Responses of grassland birds to patch-burn grazing in the Flint Hills of Kansas

by

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Abstract

Grassland birds are declining throughout their native range. The Flint Hills of eastern Kansas and Oklahoma contain large tracts of tallgrass prairie, but intensification of agricultural practices may be contributing to ongoing population declines. Common rangeland management practices include annual burning coupled with heavy grazing by cattle. This system, known as intensive early stocking and burning, promotes homogeneous utilization of forage by cattle but may not provide habitat for some grassland bird species. Patch-burn grazing is an alternative management system that aims to restore heterogeneity on rangelands by recreating the fire-grazing interaction that would have historically occurred throughout the Great Plains. From 2011-2013, we examined responses of grassland birds to traditional rangeland management and patch-burn grazing by conducting vegetation surveys, line transect surveys, and nest monitoring on privately-owned pastures in Chase County and Greenwood County, Kansas. Vegetative heterogeneity was higher on patch-burned pastures, with unburned patches having higher visual obstruction and less bare ground. Densities of grassland birds differed by species and among habitat strata. Unburned patches on patch-burned pastures were associated with increased densities of Dickcissels (*Spiza americana*), Eastern Meadowlarks (*Sturnella magna*) and Grasshopper Sparrows (*Ammodramus savannarum*). Henslow's Sparrows (*A. henslowii*) were only detected on patch-burned pastures. Nest survival of grassland songbirds was similar among management systems but varied by year. Probability of nest parasitism by Brown-headed Cowbirds (*Molothrus ater*) varied among years and between treatments for Dickcissels and Grasshopper Sparrows, with overall lower rates on burned areas and during drought years. For Dickcissels and Grasshopper Sparrows, there was a significant reduction in host clutch size between parasitized versus unparasitized nests. Overall, nest survival of grassland songbirds in managed rangelands was low. Patch-burn grazing improved rangeland conditions and provided habitat for more species of birds, but did not increase nest survival. Drought conditions in 2012 and 2013 may have influenced the results of this study, as many landowners were unable to burn as planned. Further study is needed to determine underlying factors driving variation in nest success and parasitism rates for grassland birds, particularly on private lands which make up the vast majority of remnant tallgrass prairies.

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Dedication

This thesis is dedicated to the birds that inspire me. I do not often look at birds with a scientific eye - this project being the one major exception in my life. To me, a bird is more than just the sum of its parts, and the things that I want to learn from birds cannot be found in any book or journal article. I find them fascinating in so many ways. It's the light in their eyes, their quirky movements, the way their feathers shimmer across their body. I see them all as beautiful individuals, each one a miracle of form and function. The thing that compells me to look at birds cannot be written down on a data sheet and analyzed on a computer. I rarely keep a list or take notes when I am looking at birds. The benefit I get from observing them is personal, intimate, not meant to be shared. Birds simply make me feel happy.

Chapter 1 - Introduction

Grasslands are one of the most widespread biomes found on our planet, covering an estimated 31 to 43% of Earth's terrestrial surface (Whittaker and Likens 1975, Atjay et al. 1979, Olson et al. 1983). All of the world's grasslands have been reduced in size due to changes in human land use practices, but the tallgrass prairie ecosystem has experienced the most dramatic area reduction of any biome in North America. Today, the North American tallgrass prairie covers less than 4% of its historical extent (Samson and Knopf 1994), with 71% of the area converted to row-crop agriculture and 19% transformed into urban landscapes (White et al. 2000).

The conversion of native prairie to agricultural production was mostly completed by the 1940s (Waisanen and Bliss 2002). A notable exception is the Flint Hills ecoregion of eastern Kansas and northeastern Oklahoma. The steep slopes and rocky soils of the Flint Hills are unsuitable for row crop agriculture and most of the area remains intact with native vegetation. Today, more than 90% of the Flint Hills are intensively managed with prescribed fire and grazing to support a major cattle industry with an inventory of over one million cattle and annual sales exceeding $500 million (With et al. 2008, USDA 2012). Around 80% of the remaining North American tallgrass prairie is found in the Flint Hills, and the ecoregion is often considered by conservationists to be vital to the long-term persistence of many sensitive species of grassland birds (Svedarsky et al. 2003, Reinking 2005).

