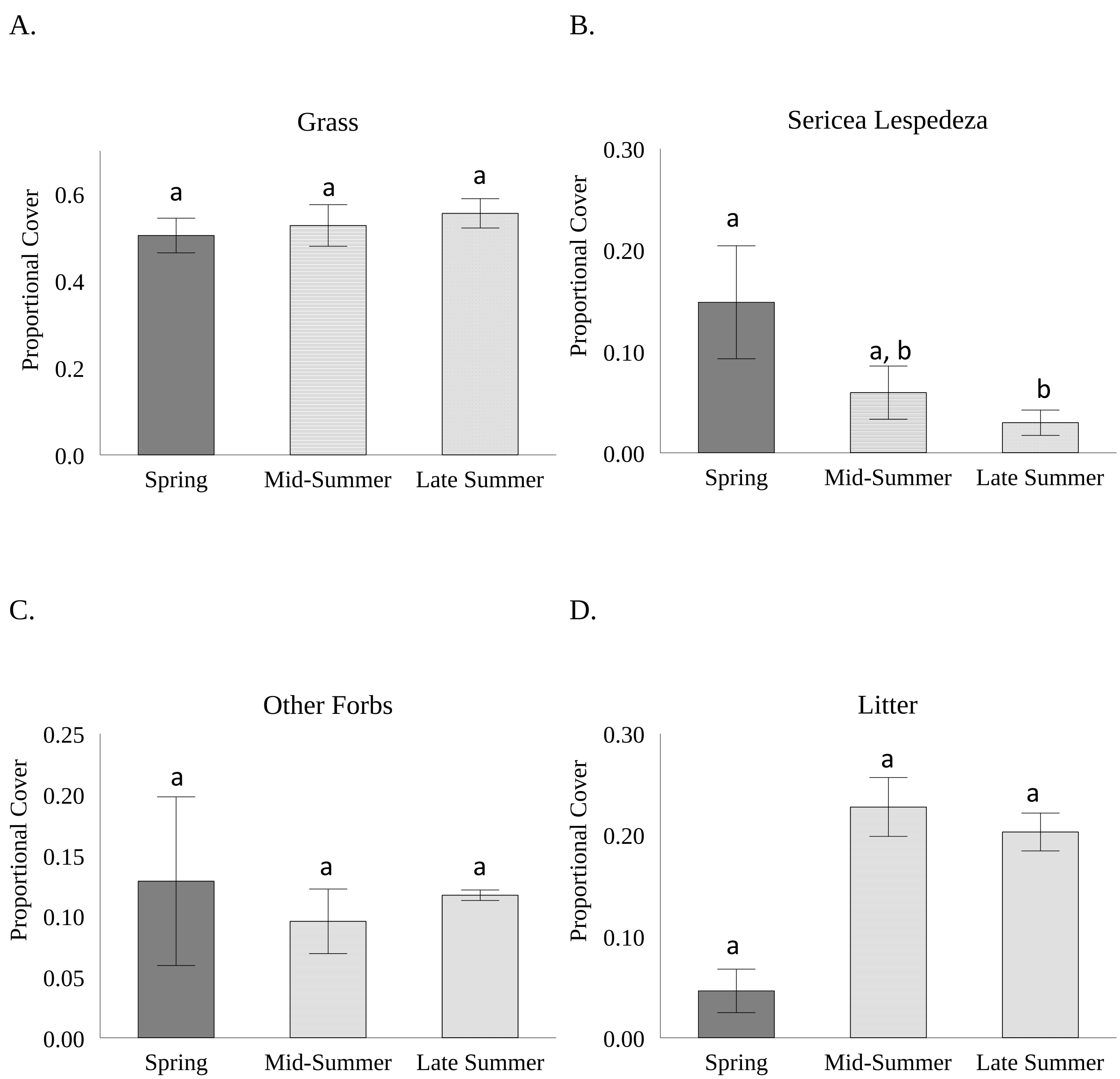

VOR
Visual Obstruction Reading (dm)
5
4
3
2
1
0
a
b
b
Spring
Mid-Summer
Late Summer

Figure 2.7 Proportional basal land cover measurements (± SE) taken along 100-m transects once per year in between mid-June and mid-July 2015 and 2016 in 50 ha of tall-grass prairie in Geary County, Kansas. Measurements averaged across three replicate plots per fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire). Fires were applied annually from 2014 to 2016. Treatment means with the same lower-case letter do not differ ($P \leq 0.05$).



E.

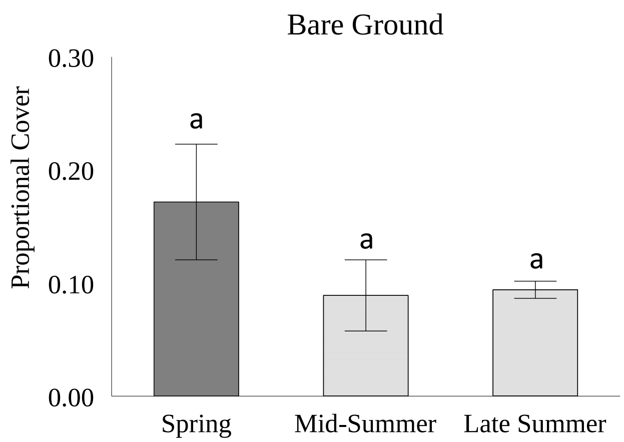
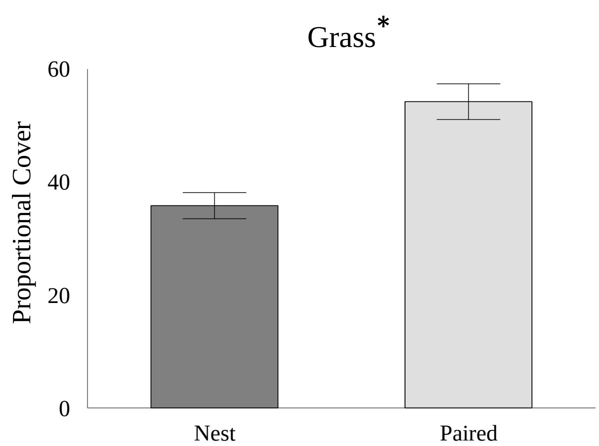
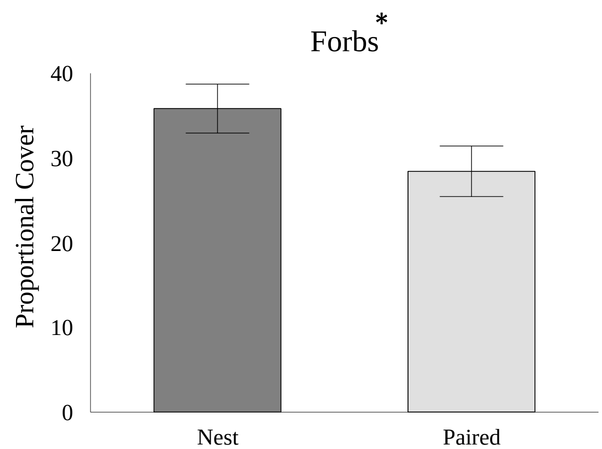

Bare Ground
0.30
0.20
0.10
0.00
Proportional Cover
a
a
a
Spring
Mid-Summer
Late Summer

Figure 2.8 Measurements of habitat conditions between Dickcissel nests and nearby paired, unused points. Proportional canopy cover (± SE; A-F) within a 1-m^2 Daubenmire frame, (G) litter depth (± SE), (H) height of tallest vegetation (± SE), and (I) and visual obstruction reading (± SE) as measured using a Robel pole in tall-grass prairie in Geary County, Kansas. Nests were located from late May to mid-July 2015 and 2016. Measurements were recorded between mid-June and late July and were pooled across all three fire treatments: Spring Fire (burned mid-April), Mid-Summer Fire (burned early August), and Late Summer Fire (burned early September). Fires were applied annually from 2014 to 2016. Measurements taken in 2015 and 2016 were pooled except for proportional cover of sericea lespedeza, which was only measured in 2016. Asterisks denote means differed between point types ($P \leq 0.05$).

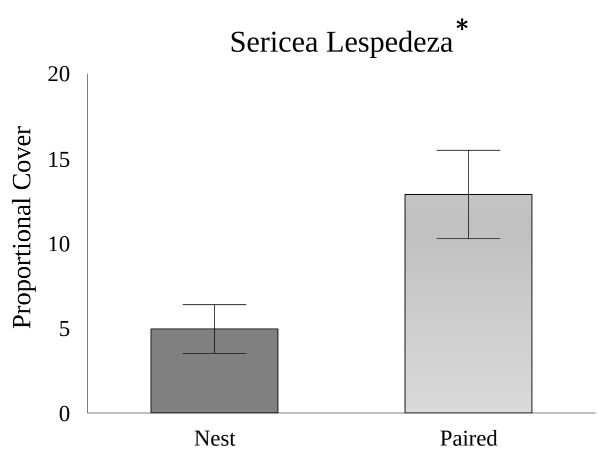
A.



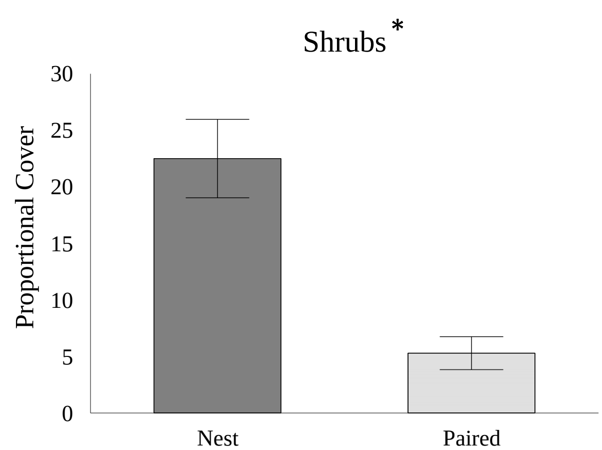
B.



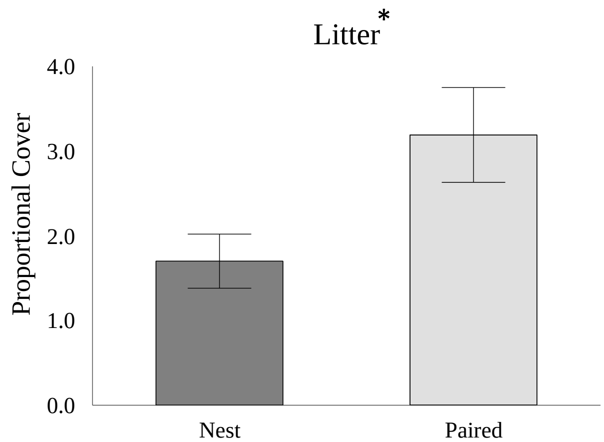
C.



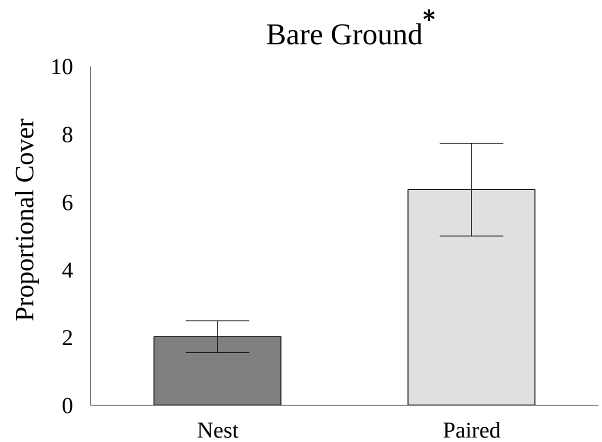
D.



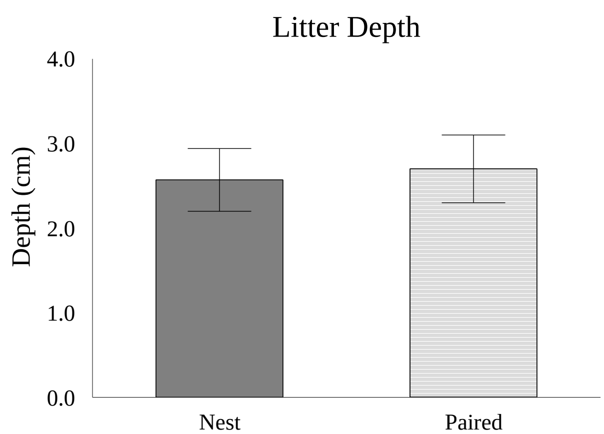
E.


Litter*
Proportional Cover
4.0
3.0
2.0
1.0
0.0
Nest
Paired

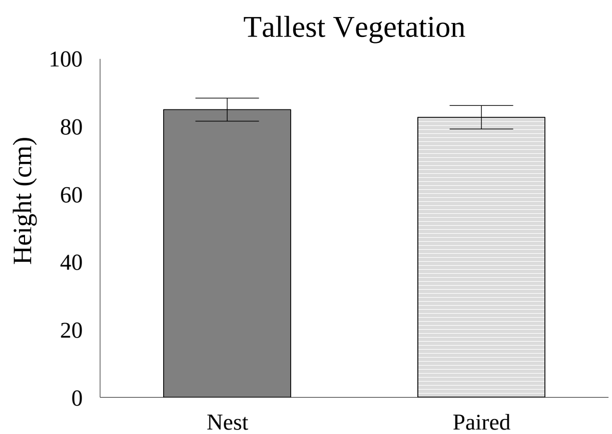
F.


Bare Ground*
Proportional Cover
10
8
6
4
2
0
Nest
Paired

G.


Litter Depth
Depth (cm)
4.0
3.0
2.0
1.0
0.0
Nest
Paired

H.


Tallest Vegetation
Height (cm)
100
80
60
40
20
0
Nest
Paired

I.

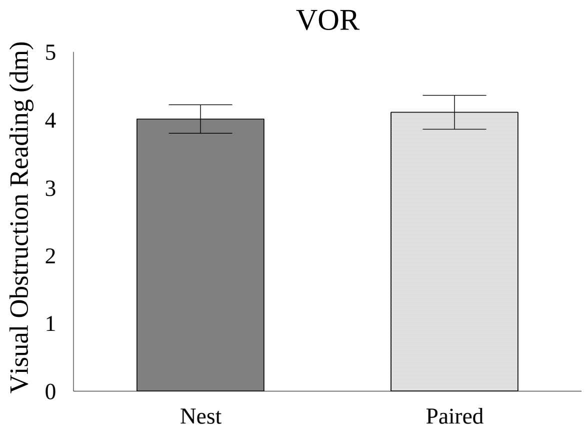
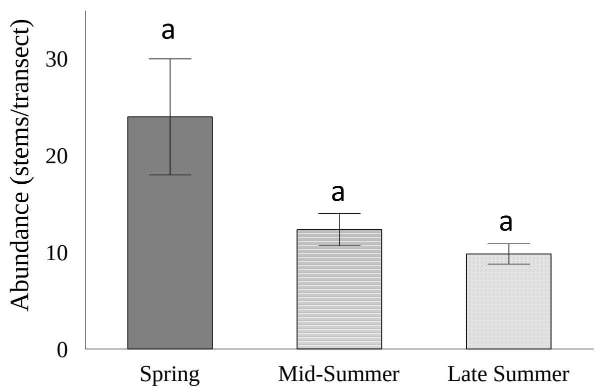


Figure 2.9 Average abundance (± SE) of nectar sources for A) all butterflies detected during surveys and, B) grassland specialist butterfly species (*Vernonia, Asclepias,* and *Sativa* spp.) recorded on 50 ha of tall-grass prairie in Geary County, Kansas during 2015 and 2016. Forb abundance was measured along a 100 m permanent transect in each plot. Each fire treatment (Spring, Mid-Summer, and Late Summer) had three replicate plots. Fires were applied annually from 2014 to 2016. Treatment means with the same lower-case letter do not differ ($P \leq 0.05$).

A.



B.

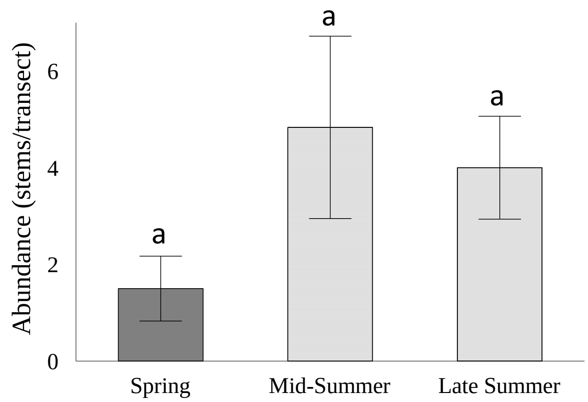


Figure 2.10 Average visual obstruction readings (VOR; ±SE) as measured using a Robel Pole in the Early Season (June 1 – 15) and Late Season (June 16 – July 31) 2015 and 2016 in tall-grass prairie in Geary County, Kansas.

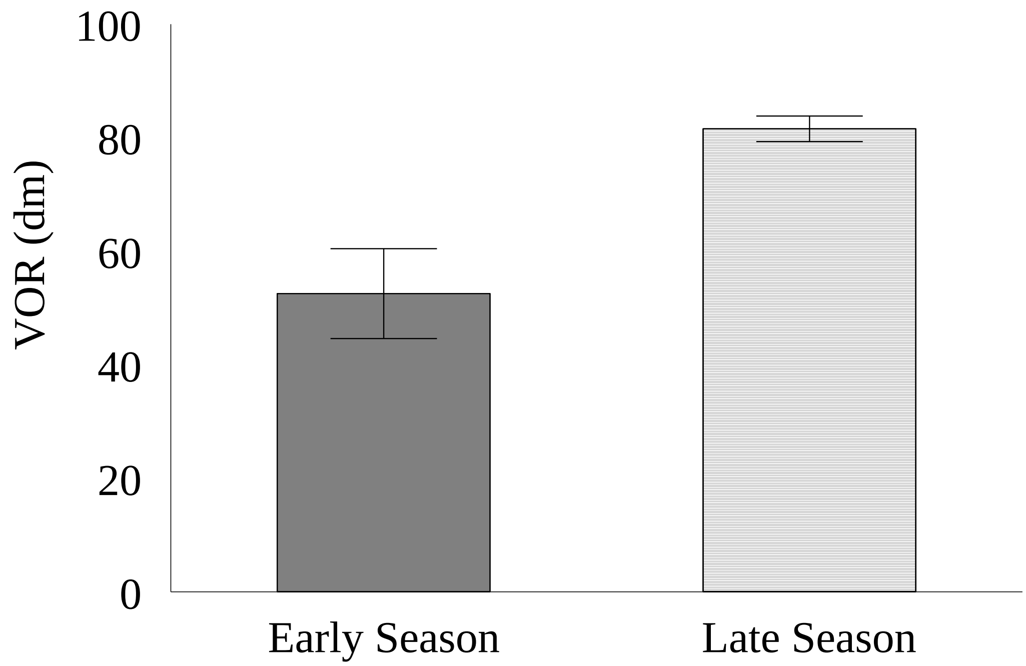


Table 2.1 Bird species recorded during point-count surveys conducted from mid-May to early June in 2015 and 2016 in 50 ha of tall-grass prairie in Geary County, Kansas. Fire treatments (Spring Fire, Mid-Summer Fire, and Late Summer Fire) were each applied to three replicated plots from 2014 to 2016.

		Number Counted				
Common Name	Scientific Name	Spring	Mid-Summer	Late Summer	Total	Proportion
Dickcissel	*Spiza americana*	262	261	162	685	0.55
Grasshopper Sparrow	*Ammodramus savanarrum*	35	149	75	259	0.21
Brown-headed Cowbird	*Molothrus ater*	67	43	20	130	0.10
Eastern Meadowlark	*Sturnella neglecta*	17	24	11	52	0.04
Barn Swallow	*Hirundo rustica*	15	25	1	41	0.03
Tree Swallow	*Tachycineta bicolor*	6	12	1	19	0.02
Eastern Bluebird	*Sialia sialis*	10	0	0	10	0.01
Eastern Kingbird	*Tyrannus tyrannus*	2	4	2	8	0.01
Ruby-throated Hummingbird	*Archilochus colubris*	4	1	2	7	0.01
Field Sparrow	*Spizella pusilla*	4	2	0	6	<0.01
Indigo Bunting	*Passerina cyanea*	2	0	4	6	<0.01
Northern Cardinal	*Cardinalis cardinalis*	0	3	2	5	<0.01
American Goldfinch	*Spinus tirstis*	3	0	1	4	<0.01
Downy Woodpecker	*Picoides pubescens*	1	3	0	4	<0.01
Red-bellied Woodpecker	*Melanerpes carolinus*	3	0	0	3	<0.01
Unidentified sparrow species	*Spizella* spp.	2	1	0	3	<0.01
Yellow-billed Cuckoo	*Coccyzus americanus*	0	3	0	3	<0.01
Eastern Phoebe	*Sayornis phoebe*	2	0	0	2	<0.01
Mourning Dove	*Zenaida macroura*	1	0	1	2	<0.01
Orchard Oriole	*Icterus spurius*	0	0	2	2	<0.01
Brown Thrasher	*Toxostoma rufum*	1	0	0	1	<0.01
Eastern Wood Pewee	*Contopus virens*	0	1	0	1	<0.01
Least Flycatcher	*Empidonax minimus*	0	1	0	1	<0.01

Table 2.2 Detection probabilities at point-count center, 95% lower confidence intervals (LCI), and 95% upper confidence intervals (UCI) for Dickcissels, Grasshopper Sparrows, Eastern Meadowlarks, and Brown-headed Cowbirds as calculated in Program Distance from 50-m radius point-count data collected from mid-May to early June in 2015 and 2016 in 50 ha of tall-grass prairie in Geary County, Kansas. Fire treatments (Spring Fire, Mid-Summer Fire, and Late Summer Fire) were each applied to three replicate plots from 2014 to 2016.

Species	Treatment	Detection Probability	LCI	UCI
Dickcissel	Spring	0.94	0.73	1.00
	Mid-Summer	1.00	0.79	1.00
	Late Summer	1.00	0.72	1.00
Grasshopper Sparrow	Spring	0.73	0.42	1.00
	Mid-Summer	0.81	0.59	1.00
	Late Summer	1.00	0.61	1.00
Eastern Meadowlark	Spring	1.00	0.34	1.00
	Mid-Summer	1.00	0.46	1.00
	Late Summer	1.00	0.27	1.00
Brown-headed Cowbird	Spring	0.55	0.10	1.00
	Mid-Summer	1.00	0.51	1.00
	Late Summer	1.00	0.41	1.00

Table 2.3 Number of nests located and monitored from late May to mid-July 2015 and 2016 in tall-grass prairie in Geary County, Kansas. Fire treatments (Spring Fire, Mid-Summer Fire, and Late Summer Fire) were each applied to three replicate plots from 2014 to 2016.

Treatment	Species	2015 Nests	2016 Nests	Total Nests
Spring Fire	Dickcissel	9	11	20
	Eastern Meadowlark	1	2	3
	Grasshopper Sparrow	0	1	1
Mid-Summer Fire	Dickcissel	8	17	25
	Eastern Meadowlark	3	3	6
	Grasshopper Sparrow	0	1	1
Late-Summer Fire	Dickcissel	4	12	16
	Eastern Meadowlark	0	2	2
	Grasshopper Sparrow	0	0	0

Table 2.4 Rankings of competing models of Dickcissel nest survival for Dickciseels within the incubation and nestling stages. Nests were located in a 50 ha grassland in Geary County, Kansas tall-grass prairie from late May to mid-July 2015 and 2016. Each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire) were each applied to three replicate plots annually from 2014 to 2016.

Stage	Model	Dev.[a]	K[b]	ΔAIC_c[c]	w_i[d]
Incubation	Treatment[e]	158.8	3	0.0[i]	0.58
	Null[f]	163.5	1	0.6	0.42
	Day[g]	125.5	36	44.3	0.00
	Treatment*Day[h]	84.7	72	118.1	0.00
Nestling	Null	53.6	1	0[j]	0.74
	Treatment	51.5	3	2.1	0.26
	Day	31.1	27	53.8	0.00
	Treatment*Day	13.9	52	211.2	0.00

a. Deviance

b. Number of parameters

c. Difference in Akaike's Information Criterion corrected for small sample size

d. Akaike weight

e. Estimates daily nest survival for each fire treatment (i.e., Spring Fire, Mid-Summer Fire, and Late Summer Fire)

f. Estimates daily nest survival disregarding any grouping or time

g. Estimates daily nest survival for each day within the nesting period

h. Estimates daily nest survival considering an interaction between treatment and day of nesting period.

i. Minimum AIC_c = 164.85

j. Minimum AIC_c = 55.65

Table 2.5 Period survival estimates (±SE) and model-averaged daily survival rate (DSR) estimates (±SE) for Dickcissel nests within the incubation and nestling stages in each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire). Nests were located in 50 ha of tall-grass prairie in Geary County, Kansas, from late May to mid-July 2015 and 2016. Each fire treatment was applied to three replicate plots annually from 2014 to 2016.

		Incubation	Nestling
Spring Fire	Period Survival	0.2507	0.3402
	Period SE	0.0803	0.1177
	DSR	0.8911	0.8871
	DSR SE	0.0238	0.0341
Mid-Summer Fire	Period Survival	0.1136	0.2940
	Period SE	0.0488	0.1476
	DSR	0.8342	0.8728
	DSR SE	0.0299	0.0487
Late Summer Fire	Period Survival	0.1605	0.2475
	Period SE	0.0783	0.1197
	DSR	0.8586	0.8563
	DSR SE	0.0349	0.0460

Table 2.6 Butterfly species identified during transect surveys conducted from June to September in 2015 and May to September in 2016. Study site consists of 50 ha of tall-grass prairie in Geary County, Kansas. Each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire) were each applied to three replicate plots annually from 2014 to 2016.

		Number Counted				
Common Name	Scientific Name	Spring	Mid-Summer	Late Summer	Total	Proportion
Eastern Tailed-blue[g]	*Cupido comyntas*	275	56	68	399	0.58
Sulphur spp.[g]	*Colias* spp. and *Nathali iole*	18	73	10	101	0.15
Common Wood-nymph[s]	*Cercyonis pegala*	10	12	20	42	0.06
Variegated Fritillary[g]	*Euptoieta claudia*	4	26	6	36	0.05
Grass Skipper spp.[g,s]	Family Hesperiidae, subfamily Hesperiinae	4	18	8	30	0.04
Monarch[g]	*Danaus plexippus*	2	14	3	19	0.03
Regal Fritillary[s]	*Speyeria idalia*	2	11	2	15	0.02
Pearl Crescent[g]	*Phyciodes tharos*	4	0	2	6	0.01
Cabbage White[g]	*Pieris rapae*	3	2	0	5	0.01
Gray Hairstreak[g]	*Strymon melinus*	4	1	0	5	0.01
Painted Lady[g]	*Vanessa cardui*	0	5	0	5	0.01
Common Sootywing[g]	*Pholisora catullus*	1	0	3	4	0.01
Silvery Checkerspot[g]	*Chlosyne nycteis*	1	1	1	3	<0.01
American Lady[g]	*Vanessa virginiensis*	1	0	1	2	<0.01
Black Swallowtail[g]	*Papilio polyxenes*	0	1	1	2	<0.01
Red Admiral[g]	*Vanessa atalanta*	0	1	1	2	<0.01
Great Spangled Fritillary[s]	*Speyeria cybele*	0	0	2	2	<0.01
Azure spp.[g]	*Celastrina* spp.	0	1	0	1	<0.01
Common Checkered Skipper[g]	*Pyrgus communis*	0	1	0	1	<0.01
Eastern Tiger Swallowtail[g]	*Papilio glaucus*	0	1	0	1	<0.01
Giant Swallowtail[g]	*Papilio cresphontes*	0	1	0	1	<0.01
Hoary Edge[g]	*Achalarus lyciades*	1	0	0	1	<0.01
Little Wood Satyr[g]	*Megisto cymela*	0	1	0	1	<0.01

g = Generalist species

s = Grassland specialist species

Table 2.7 Mean ($\overline{\boldsymbol{x}}$), standard errors, *F* statistic, and *P*-value (resulting from ANOVA on arcsin-transformed proportions) of vegetation and land-cover measurements taken at Eastern Meadowlark nests (Used) and paired, unused points (Unused) in tall-grass prairie in Geary County, Kansas. Nests were located from late May to mid-July 2015 and 2016. Measurements were recorded between mid-June and late July and were averaged within treatments (Spring Fire, Mid-Summer Fire, Late Summer Fire) applied annually from 2014 to 2016.

	Used		Unused			
Measurement	Used $\overline{x}$	SE	Unused $\overline{x}$	SE	F_1	$P\leq$
Grass	59.77	5.64	65.23	6.09	0.34	0.567
Forbs	31.32	4.72	21.82	3.76	2.59	0.123
Sericea lespedeza	3.86	1.72	4.29	1.83	0.01	0.934
Shrubs	1.36	1.36	3.41	3.41	0.12	0.738
Litter	4.55	1.65	4.32	1.82	0.06	0.810
Bare ground	1.41	0.63	5.23	1.86	3.41	0.798
Litter depth	2.66	0.71	2.90	0.73	0.06	0.816
Tallest vegetation	64.78	7.01	70.79	6.02	0.42	0.523
VOR	3.02	0.30	3.36	0.53	0.32	0.580

a. Proportional canopy coverage as measured within a 1-m^2 Daubenmire frame centered on the nest or unused point

b. Measured in cm at the north-western corner of a 1-m^2 Daubenmire frame centered on the nest or unused point

c. Measured in cm within a 1-m^2 Daubenmire frame centered on the nest or unused point

d. 100% Visual Obstruction Reading, averaged among measurements at 4 cardinal directions, measured in dm using a Robel Pole centered on the nest or unused point and read from a distance of 4 m at a height of 1 m

Table 2.8 Forb and shrub plants identified to genus or species along permanent 100-m transects surveyed once per year between mid-June and mid-July 2015 and 2016. Study site consists of 50 of tall-grass prairie in Geary County, Kansas. Each fire treatment (Spring Fire, Mid-Summer Fire, and Late Summer Fire) were each applied to three replicate plots annually from 2014 to 2016.

		Number Counted				
Common Name	Scientific Name	Spring Fire	Mid-Summer Fire	Late Summer Fire	Total	Proportion
Sericea lespedeza[g]	*Lespedeza cuneata*	90	36	18	144	0.41
Ironweed[s]	*Vernonia* spp.	15	13	11	39	0.11
White sage[g]	*Salvia apiana*	10	4	11	25	0.07
Common ragweed	*Ambrosia artemisiifolia*	8	4	7	19	0.05
Leadplant[g]	*Amorpha canescens*	3	5	9	17	0.05
Spanish needles	*Bidens alba*	12	2	2	16	0.05
Buckbrush[g]	*Ceanothus cuneatus*	7	6	2	15	0.04
Smooth sumac[g]	*Rhus glabra*	5	2	5	12	0.03
Wavy-leaf thistle	*Cirsium undualtum*	1	4	3	8	0.02
Scurfy pea	*Psoralidium tenuiflorum*	0	4	3	7	0.02
Grooved flax[g]	*Linum sulcatum*	0	2	3	5	0.01
Wild alfalfa[g]	*Medicago sativa*	3	0	2	5	0.01
White clover[g]	*Trifolium repens*	1	0	4	5	0.01
False boneset	*Brickellia eupatorioides*	0	3	1	4	0.01
Ashy sunflower[g]	*Helianthus mollis*	3	0	0	3	0.01
Prairie Petunia[g]	*Ruellia humilis*	3	0	0	3	0.01
Crown vetch	*Securigera varia*	0	0	3	3	0.01
Green antelopehorn milkweed[s]	*Asclepias verticillata*	2	0	0	2	0.01
Corn gromwell	*Buglossoides arvensis*	0	2	0	2	0.01
New Jersey tea[g]	*Ceanothus americanus*	1	0	1	2	0.01
Purple prairie clover[g]	*Dalea purpurea*	0	1	1	2	0.01
Horseweed[g]	*Erigeron canadensis*	0	0	2	2	0.01

Toothed spurge[g]	*Euphorbia dentata*	2	0	0	2	0.01
Narrowleaf bluet	*Houstonia longifolia*	1	1	0	2	0.01
Pinnate tansymustard	*Descurainia pinnata*	0	0	1	1	<0.01
Daisy fleabane[g]	*Erigeron strigosus*	0	1	0	1	<0.01
Wild licorice	*Glycyrrhiza lepidota*	1	0	0	1	<0.01
Pepppergrass	*Lepidium virginicum*	0	0	1	1	<0.01
Black medick[g]	*Medicago lupulina*	0	1	0	1	<0.01
Yellow wood sorrel	*Oxalis stricta*	0	0	1	1	<0.01
Carolina horsenettle[g]	*Solanum carolinense*	0	1	0	1	<0.01
Smoothseed wildbean	*Strophostyles leiosperma*	0	1	0	1	<0.01
Red clover[g]	*Trifolium pratense*	0	1	0	1	<0.01
Moth mullein	*Verbascum blattaria*	0	0	1	1	<0.01
Speedwell	*Veronica* spp.	0	0	1	1	<0.01

g = Species within the genus documented as a nectar source for generalist butterfly species by Moranz (2010) and Moranz et al. 2012

s = Species within the genus documented as a nectar source for grassland specialist butterfly species by Moranz (2010)

Chapter 3 - Grassland Bird and Butterfly Response to Sericea Control Using Livestock Grazing

Introduction

North American grasslands, including short-grass, mixed-grass, and tall-grass prairies, are examples of ecosystems whose persistence depend on frequent disturbances (Hobbs and Huenneke 1992). Prior to European settlement, ecological disturbances existed in the form of fires ignited by lightning and Native Americans and preferential grazing by bison (*Bison bison*) on the nutritious regrowth (Mack and Thompson 1982, Anderson 1990). As homesteaders populated the Great Plains, converting native prairie to agricultural fields and eventually urban centers, bison were functionally extirpated and fire was largely suppressed (Umbanhowar 1996, Freese et al. 2007). In some areas, cattle grazing replaced bison grazing but, for the most part, if an area was amenable to row-crop agriculture, this more profitable practice was implemented (Luaenroth et al. 1999, Askins et al. 2007). Parcels of grassland converted to row-crop agriculture have vegetation communities with little resemblance to native prairie; each parcel converted to row-crop agriculture contributes to the reduction in grassland area and fragmentation of remaining prairie (Luaenroth et al. 1999, Peterjohn 2003, Askins et al. 2007, Matson et al. 2007).