Less than 2 percent of the land in Kansas is publically owned (US General Services Administration 2013), which creates unique challenges and opportunities for conservationists since management practices for the majority of the tallgrass prairie are left to the discretion of private landowners. By the 1980s, rangeland management in the Flint Hills had shifted from periodic prescribed burning with season-long stocking of steers or cow-calf pairs to a system based on annual spring burning combined with intensive early stocking of steers or cow-calf pairs during April–July (IESB; Smith and Owensby 1978). The intensive early stocking management system aims to maximize livestock production by promoting the growth of high quality forage and allows ranchers to stock rangelands with a greater number of cattle early in the growing season for a shorter period of time. Consequently, most of the Flint Hills is under a more intensive rangeland management than the ecoregion would have experienced historically with periodic grazing by native ungulates such as Plains Bison (*Bison bison*) and wildfires lit by lightning strikes or native people.

One of the guiding principles of rangeland management is to maintain uniform grazing across the landscape (Holechek et al. 2010). Uniform grazing is thought to improve animal performance but leads to a homogeneous landscape without the patchy mosaic of habitat types formed by natural wildfires and spatial variation in grazing intensity (Fuhlendorf and Engle 2001, 2004). Implementation of intensive early stocking and other intensive grazing practices has coincided with ongoing declines in the diversity and abundance of native species of grassland wildlife (Zimmerman 1997, Reinking 2005, Fuhlendorf et al. 2006, Rahmig et al. 2009).

Heterogeneity-based management systems, such as patch-burn grazing (PBG), recreate natural fire-grazing interactions and may be beneficial for birds (Herkert et al. 1996, Fuhlendorf et al. 2006, Churchwell et al. 2008, Davis et al. 2016, Hovick and Miller 2016), as well as grassland plants (Hobbs et al. 1992, Vinton et al. 1993, Fuhlendorf and Engle 2004), insects (Swengel 2001, Engle et al. 2008), and small mammals (Fuhlendorf et al. 2010, Ricketts and Sandercock 2016). Under a patch-burn grazing management, a portion of a pasture (generally one-third) is burned each year on a rotational schedule. There are no cross-fences between the burn treatments within each pasture, giving cattle potential access to both burned and unburned areas for grazing. Cattle prefer to graze on the high-quality forage in the most recently burned areas, allowing taller vegetation and litter to accumulate on unburned patches. Rotational fire and grazing increases spatial heterogeneity of the vegetation, leading to floristic and structural variability that can increase grassland wildlife diversity, provide enhanced ecosystem functions (Fuhlendorf et al. 2006, Swinton et al. 2007, Churchwell et al. 2008, Coppedge et al. 2008, Black et al. 2011), and can have stabilizing effects on livestock productivity (Allred et al. 2014).

The goal of my field study was to examine how a patch-burn grazing rangeland management system compares with intensive early stocking and annual burning for population dynamics of grassland songbirds. All data for this study were collected on private working lands by consent of local landowners. Since the vast majority of remaining grasslands are privately owned, it is critically important for researchers to work alongside private landowners in the ranching community and to keep their economic and personal goals in mind when making recommendations for grassland wildlife conservation. The ability to control burn frequency and stocking rates is an advantage for experimental work at research sites such as the Tallgrass

Prairie National Preserve in Chase County, KS; the Tallgrass Prairie Preserve in Osage County, OK; and the Konza Prairie Biological Station in Riley County, KS. However, experimental conditions in natural preserves may not accurately reflect the options and choices of local landowners and ranch managers who own and make management decisions for livestock production on the vast majority of remaining tallgrass prairies. My field study aims to look at the effects of different rangeland management strategies as initiated by local landowners and ranch managers.

My Master's thesis is divided into four chapters. Here, I provide a short history of the North American tallgrass prairie along with an overview of different rangeland management systems and how they may affect grassland wildlife. In chapter two, I compare vegetation data and species-specific line transect survey data across a gradient of rangeland management systems. Line transect data were collected over three field seasons and include six pastures and 432 surveys conducted during three survey rounds each summer. Changes in bird density are one possible response to habitat conditions in managed rangelands, and I predicted greater benefits for specialist species that need undisturbed prairie during the breeding season. In chapter three, I compare nest survival and nest parasitism rates for four species of grassland songbirds between two pastures: one managed with intensive early stocking and annual spring burning and one managed with patch-burn grazing with a three-year burn rotation. I predicted that patch-burn grazing would lead to greater heterogeneity in habitat conditions, potentially aiding nest concealment to increase nest survival of grassland songbirds and reduce nest parasitism by Brown-headed Cowbirds (*Molothrus ater*). Nest survival data were collected over three breeding seasons and, along with the vegetation surveys and line transect surveys, spans one full burn rotation within the PBG pasture. In chapter four, I synthesize the results of my field study and discuss implications of my project results for wildlife conservation.

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Chapter 2 - Effects of prescribed burns and grazing management on the population densities of six species of grassland birds

Abstract

Grassland birds evolved under a shifting mosaic of habitat patches created via the interaction of fire and large grazing animals. Commonly used management practices on remaining tallgrass prairies include annual fire and heavy stocking rates to promote even grazing and homogenous utilization of forage by livestock, which may not create adequate habitat for some grassland obligate species. Heterogeneity-based management systems such as patch-burn grazing may provide habitat for more species of grassland birds than traditional management practices. We examined vegetation characteristics and grassland bird densities on six privately-owned pastures in the Flint Hills of Kansas. Three pastures were managed with patch-burn grazing, two pastures were managed with intensive-early stocking and annual spring burning, and one pasture was managed with season-long stocking and annual spring burning. Vegetative heterogeneity was higher on patch-burned pastures, with higher visual obstruction and percent cover of grass on unburned patches. Densities of six species of grassland birds differed among habitat strata. Unburned patches on patch-burned pastures were associated with increased densities of Dickcissels, Eastern Meadowlarks and Grasshopper Sparrows. Upland Sandpipers, which prefer shorter vegetation in disturbed sites, were found at highest densities on burned and heavily grazed areas. Brown-headed Cowbirds, an obligate brood parasite, were found in all habitat strata but were at highest densities on unburned patches and in the season-long stocked pasture. One habitat specialist, the Henslow's Sparrow, was only found on patch-burned pastures with greater vegetative structure. Overall, our field study indicates that patch-burn management creates vegetative heterogeneity which leads to a higher density of some grassland bird species and provides habitat for more species than rangeland management practices that promote homogeneous utilization of forage by domestic livestock.

Introduction

Grassland bird populations have declined sharply throughout their range, more so than any other guild of birds in North America (Sampson and Knopf 1994, Peterjohn and Sauer 1999, With et al. 2008). Conversion of native grasslands to agriculture has slowed considerably since the 1940s (Waisanen and Bliss 2002), but grassland bird populations have continued to decline. Current agricultural practices on extant grasslands are often much more intensive than natural events such as grazing by Bison (*Bison bison*) and other native ungulates following periodic fires lit by lightning strikes or native people. Intensive livestock grazing during the growing season and frequent use of prescribed fire on remaining grasslands may make otherwise suitable habitat unavailable for use by many native grassland bird species.

The Flint Hills ecoregion of eastern Kansas and Oklahoma represents the largest intact tallgrass prairie landscape in the world. The vast majority of the land in Kansas is privately owned (>98%), leaving management decisions on most of the remaining tallgrass prairie up to the discretion of local landowners. The Flint Hills contain nearly two million hectares of native tallgrass prairie and the ecoregion is intensively managed for cattle production with an inventory of over one million cattle and annual sales of over $500 million (USDA 2012). A common management practice in the Flint Hills involves complete burning of pastures every year in March or April followed by double-stocking of cattle (usually steers) for ~90 days early in the growing season. This management system, known as *intensive early stocking and burning* (IESB, Smith and Owensby 1978), aims to maximize livestock production by promoting homogeneous use of forage by cattle. Another common management practice, *season-long stocking and burning* (SLSB), is similar to IESB in that entire pastures are burned on an annual basis to promote even forage utilization. With SLSB, steers or cow-calf pairs are stocked at a lower density for a longer duration, usually 150-180 days.