Of the three types of North American grassland, the tall-grass prairie ecosystem is the most endangered, having been reduced to ~4% of its pre-European settlement extent due to its highly fertile soils (Samson and Knopf 1994, Askins et al. 2007). The largest continuous extent of the remaining tall-grass prairie exists in the Flint Hills ecoregion, extending from northeastern Kansas to north-central Oklahoma (Figure 3.1). The ecoregion is named for its flint and limestone substrate, which makes it unsuitable for row-crop agriculture and thus, has been spared the plow in favor of cattle grazing (Anderson and Fly 1955). Unlike plant communities in row-crop agricultural fields, vegetation communities in cattle-grazed pastures can be similar to that of native tall-grass prairie, making them immensely valuable to conservation of native wildlife (Fuhlendorf and Engle 2001, 2004). Several wildlife species of conservation concern are dependent on the tall-grass prairie including Greater Prairie-chicken (*Tympanuchus cupido*; BirdLife International 2015), Dickcissel (*Spiza americana*; Sauer et al. 2014), Grasshopper Sparrow (*Ammodramus savanarrum*; Sauer et al. 2014), Regal Fritillary (*Speyeria idalia*; Selby 2007), and Ottoe Skipper (*Hesperia ottoe*; Selby 2005).

Managing grasslands for cattle production versus conservation of native wildlife populations presents unique challenges and can sometimes be divisive among ranching and environmental steward interest groups. There are, however, management decisions upon which the two groups largely agree. For example, sericea lespedeza (*Lespedeza cuneata*; hereafter sericea) is an invasive forb species capable of reducing the abundance of native grasses and forbs in tall-grass prairie by up to 92% and needs to be controlled for the benefit of the ranching community and conservation of the tall-grass prairie (Eddy and Moore 1998). Sericea has high concentrations of condensed tannins that, in addition to making it unpalatable to cattle, if consumed, may bind with proteins, reducing digestibility of complex carbohydrates (Donnelly and Anthony 1970, Cope and Burns 1971). Reduced carrying capacity of pastures results in reduced income for cattle producers, making it a high priority to control any sericea invasion. For wildlife managers, there is little empirical evidence to draw on regarding the effect of sericea lespedeza on native grassland wildlife species, but it is expected that sericea-invaded grasslands, with reduced abundance of invertebrates and native plants, provide lower quality habitat for grassland obligate wildlife species (Eddy and Moore 1998, Brooke et al. 2016). The effect of the sericea invasion on wildlife survival and recruitment is an area of research that deserves more attention, but in the absence of such information, the most responsible course of action is to proceed under the assumption that the invasion is harmful to native wildlife species.

The decision to take action against the spread of sericea lespedeza may be straightforward but achieving such a goal is a challenge, particularly in the Flint Hills ecoregion. Broad-spectrum herbicide application, besides being expensive and targeting beneficial native forbs, results in incomplete coverage due to the rocky terrain of the Flint Hills and the robust nature of the canopy (Eddy et al. 2003). Prescribed fire applied during spring is often used in the Flint Hills to control woody encroachment and spread of invasive species. Sericea lespedeza, however, as a warm-season forb is not vulnerable to spring fires, but fire applied later in the growing season is effective at controlling the invasion (Alexander et al. 2016, Chapter II).

Cattle production is the most common agricultural practice in the Flint Hills and grazing is often used as a land management tool (Fuhlendorf and Engle 2004). The unpalatability and indigestibility of sericea by cattle not only presents a challenge to land management, it has economic consequences for livestock producers in the Flint Hills. Grazing by tannin-tolerant herbivores, however, is a viable option for sericea lespedeza control. Hart (2001) demonstrated that goats can develop a preference for sericea and selectively forage on the species. Using a combination of steer and sheep grazing, Lemmon et al. (2016) demonstrated that additional herbivory by sheep reduces sericea lespedeza whole plant dry mass, number of seeds produced, and seed mass compared to grazing by steer only (Figure 3.2). Although these are encouraging results for land managers, before promoting the use of additional herbivory by tannin-tolerant herbivores for controlling sericea lespedeza, it is important to understand how the native wildlife communities are affected by such a practice. In cooperation with Lemmon et al. (2016) who focused on sericea performance, I assessed responses by grassland nesting songbirds and prairie butterflies to a combination of steer and sheep grazing compared to grazing by steers only. Specifically, I estimated grassland songbird density and daily nest survival in both treatments and compared species composition and density of butterflies between treatments. Additionally, I measured vegetation and land-cover characteristics in both treatments with the aim of explaining patterns revealed for the avian and butterfly communities.

Methods

Study Site

The study site consisted of 248 ha of sericea lespedeza-invaded tall-grass prairie in Woodson County, Kansas, on the Bressner Pasture leased by the Department of Animal Science and Industry, Kansas State University, within the central portion of the Flint Hills ecoregion (37°51'51.89”N; 95°47’38.20”W; Figure 3.1). A riparian zone was located in the middle of the study site, the majority of which was fenced off from livestock access. Mean daily high temperature during the growing season from March through September in Yates Center, Kansas, (6 km NE of the study site) ranges from 13.5 to 31.4° C. Mean daily high temperatures in 2015 and 2016 ranged from 15.4 to 32.1° C and 17.8 to 32.3° C, respectively (www.usclimatedata.com). Historical mean precipitation in Woodson County, Kansas, from March to September is 810 mm. In 2015 and 2016, from March to September, precipitation totaled 591 mm and 501 mm, respectively (mesonet.k-state.edu).

The study site was divided into eight plots (31 $\pm$ 3.6 ha), each randomly assigned to one of two treatments: early-season grazing by steers only (Steer; control) and early-season grazing by steers followed by late-season grazing by sheep (Steer+Sheep; Figure 3.1). The entire area was annually burned in early April and yearling steers (1.1 ha/steer) were stocked on all eight plots from mid-April to mid-July. In July, steers were removed from all units. From early August to early October, mature ewes (0.2 ha/sheep) were stocked on the four Steer+Sheep plots and the Steer plots were rested. These treatments were applied annually from 2013-2016.

Breeding Grassland Birds

I assessed grassland bird density using double observer fixed-radius point-count surveys with distance sampling (Buckland et al. 2001). Point-count surveys were conducted during two four-day bouts separated by five days from mid-May to early June in 2015 and 2016. Point-counts were conducted between first light and 11:00 hours on mornings with no precipitation, wind ≤32 kph, and good visibility. I selected point-count locations first by superimposing a maximal number of 100-m radius circles over the study site, each circle being contained within one grazing plot. I then superimposed a maximal number of 50-m radius circles between 100-m radius circles. For each bout, I randomly selected three point-count stations in each plot to survey. In both 2015 and 2016, I surveyed 16, 50-m and 32, 100-m radius point-count stations. Each morning, among the 24 randomly selected point-count stations, a random start point was generated and subsequent order was based on nearest-neighboring point-count stations. The point-count period began with a two-minute acclimation period, followed by five minutes of survey in which two independent observers recorded the species of each bird detected by sight or sound within the survey area. The distance from the observer to each bird was measured with a Leica Rangemaster CRF 1000-R rangefinder. Following each five-minute survey, the two observers compared detections and arrived at a consensus regarding the number of individuals of each species within the survey area and the distance from the point-count center to each individual.

Nest searching was targeted at Eastern Meadowlarks (*Sturnella neglecta*), Grasshopper Sparrows (*Ammodramus savanarrum*), and Dickcissels *(Spiza americana*), as these were the most common grassland nesting songbirds in the area. I located nests via rope dragging, following females to their nests, and serendipitous flushing from late May to late July in 2015 and 2016. In 2015, a 500-m x 180-m area in each plot was searched via rope dragging one time between early and late June. In 2016, each plot was searched via rope dragging five times for 45-minute bouts, passing over any areas that appeared to be potential nesting habitat for any of the three focal grassland nesting species, with the intention of covering the majority of each unit. Upon locating a nest, I recorded nest location in Universal Transverse Mercator (UTM) units using a handheld Global Positioning System (GPS) device and marked each nest using flagging 5 m north and south of the nest. I recorded nest contents (number of host eggs and presence and number of parasitic Brown-headed Cowbird [*Molothrus ater*] eggs or chicks) and candled eggs to estimate days since incubation started. I monitored each nest every two to three days until it was determined to have failed or the chicks to have fledged (defined as chicks leaving the nest).

Butterflies

I surveyed the butterfly (Order Lepidoptera) community using a modified Pollard walk method (Pollard 1977). Surveys were conducted along permanent 100-m transects between 09:00 and 18:00 hours on days with no precipitation, winds $\leq$24 kph, and good visibility. Each of the eight plots in the study site contained four permanent 100-m transects and I surveyed each transect mid-month from June to September in 2015 and May to September in 2016. All butterflies detected within 5 m of either side of each transect and within 15 m above the ground were recorded and identified to species or lowest possible taxonomic level. Orange, Clouded, and Dainty Sulphur butterfly species (*Colias eurytheme*, *C. philodice*, and *Nathalis iole*) were difficult to distinguish without capture and were combined as Sulphur species. Likewise, due to difficulty of distinguishing without capture, Spring and Summer Azures (*Celastrina ladon* and *Celastrina neglecta*) were combined as Azure species; and all species within the Grass Skipper subfamily (Family Hesperiidae, subfamily Hesperiinae) were combined as Grass Skipper species. I averaged detections among transects within plots, then averaged detections within treatments.

Plant Community and Land Cover

I measured canopy land cover at each monitored grassland songbird nest and a random-paired unused point 5 m away from the nest. Measurements were made one day post-fledging or anticipated fledge date if the nest had failed. Between early June and late July 2015 and 2016 I estimated the proportional canopy cover of grass, forbs, bare ground, and litter within a 1-m^2 Daubenmire frame. In 2016, I also estimated proportional canopy coverage of sericea lespedeza. Proportions were placed into six classes (0.0-0.05, 0.06-0.25, 0.26-0.50, 0.51-0.75, 0.76-0.95, and 0.95-1.0) and the midpoint of each class was used for analyses (Daubenmire 1959). I recorded litter depth to the nearest centimeter at the northwest corner of the Daubenmire frame. I measured 100% visual obstruction using a Robel pole to the nearest decimeter at a distance of 4 m and 1 m above the ground at all four cardinal directions from the nest or paired unused point (Robel et al. 1970).

Once per year between mid-May and mid-July 2015 and 2016, I measured basal land-cover measurements and forb and shrub species composition along the permanent 100-m transect within each plot. I recorded the occurrence of grass, forb/shrub, litter, or bare ground at each 1-m mark. If a forb or shrub was detected, it was identified to species. I estimated percent composition of grass, forb/shrub, litter, and bare ground by dividing the number of points at which each was recorded by the total number of points on the transect. I pooled vegetation measurements among all four transects within each unit.

Statistical Analyses

I estimated avian detection probabilities and densities using Distance (version 6.2 Release 1; Thomas et al. 2010). Densities were estimated separately by species for Eastern Meadowlarks, Grasshopper Sparrows, and Dickcissels, as the focal grassland songbirds, and Brown-headed Cowbirds, their brood parasite. I pooled observations from 2015 and 2016 to increase sample size. I right-truncated observations at 50 m to allow calculation of more precise detection probabilities. Detection functions were calculated using the program's default settings, a half-normal key function and a cosine series expansion. Densities were post-stratified by species and I compared rankings of a model using treatment as a covariate to a model without any covariates. Models were ranked using Akaike's Information Criterion, corrected for a small sample size (AIC_c; Burnham and Anderson 2002). For each species, I tested for differences in avian density between treatments using a chi-square test in Program CONTRAST (version 2.0; Hines and Sauer 1989).

I estimated daily nest survival using the Nest Survival option in Program MARK (version 6.2; White and Burnham 1999, Dinsmore et al. 2002). I was primarily interested in grazing treatment effects and I pooled nests found in 2015 and 2016 to increase sample size. I tested four competing models: a null model (null), a model considering grazing treatment type (treatment), a model considering each day separately (day), and a model considering the interaction between treatment and day (treatment*day). Models were ranked using AIC_c. Period survival within the incubation (nest initiation to hatching) and nestling (hatching to fledging) stages was calculated by exponentiating daily nest survival estimates by the typical number of exposure days within each stage for each species (Table 3.1). Standard errors for period survival estimates were calculated using the Delta method.

I estimated songbird nest density by dividing the number of nests found in each plot in both years by the area searched of each plot and averaging within treatments. I tested for differences in parasitism rates and nest density between treatments using an analysis of variance (ANOVA). I estimated butterfly density by tallying the number of butterflies recorded within each 15,000-m^3 survey area for all months combined and averaging within treatments. I tested for differences in butterfly density between treatments and between years using a chi-square test in Program CONTRAST. To test for differences in nectar source abundance between treatments, I used an ANOVA on $\log_e(x+1)$ transformed counts of nectar forbs. I estimated species diversity for the butterfly and forb/shrub communities using Shannon's Diversity Index and divided diversity by log-species richness to estimate species evenness.

I compared land cover measurements between years, between nests and random points, and between treatments (pooling measurements at nests and random points) using Wilks' lambda multivariate analysis of variance (MANOVA) tests in Program R (version 3.1.1; R Development Core Team 2010) and subsequent ANOVA and Tukey HSD tests following a significant MANOVA to univariately separate treatments for each dependent variable. Proportional coverage of grass, forbs, litter, and bare ground, litter depth, height of tallest vegetation, and visual obstruction reading (VOR) were included as dependent variables for the canopy coverage MANOVA. Differences in proportional canopy coverage of sericea lespedeza between point use (i.e., nest or random) or between treatments in 2016 was tested using an ANOVA. Proportional coverage of grass, sericea lespedeza, forbs other than sericea lespedeza, litter, and bare ground were included as independent variables for the basal coverage MANOVA. I tested treatment, year, and the interaction of treatment and year as independent variables in MANOVA for both canopy and basal coverage models. Likewise, I tested for differences in average vegetation metrics between nest sites and random points, years, and the interaction between point use and year as independent variables in MANOVA. Proportional land cover measurements were arcsin-transformed prior to analysis to meet the assumption of normality. I set $\alpha = 0.05$ for all statistical tests.

Results

Breeding Grassland Birds

Across the two years, I detected 16 bird species within 50-m radius survey areas from 284 point-count surveys (Table 3.2). Dickcissels, Grasshopper Sparrows, and Eastern Meadowlarks were the most abundant species. Detection probabilities at point-count center for the three focal grassland songbird species and Brown-headed Cowbirds were similar across treatments and ranged from 0.81 to 1.00, indicating that a majority of individuals were detected (Table 3.3). Female songbirds were less conspicuous than singing male songbirds and less likely to be detected. Density estimates are therefore conservative and reflect minimum density estimates. Eastern Meadowlark ($\chi^2_1 = 0.04$, $P = 0.83$), Dickcissel ($\chi^2_1 = 0.02$, $P = 0.88$), and Brown-headed Cowbird ($\chi^2_1 = 0.18$, $P = 0.67$) density estimates were similar between treatments (Figure 3.3). Average Grasshopper Sparrow density, on the other hand, was 60% greater in the Steer+Sheep treatment than the Steer treatment, although there was a great deal of variation in both treatments ($\chi^2_1 = 1.53$, $P = 0.22$; Figure 3.3). Overall, of the focal grassland nesting species, Grasshopper Sparrows were present in the greatest densities, Eastern Meadowlarks were present in the lowest densities, and Dickcissels were present in intermediate densities.

In 2015, I monitored nests of nine Eastern Meadowlarks, eight Grasshopper Sparrows, and six Dickcissels. In 2016, I monitored nests of 32 Eastern Meadowlarks, 15 Grasshopper Sparrows, and 11 Dickcissels (Table 3.4). A complete census of songbird nests was not possible, therefore nest density estimates are conservative and reflect minimum nest density. There was no interaction between year and treatment for nest density of all species combined ($F_{1,12}$ = 0.34, P = 0.42) and there was no difference in nest density between treatments ($F_{1,14}$ = 0.28, P = 0.61; Figure 3.4A). Eastern Meadowlark nests contained an average of 4.1 host eggs per nest (range 1-6; SE = 0.17); Grasshopper Sparrow nests contained an average of 3.8 host eggs per nest (range 1-5; SE = 0.24); and Dickcissel nests contained an average of 3.9 host eggs per nest (range 2-5; SE = 0.21). Of all nests monitored, only 11.1% were parasitized by Brown-headed Cowbirds. Among parasitized nests, an average of 1.4 Brown-headed Cowbird eggs were counted (range 1-4; SE = 0.34). None of the parasite eggs hatched. There was no interaction between treatment and year on parasitism rates ($F_{1,12}$ = 0.28, P = 0.61). Across years, there was no evidence of a treatment effect on parasitism rates ($F_{1,14}$ = 0.53, P = 0.48; Figure 3.4B).