Implementation of intensive early stocking and other intensive grazing practices has coincided with ongoing declines in the diversity and abundance of native species of grassland wildlife (Zimmerman 1997, Reinking 2005, Fuhlendorf et al. 2006, Rahmig et al. 2009). While IESB management may create useable habitat for some habitat generalists, uniform heavy grazing produces a landscape without the patchiness that would have been present prior to the 1800s (Fuhlendorf et al. 2006). Sensitive species that are dependent on taller vegetation or a deep litter layer for parts of their life cycle, such as Henslow's Sparrows (*Ammodramus henslowii*;

Reinking 2005, Powell 2006) and Greater Prairie-Chickens (*Tympanuchus cupido*; Robbins et al. 2002, McNew et al. 2015, Winder et al. 2016), are often absent from prairies that are annually burned and intensively grazed.

Prior to the 1800s, the natural interaction of fire and grazing animals created a heterogeneous mosaic of habitat patches across the tallgrass prairie landscape. Grassland birds evolved under this system, and each species has a unique set of habitat requirements for nesting and brood-rearing. Grassland patches of various sizes that had been recently burned and heavily grazed could be found alongside areas that had not been burned or grazed for a number of years. Recently burned areas would attract bison and other grazing animals which would seek out the nutritious vegetation that emerges after a burn. Heavily grazed burned areas would consist of short vegetation, increased bare ground, and little to no litter or standing dead vegetation. Unburned areas would receive comparatively light grazing pressure, accumulating a deeper litter layer and standing dead vegetation over time. Unburned areas would be more susceptible to fires than recently grazed areas, leading to a mosaic of habitat patches that shifted across time and space, providing habitat for a diverse community of grassland bird species.

Patch-burn grazing (PBG) rangeland management systems aim to increase heterogeneity on rangelands via restoration of the fire-grazing interaction, often referred to as pyric herbivory. Under a patch-burn grazing management, a portion (generally one-third) of a pasture is burned each year on a rotational schedule. There are no cross-fences in the pasture, giving cattle potential access to both burned and unburned areas on which to graze. Cattle, much like bison, spend the majority of their time grazing on the most recently burned areas which allows standing dead plant material and litter to accumulate on unburned patches. Uneven utilization of forage across a pasture produces a patchy landscape that may provide habitat for more species of grassland-nesting birds than traditional management based on uniform grazing (Fuhlendorf et al. 2006, Coppedge et al. 2008, Duchardt et al. 2016).

We studied vegetation characteristics and population densities of grassland birds over three years in six pastures managed by private landowners. We sampled vegetation on all six pastures and predicted that pastures managed with patch-burn grazing would have greater vegetative heterogeneity than pastures that were annually burned and uniformly grazed. We predicted that visual obstruction and percent cover of grass would be higher at sites that had not been recently burned, and that percent cover of bare ground would be higher on burned areas which received heavier grazing pressure.

Unburned sites have more accumulated plant biomass, which provides cover for ground-nesting birds. Therefore, we predicted that species requiring standing dead vegetation and a deep litter layer during the breeding season, such as Henslow's Sparrows, would only be found on areas that had not been burned during the previous two years. We predicted that annually burned and grazed pastures would provide useable habitat for grassland generalists such as Dickcissels and species that prefer bare ground and short grass for at least part of their breeding cycle such as Upland Sandpipers. We predicted that more bird species would be present on patch-burned pastures due to vegetative heterogeneity providing structurally diverse habitat patches.

Methods

Study Site

We selected six pastures in Chase County and Greenwood County, Kansas for vegetation surveys and line transect surveys of bird populations (Figure 2.1). Data were collected from mid-May to late July in 2011 to 2013. Three pastures were managed with patch-burn grazing and three pastures were managed with more common burning and grazing practices (Figure 2.2). Pasture size ranged from 376-587 hectares with an average pasture size of 466 hectares. Intensive early stocking and annual spring burning is one of the dominant rangeland management practices in the Flint Hills, but private landowners often choose to manage their land in other ways. Among the three pastures not managed with patch-burn grazing, two were managed with intensive early stocking and annual spring burning and one was annually burned but stocked with fewer cattle for a longer duration (season-long stocking and burning; SLSB). Patch-burned pastures chosen for this study had been managed under the system for at least three years and thus had undergone at least one full burn rotation before the study began. Stocking densities ranged from 0.8-2.1 hectares/head for a target utilization of 50% of the current year's growth, and burns were conducted in April or May (Table 2.1). Due to drought conditions in 2012 and 2013, some pastures were not burned as planned due to inadequate fuel load to carry a fire. Habitat conditions in heavily grazed pastures in drought years were comparable to burned pastures. Pasture burning is an important management practice used to increase livestock production throughout the Flint Hills, and Chase County and Greenwood County are intensively managed with prescribed fire. On average, 56% of Chase County's grasslands and 40% of Greenwood County's grasslands are burned every year (Mohler and Goodin 2012). Landowners controlled burn regimes, timing of spring burns, and cattle stocking rates for all pastures used in the study.

The climate in Chase and Greenwood counties is moderately humid during the growing season, with an average annual rainfall of 900 millimeters that occurs mainly from April to October. Late summer droughts in July and August are not uncommon. Winters are generally mild, although the temperature may fall below freezing for a few days at a time. Average annual snowfall is around 250 millimeters (Byers et al. 1914, Goodin et al. 1995).

The main soils in Chase and Greenwood County include well-drained cherty or silty clay loam underlain by limestone. The topography in this region of the Flint Hills consists of rolling hills where elevation ranges from a low of 275 meters along the Verdigris River to a high of around 500 meters along some of the ridges and hilltops (Byers et al. 1914, USDA Soil Conservation Service 1974).

Our study pastures were dominated by native warm-season bunchgrasses including Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium)*. Common forbs included ragweed (*Ambrosia* spp.), common yarrow (*Achillea millefolium*), goldenrod (*Solidago* spp.), ironweed (*Vernonia baldwinii*), blue wild indigo (*Baptisia australis*), and milkweed (*Asclepias* spp.). Shrubs and trees are relatively uncommon in tallgrass prairies that are managed with fire, but small patches of prairie were dominated by Eastern redcedar (*Juniperus virginianus*), rough-leaved dogwood (*Cornus drummondii)*, buckbrush (*Symphoricarpos orbiculatos*), and smooth sumac (*Rhus glabra*).

Study Species

We focused on six species of grassland birds for our field study: Upland Sandpiper (*Bartramia longicauda)*, Henslow's Sparrow (*Ammodramus henslowii*), Grasshopper Sparrow (*A. savannarum*), Dickcissel (*Spiza americana*), Eastern Meadowlark (*Sturnella magna*), and Brown-headed Cowbird (*Molothrus ater*).

Unlike most shorebirds, the Upland Sandpiper is an obligate grassland species that is rarely associated with coastal or wetland habitats. Upland Sandpipers use disturbed areas with low to moderate forb cover, low woody cover, moderate grass cover, moderate to high litter cover, and little bare ground (Kantrud and Higgins 1992, Dechant et al. 1999a). Moderate amounts of forbs may be an important component of suitable nesting habitat (Buhnerkempe and Westemeier 1988, Sandercock et al. 2015). Brood rearing occurs mostly in heavily grazed (vegetation <10 cm tall) pastures, followed by ungrazed pastures and hayfields (Ailes 1980). Breeding Bird Survey data collected between 1966-2015 show a survey-wide increase of 0.40% per year for Upland Sandpipers, but a decline of -1.9% per year in the Eastern tallgrass prairie region that includes our study area (Sauer et al. 2017).

Henslow's Sparrows are specialists that use grasslands with a well-developed litter layer, relatively high cover of standing dead vegetation, and generally low densities of woody stems (Herkert 2002). Henslow's Sparrow habitat is characterized by a high percentage of native grass cover and scattered forbs for song perches (Robins 1971, Herkert 1994). Henslow's Sparrows may use areas with a low density of woody vegetation (Cully and Michaels 2000), but woody encroachment eventually precludes use by this species (Melde and Koford 1996). Henslow's Sparrows are usually not found in areas that have been recently burned (>13 months; Applegate et al. 2002, Fuhlendorf et al. 2006). Breeding Bird Survey data collected between 1966-2015 show a survey-wide decline of -1.53% per year for Henslow's Sparrows, but an increase of 3.11% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

Grasshopper Sparrows can be found in various grassland habitats, but prefer to nest in grasslands of intermediate height with a clumped vegetation structure and occasional patches of bare ground (Blankespoor 1980, Vickery 1996). The species has been observed nesting in native prairies, pastures, hay fields, and occasionally in crop fields such as corn and oats (Dechant et al. 1998). Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -2.52% per year for Grasshopper Sparrows, and a decline of -4.08% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