For Eastern Meadowlark and Grasshopper Sparrow nests during incubation and nestling stages and Dickcissel nests in the nestling stage, the null model was the top-ranked daily nest survival model (Table 3.5). However, in each case, the treatment model differed by <2.0 AIC_c points, but the null and treatment models only differed by one parameter; thus, the null model was considered the most parsimonious. Period survival estimates for these species and stages ranged from 0.1392 (± 0.0533) to 0.4220 (± 0.2583; Table 3.6). Conversely, the treatment model was the top-ranked model for Dickcissel nest survival during the incubation stage, differing by >2 AIC_c points from the null model (Table 3.5). Estimated period survival for Dickcissels during incubation was 88% lower in the Steer+Sheep treatment than it was in the Steer treatment (Table 3.6).

Butterflies

Across both years, 21 butterfly taxonomic groups were detected and identified along transects (Table 3.7). Species evenness in Steer and Steer+Sheep plots was 0.330 and 0.255, respectively. Following classifications of Moranz et al. (2012), three of the species identified (Regal Fritillary [*Speyeria idalia*], Great Spangled Fritillary [*Speyeria cybele*], and Common Wood-nymph [*Cercyonis pegala*] were grassland specialist species, the remaining 16 species were generalist species; including species in the sulphur species group and azure species group. The grass skipper group potentially included both generalist and grassland specialist species. Eastern Tailed-blues (*Cupido comyntas*), Sulphur species, and Grass Skipper species were most common along transects, comprising 82.1, 5.0, and 4.9% of all butterfly detections, respectively (Table 3.7). Common wood-nymphs ranked seventh in terms of abundance, comprising 1.0% of all detections. Only two Regal Fritillaries and one Great Spangled Fritillary were detected, each comprising <0.01% of all detections.

In both years, average densities of the complete butterfly community were similar between treatments (2015: $\chi^2_1 = 3.01$, $P = 0.08$; 2016: $\chi^2_1 = 0.55$, $P = 0.46$; Figure 3.5A, B). Relative trends between treatments in average densities of grassland specialist butterfly species contrasted between years. In 2015, mean density of grassland specialist species was nearly 3-fold greater in Steer plots than Steer+Sheep plots ($\chi^2_1 = 2.93$, $P = 0.09$) whereas in 2016, density in Steer+Sheep plots was 2.3-fold greater than in Steer plots, though this difference was not statistically significant ($\chi^2_1 = 1.03$, $P = 0.31$; Figure 3.5C, D).

Plant Community and Land Cover

There was no interaction between treatment and year for canopy cover characteristics ($F_{7,150}$ = 1.75, P = 0.10) and no significant differences between treatments ($F_{7,152}$ = 0.52 P = 0.82; Figure 3.6A, B, D-G). In 2016, there was no difference in sericea lespedeza cover between treatments in 2016 (F = 0.001, P = 0.98; Figure 3.6C). Similarly, there was no interaction between treatment and year in basal coverage characteristics ($F_{4,57}$ = 1.37, P = 0.25); however, there was a treatment effect ($F_{4,59}$ = 2.62, P = 0.04; Figure 3.7). Proportional basal coverage by forbs other than sericea was 1.5-times greater in Steer+Sheep plots than Steer plots, but this difference was only marginally statistically significant ($F_{1,62}$ = 3.81, P = 0.055; Figure 3.7C).

Canopy coverage characteristics compared between nests and unused points were not characterized by an interaction between point use (i.e., nest or unused) and year for Grasshopper Sparrows ($F_{7,34}$ = 0.63, P = 0.73), Eastern Meadowlarks ($F_{7,72}$ = 0.77, P = 0.61), nor Dickcissels ($F_{7,24}$ = 1.56, P = 0.20). At Grasshopper Sparrow nests, proportional coverage of grass ($F_{1,42}$ = 4.17, P = 0.05; Figure 3.8A) and bare ground ($F_{1,42}$ = 12.68, P = 0.0009; Figure 3.8E) were lower than at paired points, with proportional coverage of forbs ($F_{1,42}$ = 6.84, P = 0.04; Figure 3.8B), height of tallest vegetation ($F_{1,42}$ = 8.46, P = 0.006; Figure 3.8G), and visual obstruction readings ($F_{1,42}$ = 5.04, P = 0.03. Figure 3.8H) greater at nests relative to paired points. Proportional coverage of bare ground ($F_{1,80}$ = 13.89, P = 0.0004; Figure 3.9E) was lower at Eastern Meadowlark nests than paired points but litter depth ($F_{1,80}$ = 4.38, P = 0.04; Figure 3.9F), height of tallest vegetation ($F_{1,80}$ = 15.96, P = 0.0001; Figure 3.9G), and visual obstruction ($F_{1,80}$ = 4.59, P = 0.04; Figure 3.9H) were greater at nests than paired points. Dickcissel nest sites contained a greater proportion of forbs ($F_{1,32}$ = 9.53, P = 0.004; Figure 3.10B) and smaller proportion of bare ground than paired points ($F_{1,32}$ = 7.00, P = 0.013; Figure 3.10E). In addition to differing from unused points, nest sites also differed among species ($F_{14,142}$ = 3.23, P = 0.0002). Specifically, Dickcissel nests contained a lower proportion of grass and a greater proportion of forbs than either Grasshopper Sparrow or Eastern Meadowlark nests (grass: $F_{2,157}$ = 6.62, P = 0.002; forbs: $F_{2,157}$ = 10.78, P < 0.001). Proportional cover of bare ground was greater at Grasshopper Sparrow nests than either Dickcissel or Eastern Meadowlark nests ($F_{2,157}$= 3.83, P = 0.03).

In total, I identified 654 forb and shrub plants within 37 taxa along transects (Table 3.8). Species evenness in Steer and Steer+Sheep plots was 0.672 and 0.544, respectively. Sericea lespedeza was the most abundant forb, occurring nearly three times more frequently than plants within the second-most abundant genus, ironweed (*Vernonia* spp.). “Ironweeds” (*Vernonia* spp.) and “milkweeds” (*Asclepias* spp.) are potential nectar sources for grassland specialist butterfly species (Moranz 2010) and detections of plants within these genera comprised 16.8% of all forbs and shrubs along transects. Following guild classifications by Moranz (2010) and Moranz et al. (2012), I detected sixteen forb and shrub species within the same genera as those documented as used by either generalist or grassland specialist species. I additionally observed Eastern Tailed-blues using sericea lespedeza as a nectar source. Including sericea lespedeza, 78.4% of all forb and shrub detections were species or genera potentially used by generalist butterfly species as nectar sources.

An interaction between treatment and year was not evident in the abundance of nectar sources for the entire butterfly community ($F_{1,60}$ = 1.46, P = 0.23), nor the grassland specialist butterfly community ($F_{1,60}$ = 0.71, P = 0.40). There was evidence, however, of a treatment effect for generalist-serving and specialist-serving nectar sources. Generalist nectar sources were 2.3-fold more abundant in Steer+Sheep plots than Steer plots ($F_{1,62}$ = 9.34, P < 0.01; Figure 3.11A).

Similarly, grassland specialist nectar sources were 1.8-fold more abundant in Steer+Sheep plots than Steer plots, though this difference was not statistically significant ($F_{1,62} = 2.91$, $P = 0.09$; Figure 3.11B).

Discussion

Breeding Grassland Birds

Livestock grazing created heterogeneity in vegetation structure, which created nesting habitat characteristics for the three most common focal grassland nesting species recorded in this study (Collins and Smith 2006, Fuhlendorf et al. 2006). Grasshopper Sparrows were present at high densities in both Steer and Steer+Sheep treatments, which is likely due to a large proportion of the study area having characteristics of Grasshopper Sparrow nesting habitat. Grasshopper Sparrows are associated with patchily distributed bare ground, moderate litter cover, and low-to-moderate forb coverage, often created by moderate levels of grazing (Blankespoor 1980, Whitmore 1981, Herkert 1994, Patterson and Best 1996, Swengel 1996, Delisle and Savidge 1997, Jensen 1999, Swengel and Swengel 2001, Guiliano and Daves 2002, Sutter and Ritchison 2005, Hubbard et al. 2006, Powell 2006, Coppedge et al. 2008, Powell 2008). The estimated density and daily nest survival rates for Grasshopper Sparrows were consistent with or greater than those reported in the literature, demonstrating that the study site provided high quality Grasshopper Sparrow nesting habitat (Fletcher and Koford 2002, Renfrew and Ribic 2002, Frey et al. 2008, Jacobs et al. 2012). My results corroborate previous findings that annual fire and moderate livestock grazing is conducive to creating Grasshopper Sparrow nesting habitat and additionally demonstrate that supplementing steer grazing with sheep grazing does not reduce the abundance of Grasshopper Sparrow nesting habitat. Furthermore, these grazing treatments did not have an effect on Grasshopper Sparrow nest survival rates during incubation or nestling nest stages, demonstrating that supplementing steer grazing with sheep grazing does not reduce demographic performance of Grasshopper Sparrows.

Previous research results indicate that Eastern Meadowlarks are positively associated with moderate grazing that results in low forb-to-grass ratios, moderate live and dead grass coverage, and enough litter for nest concealment (Wiens 1969, Wiens 1974, Skinner 1975, Roseberry and Klimstra 1970, Rotenberry and Wiens 1980, Bock et al. 1993, Granfors et al. 1996, Jensen 1999, Rohrbaugh et al. 1999, Hubbard et al. 2006, Coppedge et al. 2008, Powell 2008). Structural heterogeneity, which is created by the fire-grazing interaction, is additionally important for Eastern Meadowlarks, as they require height and density of litter and vegetation sufficient to conceal nests but place their nests in close proximity to areas with shorter and less dense vegetation more suitable for foraging (Schroeder and Sousa 1982). I observed Eastern Meadowlark nest densities exceeding what was expected based on their $\geq$2 ha/nest estimated space requirement, which is indicative of the presence of high quality habitat (Wiens 1969, 1971). The high nest densities and daily nest survival rates for Eastern Meadowlarks, which are consistent with or exceed estimates reported by other investigators, are further evidence of the high quality of the Eastern Meadowlark nesting habitat on the study site (Renfrew and Ribic 2002, Frey et al. 2008, Hovick and Miller 2016). The combination of annual spring fire and moderate grazing pressure, whether by steers alone or steer and sheep, appears to have created the structure and heterogeneity characteristic of high quality Eastern Meadowlark nesting habitat.

Consistent with results from previous studies, my data show that Dickcissel nesting habitat characteristically has greater proportions of forbs and shrubs and taller vegetation than surrounding areas (Skinner 1975, Rotenberry and Wiens 1980, Finck 1984, Frawley and Best 1991, Patterson and Best 1996, Delisle and Savidge 1997, Jensen 1999, Winter 1999, Churchwell 2005, Powell 2006, Churchwell et al. 2008). Additionally, areas subjected to fire and grazing disturbances in the same year, which typically reduces the abundance of forbs and shrubs, are of lower quality for nesting Dickcissels than areas subjected to only fire or grazing in a given year (Rohrbaugh et al. 1999, Powell 2006, Churchwell et al. 2008). Forbs were at low abundance on the study site and shrubs were effectively absent, which explains the relatively low abundance of Dickcissel nests (see Chapter II). Contrary to the low nest abundance observed for Dickcissels, density of individuals was relatively high and consistent with previous estimates in tall-grass prairie (Fletcher and Koford 2002, Jacobs et al. 2012).

Evidently, density was not a reliable indicator of patch quality for Dickcissels. I most often detected singing males in areas dominated by sericea lespedeza, likely because sericea and ironweed were the tallest forb species present. Plant communities dominated by sericea lespedeza, however, support fewer invertebrate species than those composed of native tall-grass prairie forb species (Eddy and Moore 1998). Invertebrates are a food item for Dickcissels and female Dickcissels may have been deterred from placing nests in the areas of low invertebrate abundance (Kobal et al.1998). A false perception by male Dickcissels of sericea lespedeza providing high habitat quality could explain the disparity in Dickcissel density and nest abundance.

Of the three grassland songbird species considered here, Dickcissel was the only species for which treatment appeared to have an effect on nest survival. Estimated period survival during the nestling stage for Dickcissels in the Steer+Sheep treatment was 0.0047, 80% lower than what was estimated for the same stage in the Steer treatment. The nest survival estimates for the Steer treatment are consistent with estimates reported in the literature for Dickcissels in tall-grass prairie (Churchwell et al. 2008, Frey et al. 2008, Conkling et al. 2015). The low daily nest survival estimate for the nestling stage in Steer+Sheep, however, was based on only two nests that survived to the nestling stage in the Steer+Sheep treatment, one of which fledged. In the Steer treatment, four nests survived to the nestling stage and three of those fledged. These small sample sizes render the daily nest survival estimates unreliable and do not provide evidence of a treatment effect on Dickcissels. Although Dickcissels did not respond differently to the Steer+Sheep treatment than to the Steer treatment, neither treatment is effective at creating Dickcissel nesting habitat.

Butterflies

Species composition, richness, and density of pollinator communities are commonly linked to species composition, richness, and density of floral resources (e.g., Kearns et al. 1998, Schultz and Dlogosch 1999, Biesmeijer et al. 2006, Rudolph 2006, Moranz 2010, Potts et al. 2010). Density of the entire butterfly community was similar to values reported by Moranz et al. (2012), whereas the densities of grassland specialist species were at least an order of magnitude lower. Fewer than 2% of all butterflies detected were grassland specialists and many grassland specialist species that have been documented in Kansas tall-grass prairie (e.g., Gorgone Checkerspot [*Chlosyne gorgone*], Olympia Marble [*Euchloe olympia*], Henry’s Elfin [*Callophrys henrici*]; Swengel 1998) were not detected. These results suggest that the study site may have been lacking resources, such as nectar sources for grassland specialist species (Schultz and Dlugosch 1999, Rudolph 2006, Moranz 2010).

There was a trend of greater density of the entire butterfly community in Steer+Sheep plots than Steer plots, which is consistent with a greater abundance of nectar sources in Steer+Sheep plots. These results suggests that grassland specialist butterfly populations were at least partially limited by the availability of nectar sources. Indeed, previous research has correlated abundance of nectar sources with butterfly abundance (Schultz and Dlugosch 1999, Rudolph 2006, Moranz 2010). Conversely, trends in the grassland specialist butterfly community were less intuitive. The greater density of grassland specialists in Steer plots relative to Steer+Sheep plots in 2015 was inconsistent with the hypothesis that greater butterfly densities should be associated with greater abundance of nectar sources. Furthermore, there was a greater abundance of specialist-serving forbs in Steer+Sheep plots than Steer plots in both years, but trends in specialist butterfly density contrasted between years. Inconsistent trends may be a result of low grassland specialist butterfly densities on the study site, resulting in low sample sizes and unreliable density estimates but also confirm that abundance of nectar sources is not the only constraint for grassland butterfly communities (Moranz et al. 2012). Additionally, these data illustrate the pitfalls of assessing habitat quality for generalist and specialist butterfly species combined. To accurately gauge habitat quality, one must consider specialist butterfly species separately from generalists.

It is evident that conserving the grassland specialist butterfly community in tall-grass prairie requires ensuring the presence of their nectar sources; thus, controlling sericea lespedeza is critical to improving habitat quality for specialist species. Using fire and grazing as management tools is a subject of contention because of inconsistent results in determining the effects of fire and grazing on various butterfly life stages and habitat guilds (e.g., Swengel 1996, 1998; Swengel and Swengel 2001; Vogel et al. 2010; Moranz et al. 2014). In the absence of fire and grazing, woody encroachment occurs and invasion by exotic plant species (e.g., sericea lespedeza) will continue, consequently reducing abundance of native forbs. Although my study did not address the treatment effects on larval butterflies, which often overwinter in thatch, some short-term negative effects, if present, may be considered acceptable from a conservation perspective, with the long-term goal of tall-grass prairie restoration.

Management Implications

Steer grazing supplemented with sheep grazing, relative to steer grazing alone, does not alter vegetation characteristics at a scale relevant to grassland nesting songbirds or grassland specialist butterfly species in the Flint Hills tall-grass prairie. Use of annual spring burns in conjunction with moderate intensity steer grazing, followed by late-season sheep grazing is an effective method for controlling sericea lespedeza. Application of fire and grazing in the same year, however, is not conducive for creating Dickcissel nesting habitat nor adult grassland specialist butterfly habitat under current levels of sericea occurrence. Implementing grazing by tannin-tolerant herbivores will reduce the abundance of sericea and subsequent adoption of a patch-burn grazing system would be preferable for creating structural heterogeneity and maintaining biodiversity of native tall-grass prairie species.

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Figures and Tables

Figure 3.1 A) Outline of the continental United States of America with rectangle outlining placement of B) Kansas (green), the Flint Hills (gray), and Geary County (blue) with orange dot indicating C) the 248-ha study site where avian and butterfly densities were estimated from May to September 2015 and 2016. Black lines outlining plots subjected to one of two grazing treatments: Steer (Steer) or Steer+Sheep (S+S).

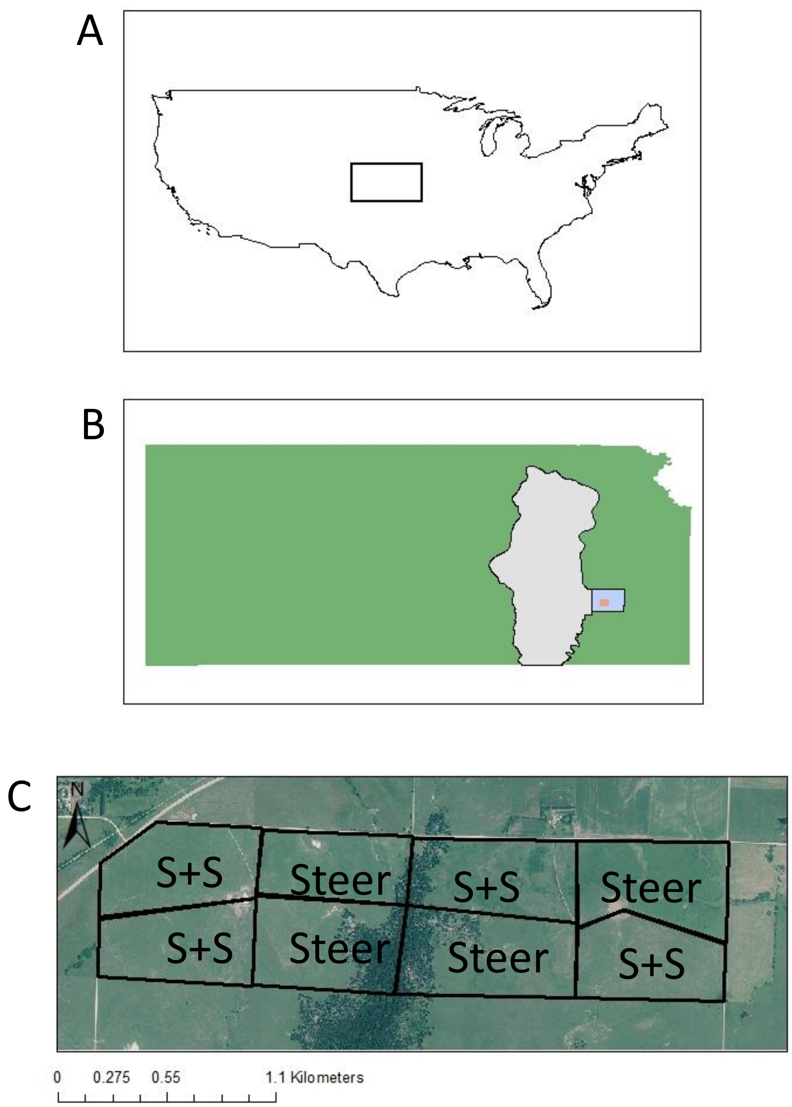


Figure 3.2 A) Average whole plant mass of sericea lespedeza (±SE), B) average seed mass of sericea lespedeza plants (±SE), and C) average number of seeds produced per sericea lespedeza plant (±SE) in 248 ha of tall-grass prairie in Woodson County, Kansas. Measurements were averaged among four replicate plots within each grazing treatment (Steer and Steer+Sheep). Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Grazing treatments and data collection occurred in 2013. Data from Lemmon et al. (2016).

A. B.

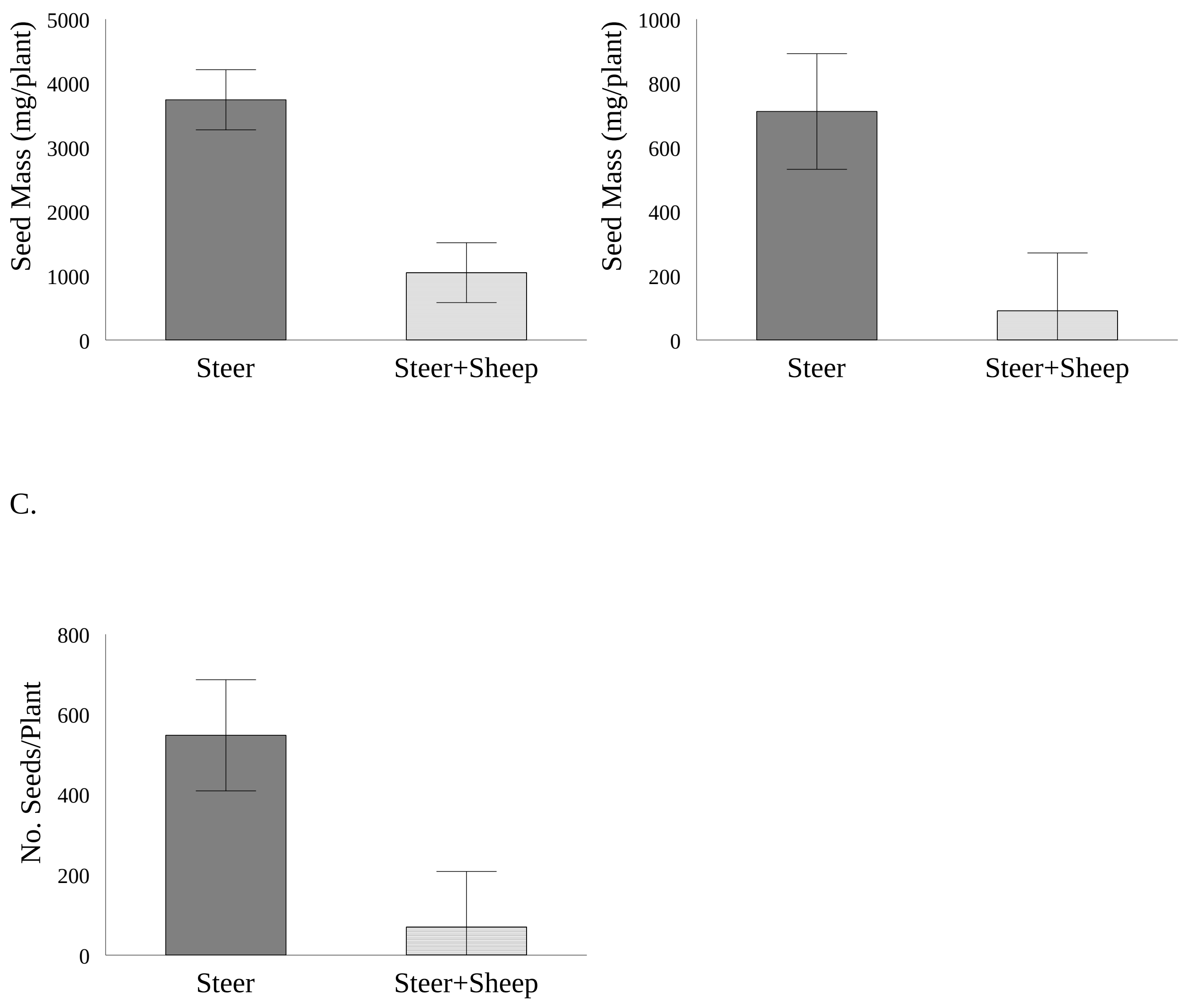


Figure 3.3 Mean bird densities (± SE) estimated in Program Distance from 50 m radius point-count surveys conducted between mid-May and early June 2015 and 2016 in 248 ha of tall-grass prairie in Woodson County, Kansas. Each grazing treatment (Steer and Steer+Sheep) was applied to four replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. DICK = Dickcissel, GRSP = Grasshopper Sparrow, EAME = Eastern Meadowlark, BHCO = Brown-headed Cowbird. Asterisks denote density estimates differed between treatments ($P \leq 0.05$).

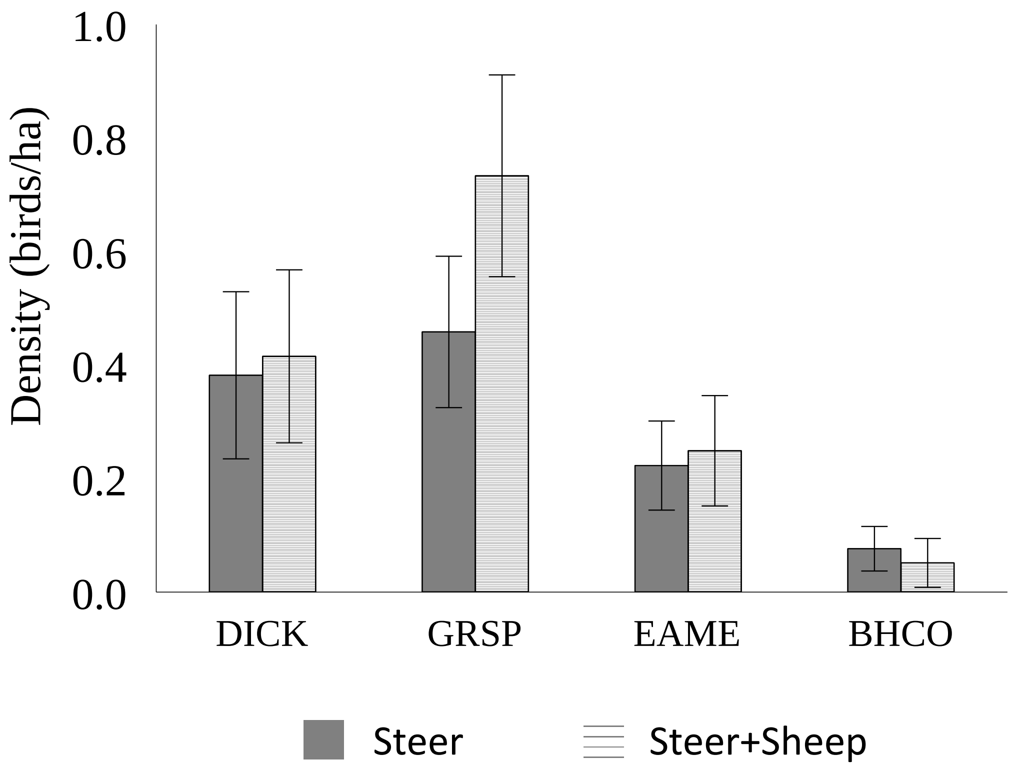
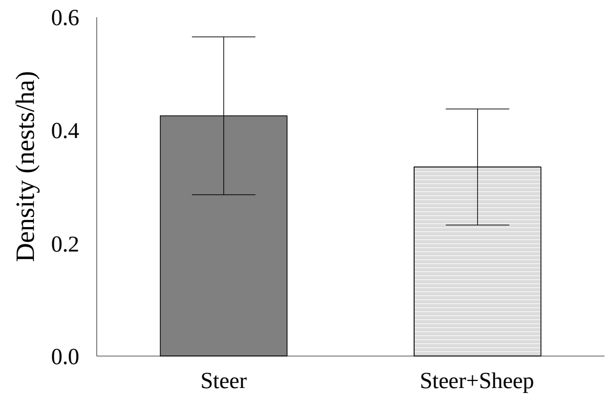


Figure 3.4 A) Estimates of nest density for grassland songbirds ($\pm$ SE) and B) average nest parasitism rates ($\pm$ SE) by Brown-headed Cowbirds in 50 ha of tall-grass prairie in Woodson County, Kansas. Nests were located from late May to mid-July 2015 and 2016. Measurements were averaged among four replicate plots within each grazing treatment (Steer and Steer+Sheep). Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Grazing treatments were applied from 2013 to 2016. Asterisks denote means differed between treatments ($P \leq 0.05$).

A.



B.

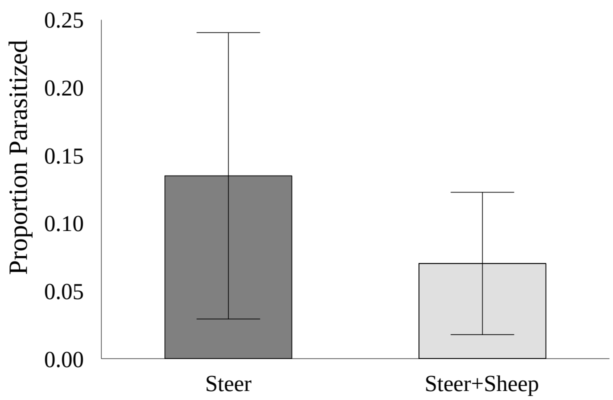


Figure 3.5 Average densities (±SE) of A) and B) all butterflies, and C) and D) grassland specialist butterflies. Butterfly communities were surveyed along four 100-m transects in each of eight plots. Grazing treatments (Steer and Steer+Sheep) were each applied to four replicate plots. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Surveys were conducted once per month from June to September 2015, and May to September 2016, in 248 ha of tall-grass prairie in Woodson County, Kansas. Grazing treatments were applied from 2013 to 2016. Asterisks denote means differed between treatments ($P \leq 0.05$).

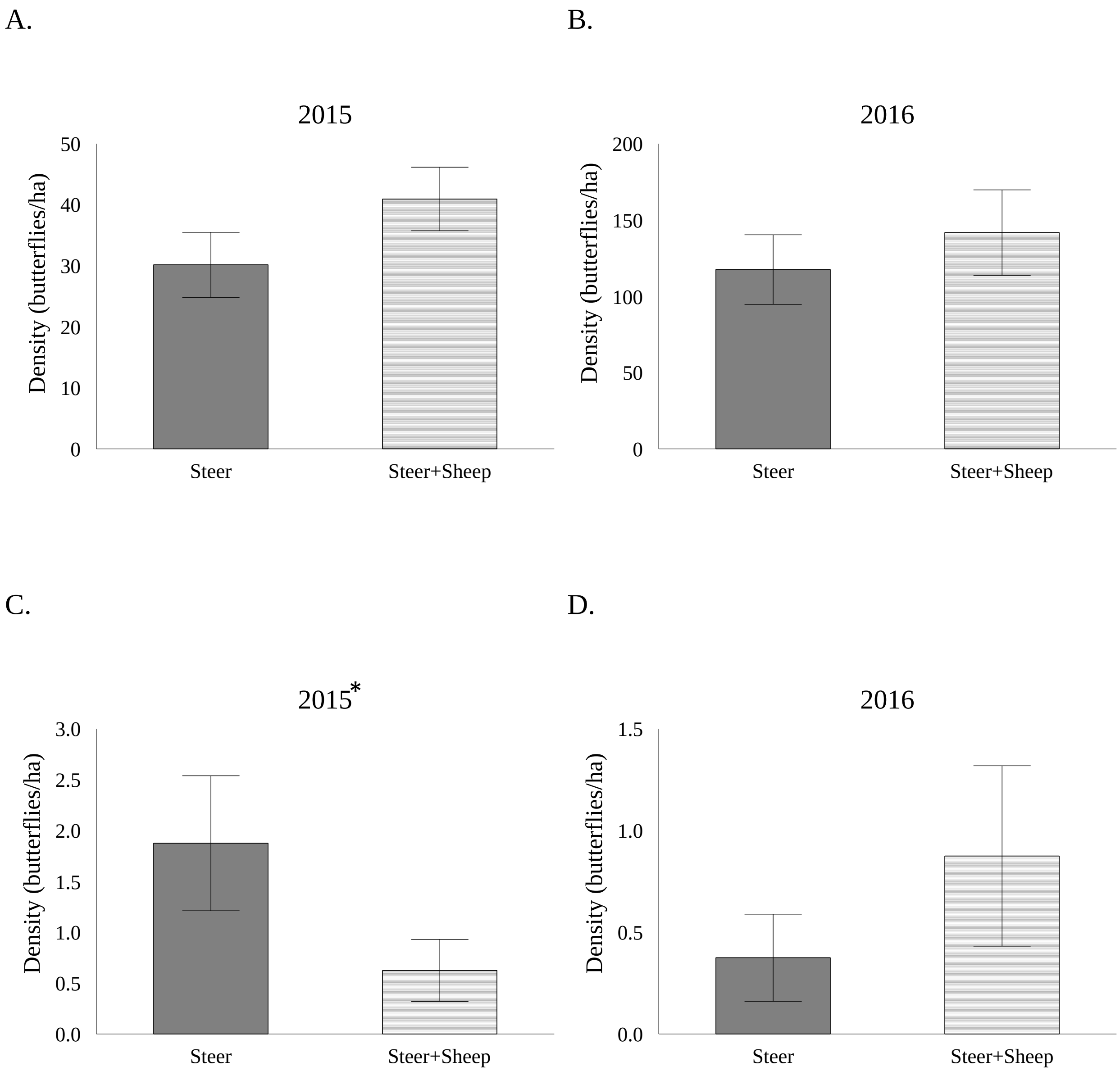
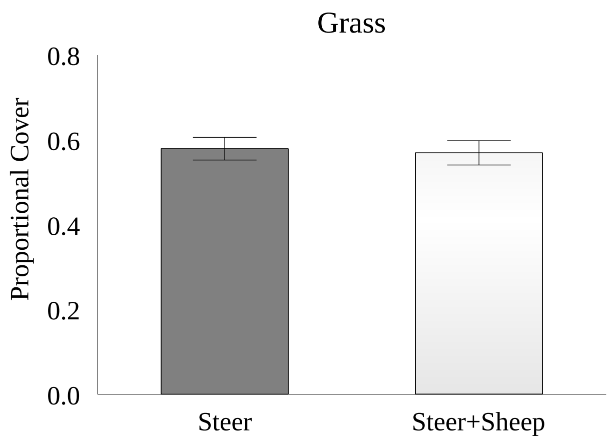
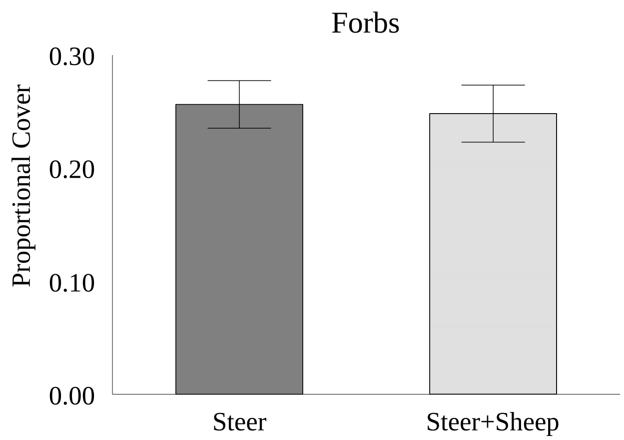


Figure 3.6 Proportional canopy cover (± SE; A-F) within a 1-m^2 Daubenmire frame, (G) litter depth (± SE), (H) height of tallest vegetation (± SE), and (I) and visual obstruction reading (± SE) in 248 ha of tall-grass prairie in Woodson County, Kansas. Measurements were taken between early June and late July 2015 and 2016 at grassland songbird nests and at nearby paired unused points and averaged among four replicate plots within each grazing treatment (Steer and Steer+Sheep). Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Grazing treatments were applied from 2013 to 2016. Measurements taken in 2015 and 2016 were pooled except for proportional cover of sericea lespedeza, which was only measured in 2016. Asterisks denote means differed between treatments ($P \leq 0.05$).