Dickcissels are habitat generalists and have been observed nesting in fallow fields, hayfields, fencerows, hedgerows, road rights-of-way, waterways, stubble fields, planted cover such as Conservation Reserve Program fields, grazed prairies, ungrazed prairies, and idle prairies (Dechant et al. 1999b). The species prefers somewhat dense vegetation cover, moderate to tall vegetation, a moderately deep litter layer, and a strong forb component with many elevated song perches (Harmeson 1974, Patterson and Best 1996). Breeding Bird Survey data collected between 1966-2015 show a survey-wide decline of -0.36% per year for Dickcissels, and a decline of -1.0% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

Eastern Meadowlarks nest in pastures, meadows, hay fields, or other grassland habitat; less often in cultivated fields (Roseberry and Klimstra 1970). In Kansas tallgrass prairies, Eastern Meadowlarks tend to select nest sites with higher vertical vegetation density (Hubbard et al. 2006, Frey et al. 2008) and with greater litter depth, less bare ground, and increased distance from large patches of bare ground. Nest sites of Eastern Meadowlarks have been associated with greater amounts of standing dead vegetation, deeper litter, and taller vegetation (Warren and Anderson 2005). Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -3.28% per year for Eastern Meadowlarks, and a decline of -2.28% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

The Brown-headed Cowbird is an obligate brood parasite that was once restricted to open grasslands in central North America but has expanded its geographic range following the clearing of forests and other human land-use changes (Mayfield 1965, Rothstein et al. 1980). Over 170 species of hosts have been reported as being parasitized by Brown-headed Cowbirds (Lowther et al. 1993, Rivers et al. 2012). Brown-headed Cowbirds may remove host eggs or even destroy broods of young to induce the host to renest (Hoover and Robinson 2007). Brown-headed Cowbird nestlings generally hatch and fledge alongside the host young, but their presence in the nest can decrease fecundity for the host species (Jensen and Cully 2005, Kosciuch and Sandercock 2008). Brown-headed Cowbirds are not a species of conservation concern, but Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -0.66% per year and a decline of -0.61% per year in the Eastern tallgrass prairie region (Sauer et al. 2017). Brown-headed Cowbirds are primarily of interest for their potential effects on the reproductive output of native species of grassland songbirds.

Field Methods

Vegetation Surveys

We collected vegetation data twice during each field season from 2011 to 2013. Vegetation was sampled along two 300-meter transects in each pasture and in each patch of the patch-burned pastures. Sampling points were spaced 75 meters apart for a total of 5 points along each transect. Vegetation sampling was performed once in mid-June at the height of the growing season, and again in mid-July as the warm season grasses began to senesce. A total of 240 vegetation points were sampled each year for a total of 720 sampling points during the three-year study.

At each vegetation sampling point, a Robel pole was used to estimate visual obstruction (VOR; Robel et al. 1970). Visual obstruction was estimated using a two-meter tall PVC pole marked with alternating red and white bands at 1 decimeter intervals. Readings were taken from a height of 1 meter and a distance of 3 meters. A Daubenmire frame was used to assess habitat cover. A 20x50 centimeter frame was placed next to the Robel pole and we visually estimated the percent cover of grass, forbs, shrubs, bare ground and litter inside the frame. Litter depth in millimeters was recorded in the bottom right corner of the frame. Three samples were taken in each of the four cardinal directions for a total of 12 samples at each point. The 12 samples were averaged to obtain an overall estimate of ground cover around each point.

Line Transects

From 2011 to 2013, birds were surveyed along 300-meter line transects (Figure 2.3). Eight transects were placed at random in each pasture and in each patch of the patch-burned pastures. ArcGIS was used to randomly assign a starting point to each transect (ESRI 2011), and a random number table was generated in Microsoft Excel to assign a compass bearing from 0-359 degrees to determine which direction each transect would run. A 100-meter buffer was drawn inside each pasture and each patch of the patch-burned pastures to ensure that birds outside of the survey area were not counted. Due to small patch size of patch-burned pastures, it was not possible to assign a random start point and direction to each transect. Here, transects were placed at least 200 meters apart. Transects on the remaining pastures were at least 300 meters apart. Bird detections were assumed to be independent on each transect. A total of 96 transects were placed across the study site. We completed 144 surveys per season for a total of 432 surveys over the three-year study period.