A.



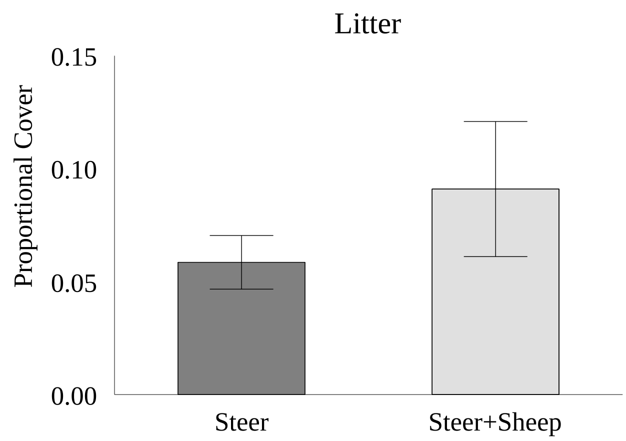
B.



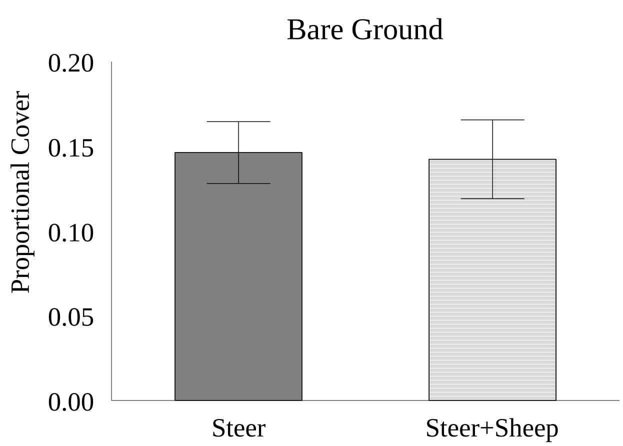
C.


Sericea Lespedeza
Proportional Cover
0.08
0.06
0.04
0.02
0.00
Steer
Steer+Sheep

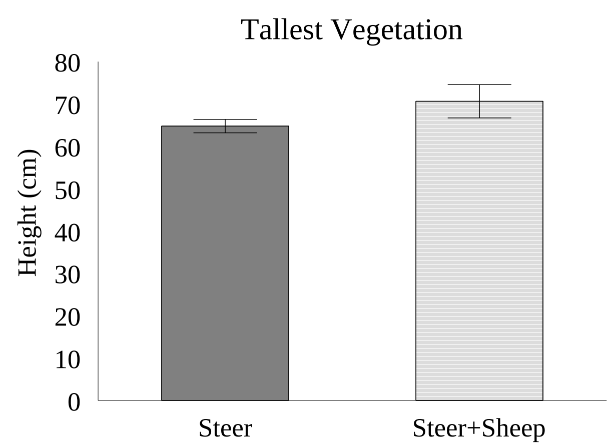
D.


Litter
Proportional Cover
0.15
0.10
0.05
0.00
Steer
Steer+Sheep

E.


Bare Ground
Proportional Cover
0.20
0.15
0.10
0.05
0.00
Steer
Steer+Sheep

F.


Tallest Vegetation
Height (cm)
80
70
60
50
40
30
20
10
0
Steer
Steer+Sheep

G.

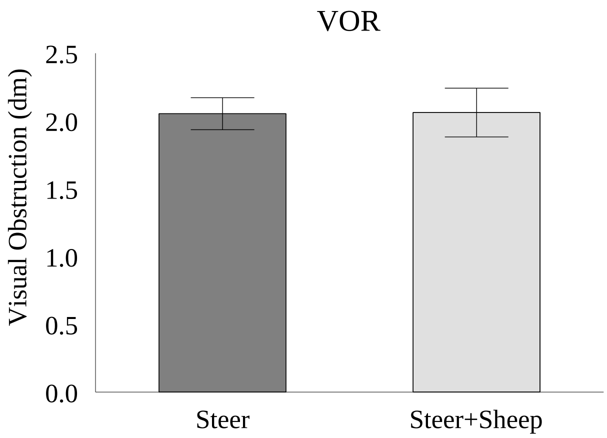
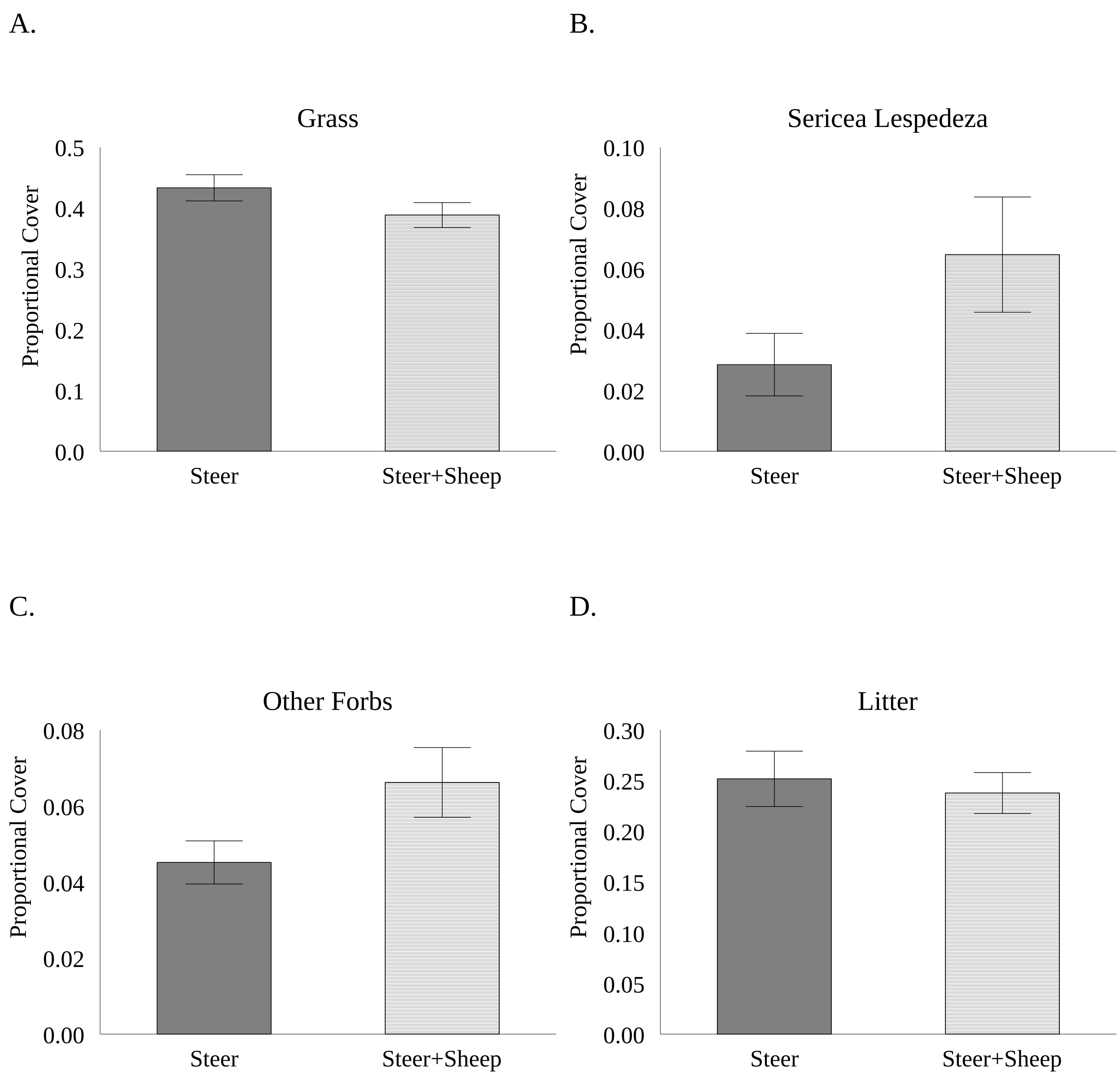


Figure 3.7 Proportional basal land cover measurements (± SE) taken along 100-m transects once per year in 2015 and 2016 in 248 ha of tall-grass prairie in Woodson County, Kansas. Measurements were taken between mid-May and mid-July 2015 and 2016 and averaged across four replicate transects within each plot and four replicate plots per grazing treatment (Steer and Steer+Sheep). Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Grazing treatments were applied from 2013 to 2016. Asterisks denote means differed between treatments ($P \leq 0.05$).



E.

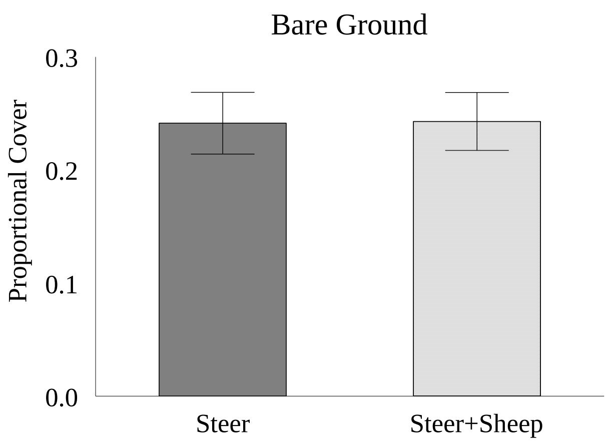
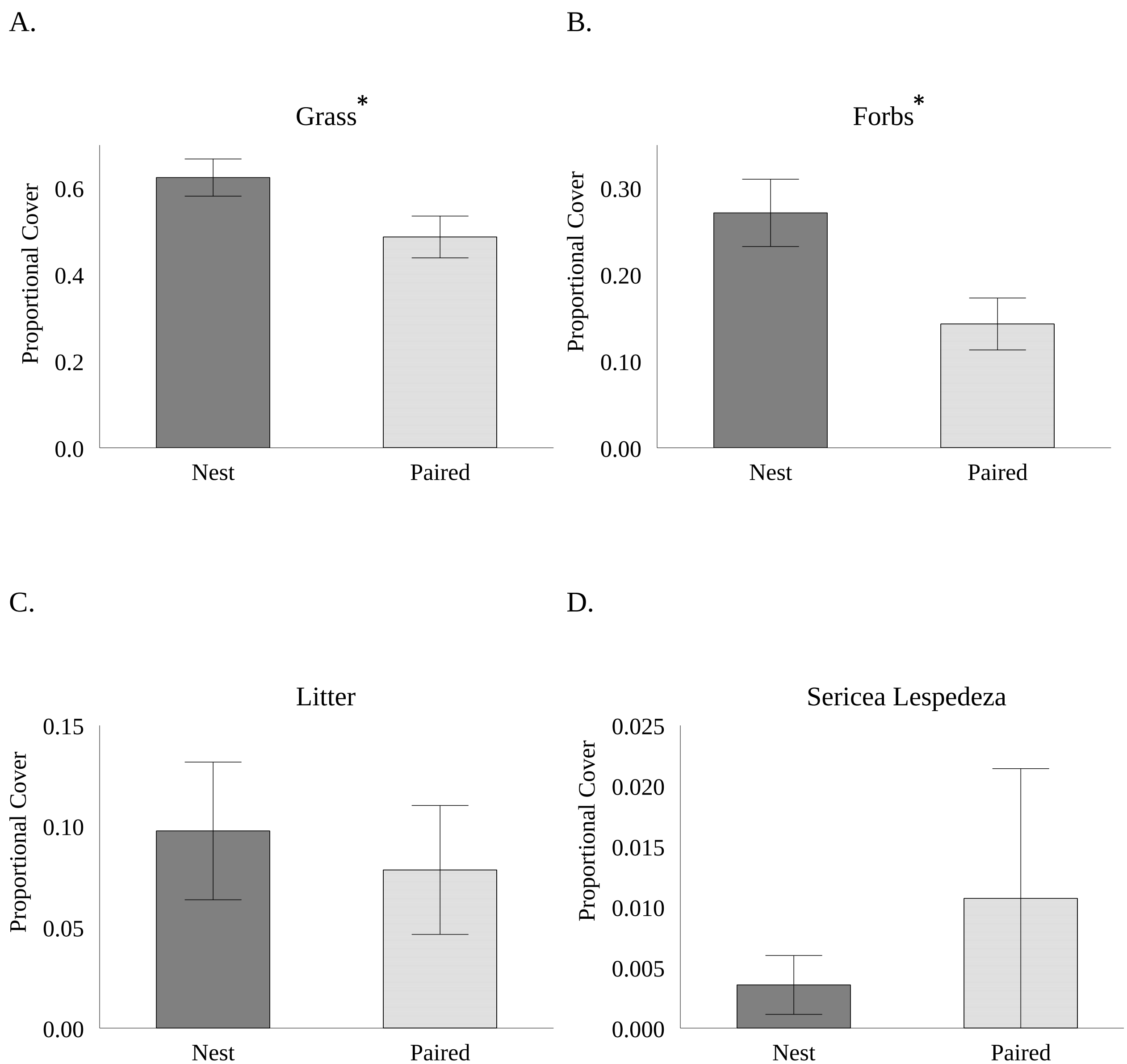
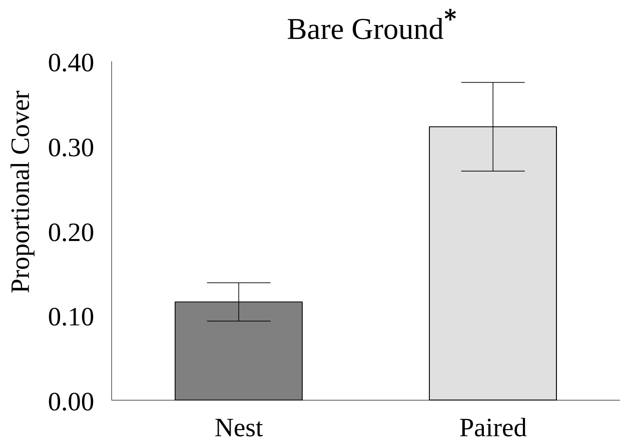

Bare Ground
Proportional Cover
0.3
0.2
0.1
0.0
Steer
Steer+Sheep

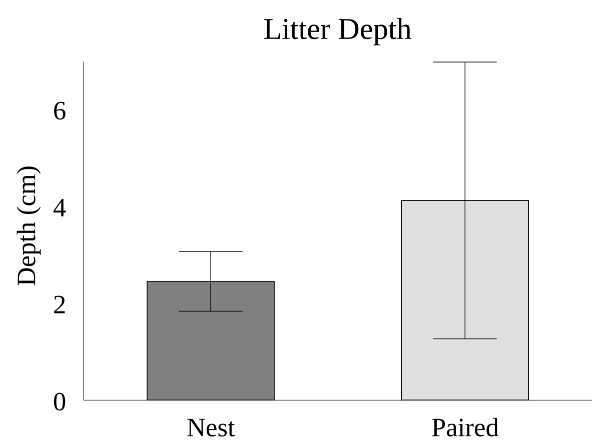
Figure 3.8 Land-cover characteristics at Grasshopper Sparrow nests and nearby paired, unused points. Proportional canopy cover (± SE; A-F) within a 1-m^2 Daubenmire frame, (G) litter depth (+ SE), (H) height of tallest vegetation (± SE), and (I) and VOR (± SE) in 248 ha of tall-grass prairie in Woodson County, Kansas. Nests were located from late May to mid-July 2015 and 2016. Measurements were recorded between early June and late July and were pooled across both grazing treatments (Steer and Steer+Sheep), applied from 2013 to 2016. Asterisks indicate means differed between point types ($P \leq 0.05$).



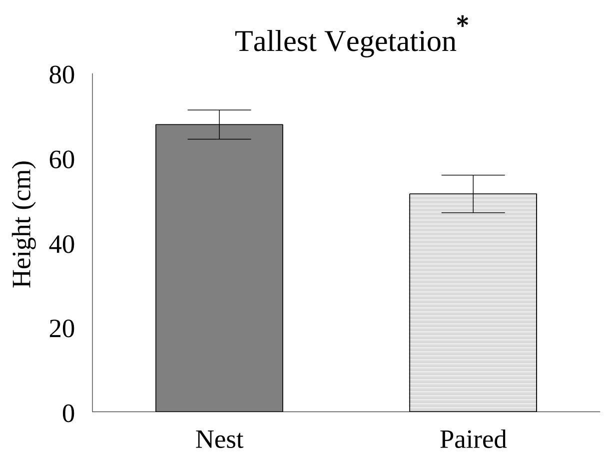
E.


Bare Ground*
0.40
0.30
0.20
0.10
0.00
Proportional Cover
Nest
Paired

F.


Litter Depth
6
4
2
0
Depth (cm)
Nest
Paired

G.


Tallest Vegetation*
80
60
40
20
0
Height (cm)
Nest
Paired

H.

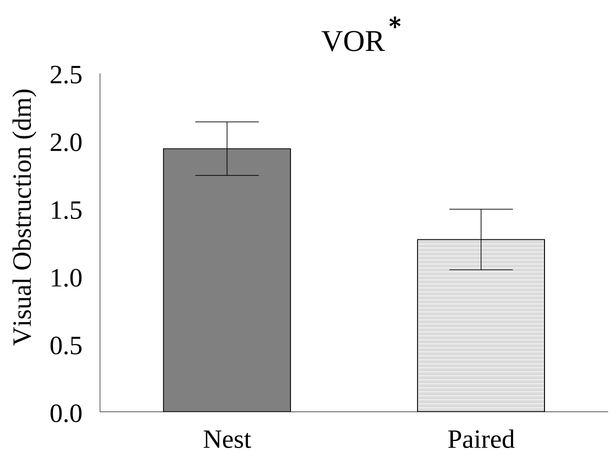
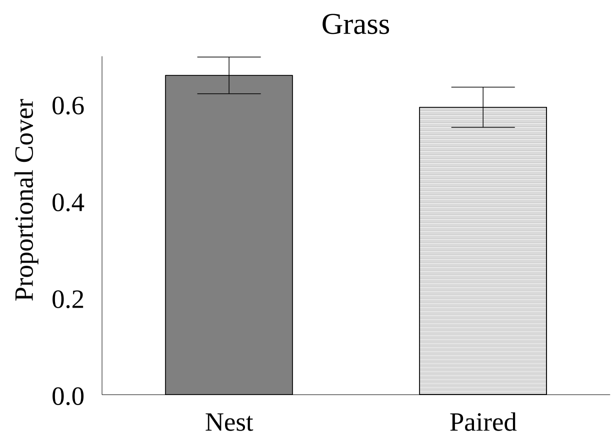
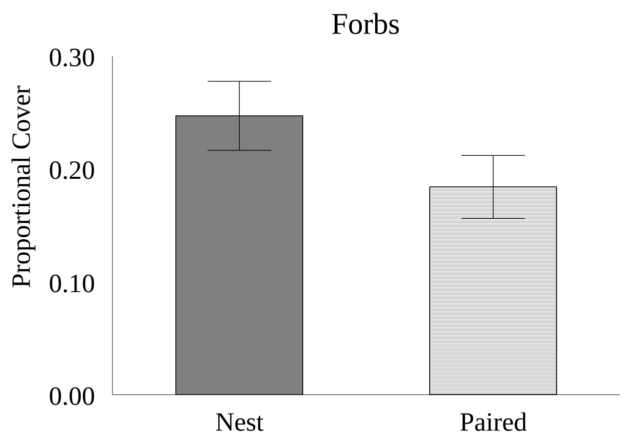

VOR*
2.5
2.0
1.5
1.0
0.5
0.0
Visual Obstruction (dm)
Nest
Paired

Figure 3.9 Land-cover characteristics at Eastern Meadowlark nests and nearby paired, unused points. Proportional canopy cover (± SE; A-F) within a 1-m^2 Daubenmire frame, (G) litter depth (+ SE), (H) height of tallest vegetation (± SE), and (I) and VOR (± SE) in 248 ha of tall-grass prairie in Woodson County, Kansas. Nests were located from late May to mid-July 2015 and 2016. Measurements were recorded between mid-June and early August and were pooled across both grazing treatments (Steer and Steer+Sheep), applied from 2013 to 2016. Asterisks indicate means differed between point types ($P \leq 0.05$).

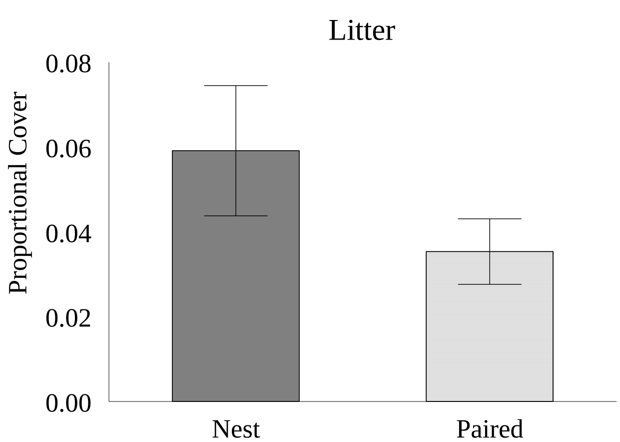
A.



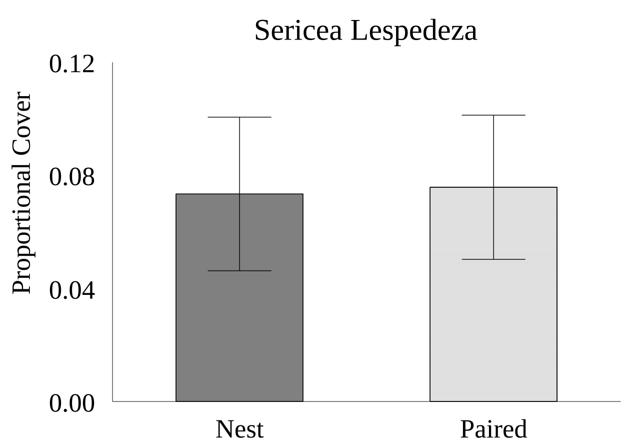
B.



C.



D.



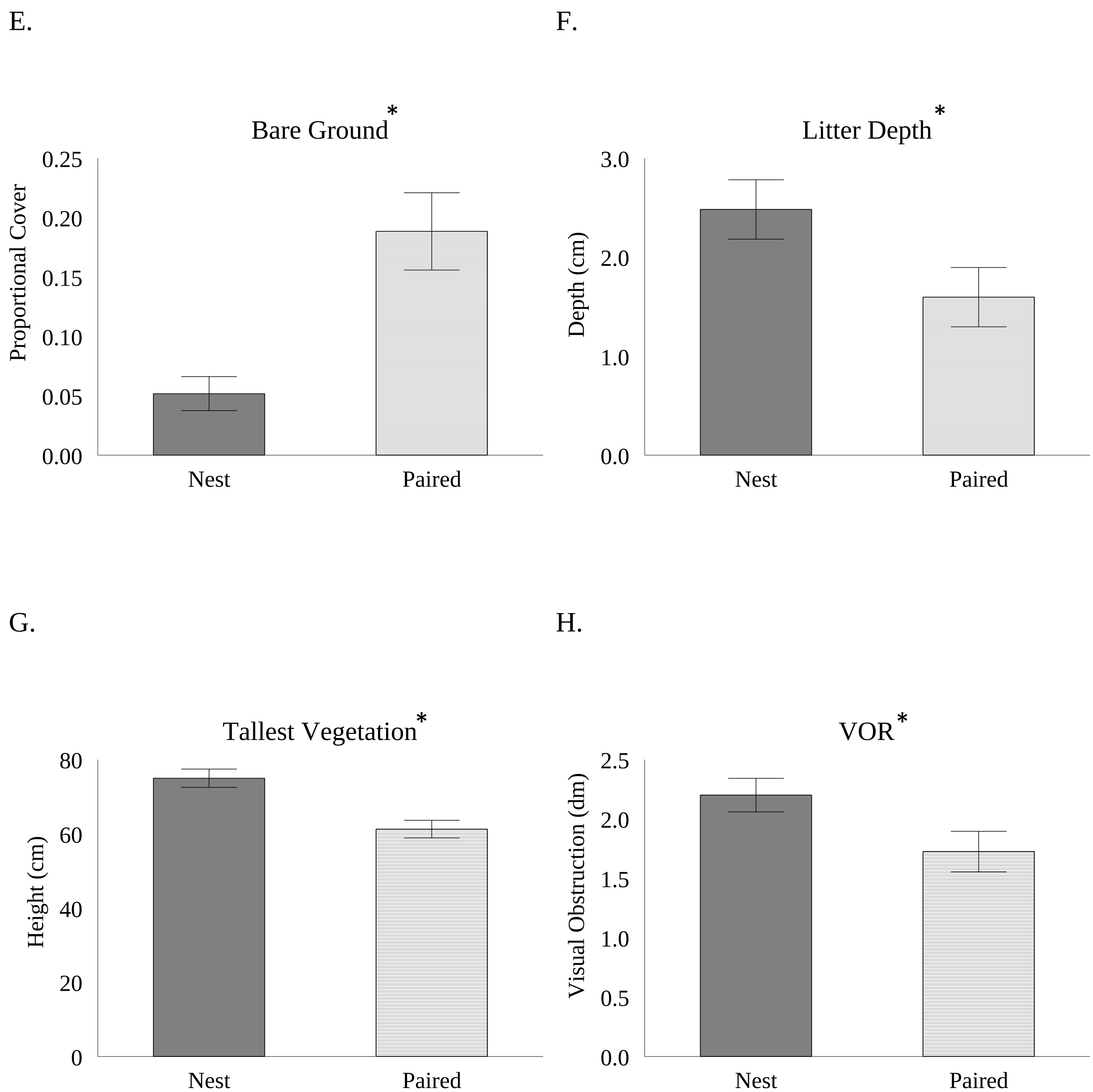
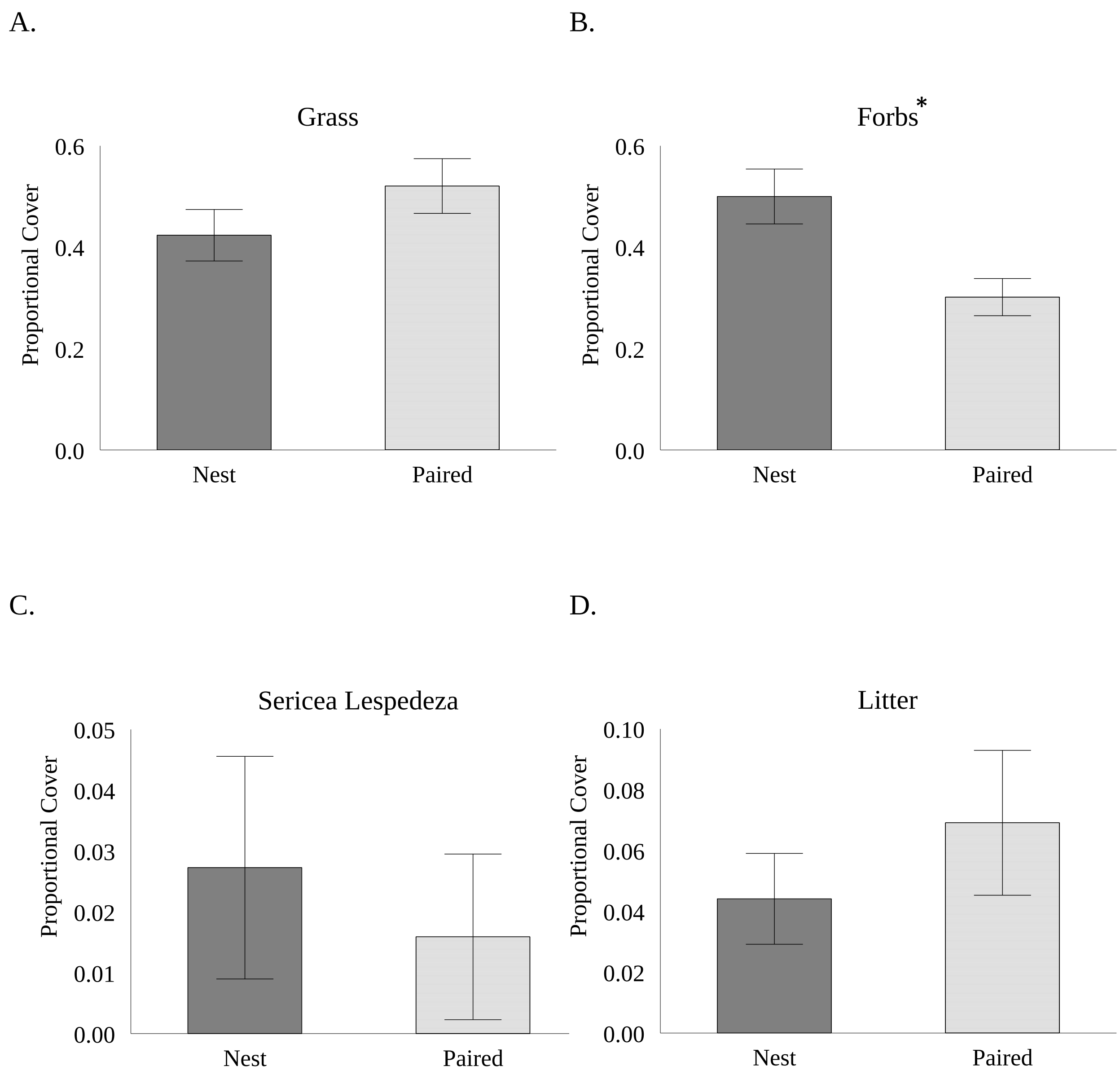
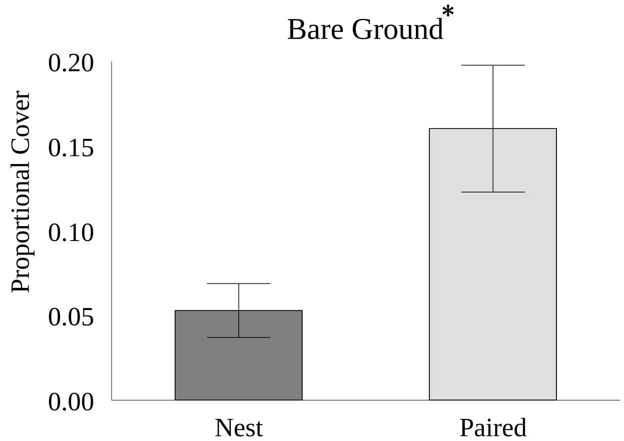

E.
Bare Ground*
Proportional Cover
0.25
0.20
0.15
0.10
0.05
0.00
Nest
Paired
F.
Litter Depth*
Depth (cm)
3.0
2.0
1.0
0.0
Nest
Paired
G.
Tallest Vegetation*
Height (cm)
80
60
40
20
0
Nest
Paired
H.
VOR*
Visual Obstruction (dm)
2.5
2.0
1.5
1.0
0.5
0.0
Nest
Paired

Figure 3.10 Land-cover characteristics at Dickcissel nests and nearby paired, unused points. Proportional canopy cover (± SE; A-F) within a 1-m^2 Daubenmire frame, (G) litter depth (± SE), (H) height of tallest vegetation (± SE), and (I) and VOR (± SE) in 248 ha of tall-grass prairie in Woodson County, Kansas. Nests were located from late May to mid-July 2015 and 2016. Measurements were recorded between mid-June and early August and were pooled across both grazing treatments (Steer and Steer+Sheep), applied from 2013 to 2016. Asterisks indicate means differed between point types ($P \leq 0.05$).

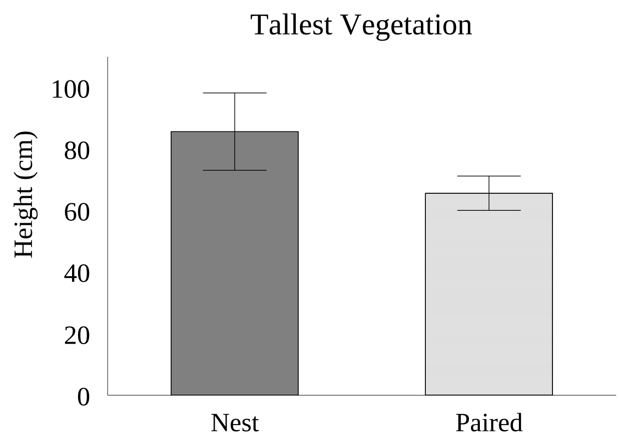


E.



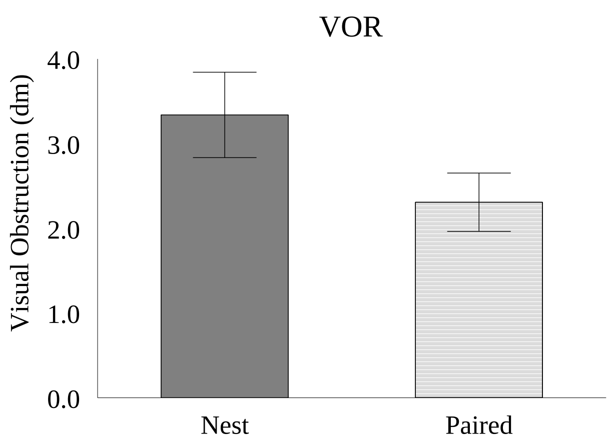
Bare Ground*
0.20
0.15
0.10
0.05
0.00
Proportional Cover
Nest
Paired

F.



Tallest Vegetation
100
80
60
40
20
0
Height (cm)
Nest
Paired

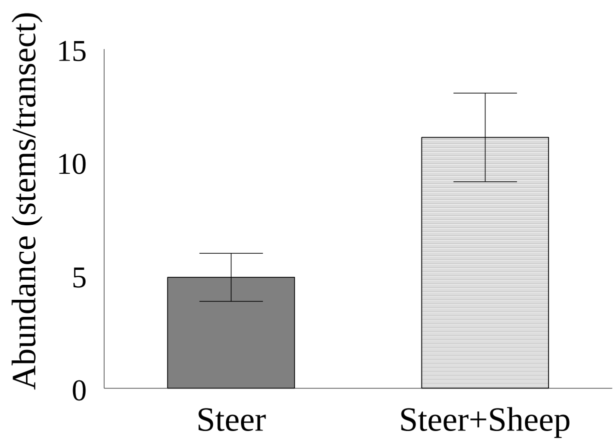
G.



VOR
4.0
3.0
2.0
1.0
0.0
Visual Obstruction (dm)
Nest
Paired

Figure 3.11 Mean abundance (± SE) of nectar sources for A) all butterflies detected during surveys and B) grassland specialist butterfly species recorded in tall-grass prairie in Woodson County, Kansas. Forb abundance was measured along four 100 m permanent transects within each of 8 plots. Each grazing treatment (Steer and Steer+Sheep) had four replicate plots. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Surveys were conducted once per between mid-May and mid-July in 2015 and 2016. Grazing treatments were applied from 2013 to 2016. Asterisks denote means differed between treatments ($P \leq 0.05$).

A.



B.

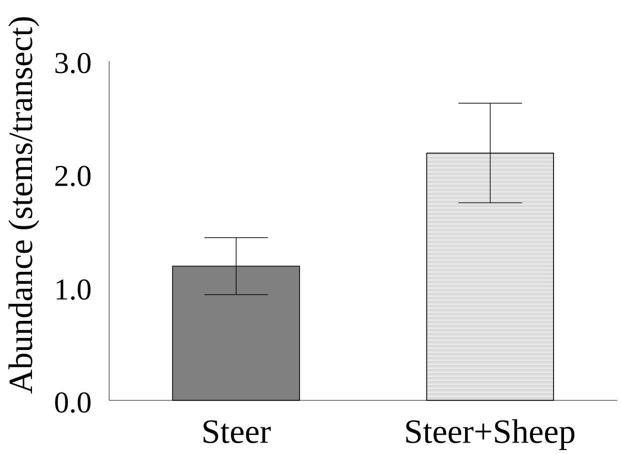


Table 3.1 Number of days within the incubation (nest initiation to hatching) and nestling (hatching to fledging) stages of the nesting period for Eastern Meadowlarks, Grasshopper Sparrows, and Dickcissels.

	Incubation	Nestling
Eastern Meadowlark[a]	18.5	11.5
Grasshopper Sparrow[b]	11	9
Dickcissel[c]	12	9

a. Values from Roseberry and Klimstra (1970)

b. Values from Hovick et al. (2012)

c. Values from Winter (1999)

Table 3.2 Avian species identified during 50 m radius point-count surveys conducted from mid-May to early June in 2015 and 2016 in 248 ha of tall-grass prairie in Woodson County, Kansas. Grazing treatments (Steer and Steer+Sheep) were applied to 4 replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year.

		Number Counted			
Common Name	Scientific Name	Steer	Steer+Sheep	Total	Proportion
Grasshopper Sparrow	*Ammodramus savannarum*	71	105	176	0.28
Dickcissel	*Spiza americana*	60	61	121	0.19
Eastern Meadowlark	*Sturnella neglecta*	37	37	74	0.12
Barn Swallow	*Hirundo rustica*	10	12	22	0.03
Brown-headed Cowbird	*Molothrus ater*	12	6	18	0.03
Killdeer	*Charadrius vociferus*	1	7	8	0.01
Common Nighthawk	*Chordeiles minor*	1	3	4	0.01
Red-winged Blackbird	*Agelaius phoeniceus*	3	0	3	<0.01
Tree Swallow	*Tachycineta bicolor*	2	1	3	<0.01
Field Sparrow	*Spizella pusilla*	1	1	2	<0.01
Northern Mockingbird	*Mimus polygottos*	2	0	2	<0.01
Blue-gray Gnatcatcher	*Polioptila caerulea*	1	0	1	<0.01
Brown Thrasher	*Toxostoma rufum*	1	0	1	<0.01
Mourning Dove	*Zenaida macroura*	0	1	1	<0.01
Scissor-tailed Flycatcher	*Tyrannus forficatus*	1	0	1	<0.01
Vesper Sparrow	*Pooecetes gramineus*	0	1	1	<0.01

Table 3.3 Detection probabilities, 95% upper confidence interval (UCI) and 95% lower confidence interval (LCI) for Dickcissels, Grasshopper Sparrows, Eastern Meadowlarks, and Brown-headed Cowbirds as calculated in Program Distance from 50-m radius point count data collected in mid-May to early June in 2015 and 2015 in 248 ha of tall-grass prairie in Woodson County, Kansas. Grazing treatments (Steer and Steer+Sheep) were each applied to four replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year.

Species	Treatment	Detection Probability	LCI	UCI
Eastern Meadowlark	Steer	1	0.58	1
	Steer+Sheep	1	0.59	1
Grasshopper Sparrow	Steer	1	0.62	1
	Steer+Sheep	1	0.69	1
Dickcissel	Steer	1	0.6	1
	Steer+Sheep	1	0.65	1
Brown-headed Cowbird	Steer	1	0.43	1
	Steer+Sheep	0.81	0.21	1

Table 3.4 Number of nests located and monitored from late May to mid-July 2015 and 2016 in 248 ha of tall-grass prairie in Woodson County, Kansas. Grazing treatments (Steer and Steer+Sheep) were each applied to four replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year.

Treatment	Species	2015 Nests	2016 Nests	Total Nests
Steer	Eastern Meadowlark	4	20	24
	Grasshopper Sparrow	3	6	9
	Dickcissel	3	8	11
Steer+Sheep	Eastern Meadowlark	5	12	17
	Grasshopper Sparrow	5	9	14
	Dickcissel	3	3	6

Table 3.5 Ranking of competing nest survival models for each species of grassland songbird within the incubation and nestling stages for three nesting grassland species in 248 ha of tall-grass prairie in Woodson County, Kansas, from late May to mid-July 2015 and 2016. Each grazing treatment (Steer and Steer+Sheep) was applied to four replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year.

Species	Stage	Model	Dev.[a]	K[b]	ΔAIC_c[c]	w_i[d]
Eastern Meadowlark	Incubation	Null[e]	114.3	1	0[i]	0.7
		Treatment[f]	113.9	2	1.7	0.3
		Day[g]	84.2	44	76.5	0
		Treatment*Day[h]	71.9	81	203.3	0
	Nestling	Null	48.7	1	0[j]	0.7
		Treatment	48.5	2	1.7	0.3
		Day	33.3	26	55.6	0
		Treatment*Day	20.5	50	191.1	0
Grasshopper Sparrow	Incubation	Null	44.2	1	0[k]	0.63
		Treatment	43.2	2	1.11	0.37
		Day	17	35	87.4	0
		Treatment*Day	2.8	44	132.5	0
	Nestling	Null	31.6	1	0[l]	0.74
		Treatment	31.6	2	2.1	0.26
		Day	13.9	34	136.3	0
		Treatment*Day	13.2	39	199.3	0
Dickcissel	Incubation	Treatment	29.2	2	0[m]	0.74
		Null	33.5	1	2.2	0.25
		Day	19.6	21	53.1	0
		Treatment*Day	8.3	27	77.7	0
	Nestling	Null	9.0	1	0[n]	0.65
		Treatment	7.8	2	1.3	0.35
		Day	2.8	16	204.9	0
		Treatment*Day	2.8	16	204.9	0

a. Deviance

b. Number of parameters

c. Difference in Akaike's Information Criterion corrected for small sample size

d. Akaike weight

e. Estimates daily nest survival disregarding any grouping or time

f. Estimates daily nest survival for each fire treatment (i.e., Spring Fire, Mid-Summer Fire, and Late Summer Fire)

g. Estimates daily nest survival for each day within the nesting period

h. Estimates daily nest survival considering an interaction between treatment and day of nesting period.

i. Minimum AIC_c = 116.30

j. Minimum AIC_c = 50.91

k. Minimum AIC_c = 46.23

l. Minimum AIC_c = 33.70

m. Minimum AIC_c = 33.38

n. Minimum AIC_c = 11.22

Table 3.6 Period survival estimates (±SE) and daily survival rate (DSR) estimates (±SE) within the incubation and nestling stages for Eastern Meadowlark, Grasshopper Sparrow, and Dickcissel nests within each treatment (Steer and Steer+Sheep) and for both treatments combined. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year. Bold values indicate estimates derived from top-ranking models based on AIC_c. Nests were located in 248 ha of tall-grass prairie in Woodson County, Kansas, from late May to mid-July 2015 and 2016. Grazing treatments were each applied to four replicate plots from 2013 to 2016.

		Eastern Meadowlark		Grasshopper Sparrow		Dickcissel	
		Incubation	Nestling	Incubation	Nestling	Incubation	Nestling
Steer	Period Survival	0.1180	0.3359	0.4354	0.3191	**0.3204**	0.5970
	Period SE	0.0586	0.1644	0.1818	0.2119	**0.1636**	0.3084
	DSR	0.8909	0.9095	0.9272	0.8808	**0.9095**	0.9443
	DSR SE	0.0239	0.0387	0.0352	0.0650	**0.0387**	0.0542
Steer+Sheep	Period Survival	0.1875	0.2043	0.2078	0.2704	**0.0047**	0.0640
	Period SE	0.1113	0.1332	0.1340	0.1651	**0.0138**	0.1821
	DSR	0.9135	0.8710	0.8669	0.8879	**0.6399**	0.7368
	DSR SE	0.0293	0.0494	0.0508	0.0475	**0.1558**	0.2330
Combined	Period Survival	**0.1392**	**0.2683**	**0.2738**	**0.2621**	0.1777	**0.4220**
	Period SE	**0.0533**	**0.1069**	**0.1157**	**0.1302**	0.1032	**0.2583**
	DSR	**0.8989**	**0.8919**	**0.8999**	**0.8854**	0.8659	**0.9086**
	DSR SE	**0.0186**	**0.0309**	**0.0302**	**0.0383**	0.0419	**0.0618**

Table 3.7 Butterfly species identified during transect surveys conducted from June to September in 2015 and May to September in 2016. Study site consists of 248 ha of tall-grass prairie in Woodson County, Kansas. Grazing treatments (Steer and Steer+Sheep) were each applied to four replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year.

		Number Counted			
Common Name	Scientific Name	Steer	Steer+Sheep	Total	Proportion
Eastern Tailed-blue[g]	*Cupido comyntas*	744	992	1736	0.82
Grass Skipper spp.[g,s]	Family Hesperiidae, subfamily Hesperiinae	50	53	103	0.05
Sulphur spp.[g]	*Colias* spp. and *Nathalis* spp.	64	42	106	0.05
Pearl Crescent[g]	*Phyciodes tharos*	18	22	40	0.02
Monarch[g]	*Danaus plexippus*	19	15	34	0.02
Silvery Checkerspot[g]	*Chlosyne nycteis*	13	13	26	0.01
Common Wood-nymph[s]	*Cercyonis pegala*	11	11	22	0.01
Common Buckeye[g]	*Junonia coenia*	2	4	6	0.00
Black Swallowtail[g]	*Papilio polyxenes*	3	3	6	0.00
Azure spp.[g]	*Celastrina* spp.	3	2	5	0.00
Gray Hairstreak[g]	*Strymon melinus*	4	1	5	0.00
Variegated Fritillary[g]	*Euptoieta claudia*	2	3	5	0.00
Checkered White[g]	*Pontia protodice*	3	2	5	0.00
Cabbage White[g]	*Pieris rapae*	3	1	4	0.00
Common Checkered-skipper[g]	*Pyrgus communis*	2	1	3	0.00
Common Sootywing[g]	*Pholisora catullus*	1	2	3	0.00
Regal Fritillary[s]	*Speyeria idalia*	2	0	2	0.00
Great Spangled Fritillary[s]	*Speyeria cybele*	1	0	1	0.00
Red Admiral[g]	*Vanessa atalanta*	0	1	1	0.00
Painted Lady[g]	*Vanessa cardui*	0	1	1	0.00

g = Generalist species

s = Grassland specialist species

Table 3.8 Forb and shrub plants identified to genus or species along permanent 100-m transects surveyed once per year in 2015 and 2016. Study site consisted of 248 ha of tall-grass prairie in Woodson County, Kansas. Grazing treatments (Steer and Steer+Sheep) were each applied to four replicate plots from 2013 to 2016. Steer plots were grazed by steers from mid-April and mid-July and rested the remainder of the year. Steer+Sheep plots were grazed by steers from mid-April to mid-July, grazed by sheep from early August to early October, and rested the remainder of the year.

		Number Counted			
Common Name	Scientific Name	Steer	Steer+Sheep	Total	Proportion
Sericea lespedeza[g]	*Lespedeza cuneata*	92	209	301	0.46
Ironweed spp.[s]	*Vernonia* spp.	38	68	106	0.16
Red clover[g]	*Trifolium pratense*	14	59	73	0.11
Korean clover	*Kummerowia stipulacea*	19	26	45	0.07
Common ragweed	*Ambrosia artemisiifolia*	16	13	29	0.04
Spanish needles	*Bidens alba*	8	9	17	0.03
Smooth-seed wild bean	*Strophostyles leiosperma*	15	0	15	0.02
White clover[g]	*Trifolium repens*	1	6	7	0.01
Toothed spurge	*Poinsettia dentata*	6	0	6	0.01
Birdsfoot trefoil[g]	*Lotus corniculatus*	0	5	5	0.01
Prairie broomweed	*Amphiachyris dracunculiodes*	0	4	4	0.01
Green antelopehorn milkweed[g]	*Asclepias viridis*	2	2	4	0.01
Violet wood sorrel	*Oxalis violacea*	2	2	4	0.01
Leadplant[g]	*Amorpha canescens*	3	0	3	<0.01
Wild Licorice	*Glycyrrhiza glutinosa*	3	0	3	<0.01
Prickly lettuce	*Lactuca serriola*	0	3	3	<0.01
Common burdock	*Arctium munus*	2	0	2	<0.01
False boneset	*Brickellia eupatorioides*	0	2	2	<0.01
Leafy spurge[g]	*Euphorbia esula*	2	0	2	<0.01
Catclaw sensitive briar[g]	*Mimosa nuttallii*	2	0	2	<0.01
Prairie petunia[g]	*Ruellia humilis*	2	0	2	<0.01
Crownvetch	*Securigera varia*	1	1	2	<0.01
Carolina horsenettle[g]	*Solanum carolinense*	1	1	2	<0.01

Large hop clover[g]	*Trifolium campestre*	0	2	2	<0.01
Pigweed	*Amaranthus rudis*	1	0	1	<0.01
Wild mustard	*Brassica kaber*	0	1	1	<0.01
Purple prairie clover[g]	*Dalea purpurea*	0	1	1	<0.01
Tickclover[g]	*Desmodium illinoense*	1	0	1	<0.01
Horseweedg	*Erigeron canadensis*	0	1	1	<0.01
Daisy fleabane[g]	*Erigeron strigosus*	1	0	1	<0.01
Yellow trefoil[g]	*Medicago lupulina*	1	0	1	<0.01
Goldenrod spp.[g]	*Solidago* spp.	0	1	1	<0.01
Chickweed	*Stellaria media*	0	1	1	<0.01
Bracted spiderwort[g]	*Tradescantia bracteata*	0	1	1	<0.01
Venus' looking glass	*Triodanis perfoliata*	0	1	1	<0.01
Moth mullein	*Verbascum blattaria*	1	0	1	<0.01
Hairy vetch	*Vicia villosa*	1	0	1	<0.01

g = Species within the genus documented as a nectar source for generalist butterfly species by Moranz (2010) and Moranz et al. (2012)

s = Species within the genus documented as a nectar source for grassland specialist butterfly species by Moranz (2010