Surveys were completed during three 2-week survey rounds beginning in mid-May and ending in early July. Two of the eight transects in each patch or pasture were designated as primary transects and were surveyed during each of the three survey rounds. The remaining six transects were surveyed once each season. Observers and survey order were rotated between sampling sessions to avoid effects of temporal or observer bias. Primary transects were the same lines used for the vegetation surveys.

Bird surveys were started no earlier than 15 minutes before sunrise and completed no later than 10:00 a.m. CST. Each 300 meter survey took 25-30 minutes to complete. Before beginning a survey, observers waited at the transect start point for five minutes and recorded wind speed, cloud cover, and temperature. Surveys were not conducted when wind speed was higher than 20 kilometers per hour or if it was raining or extremely foggy. During the survey, observers walked in a straight line using a handheld GPS to navigate from the start point in the designated direction and recorded data on every bird seen or heard. We identified all birds to species and recorded group size and perpendicular distance from the line with laser rangefinders. When birds were heard singing or calling but could not be seen, observers recorded the estimated distance to the bird. Transects were of variable width and we recorded all distances without truncation. If birds of the same species were detected in a group, we treated the group sighting as a single cluster and recorded the distance only once. Birds flying overhead were recorded, but flyover detections were not used in the analyses. Each observer was able to complete four surveys per day.

Statistical Analyses

Vegetation Surveys

We tested for differences in vegetative structure on patch-burned pastures versus pastures managed with more common burning and grazing management regimes. We used generalized linear models and analysis of variance (ANOVA) to compare visual obstruction, percent cover of grass, percent cover of forbs, percent cover of bare ground, percent cover of shrub, percent cover of litter, and litter depth on two pastures managed with intensive-early stocking and annual burning, one pasture managed with season-long stocking and annual burning, and on each patch of three pastures managed with patch-burn grazing. All analyses were conducted using the “lme4” package in Program R.

Line Transects

We modeled detections of bird clusters on line transect surveys with the “unmarked” package in Program R. We used the “unmarkedFrameDS” function to combine a reference file containing covariates for each transect with a second file containing bird detections on each transect. The range of possible perpendicular detection distances was bounded between 0-300 meters. We set a bin width of 20 meters for a total of 15 possible bins. Using the "formatDistData" function, detections were summarized as a multinomial distribution with counts of clusters in each 20-meter bin. The "distsamp" function was then used to fit alternative models for probability of detection and abundance.

We fit a model with constant detection and abundance with three different detection functions: exponential, half-normal, and hazard. Detection functions are used to describe the decay in probability of detection away from the center of the line transect. The hazard function was the best fit for all six species and received more support than the other two detection functions ($w_i/w_j > 50x$). We tested for effects of year of study (2011-2013), survey stratum (IESB, PBG0, PBG1, PBG2, SLSB), and survey round (1-3), and used the best fit model for detection to model abundance as a function of these covariates. We used the "predict" function to calculate the density of clusters of birds per hectare. Last, we calculated the estimated survey strip half-width (ESHW) of our line transect for each species using the "integrate" function to calculate the area under the detection curve. For Henslow's Sparrows, we had problems with model convergence because of zero detections at the IESB and SLSB strata. For Henslow's Sparrows, we modeled detection, abundance and ESHW for the PBG0, PBG1 and PBG2 strata only.

Results

Vegetation Surveys

We collected vegetation data at 120 sampling points twice each season for a total of 720 vegetation samples during our three-year field study. Trends were similar for survey round and among years so all data were pooled for the analyses. Treatment strata include intensive-early stocking and annual spring burning (IESB), patch-burn grazing year of burn (PBG0), patch-burn grazing one year since fire (PBG1), patch-burn grazing two years since fire (PBG2), and season-long stocking and annual spring burning (SLSB).

Visual obstruction and percent cover of grass were highest at the PBG2 stratum (median visual obstruction = 2.13 decimeters; median percent cover of grass = 55.31%), which had not been burned during the previous two years (Figure 2.4). PBG0, which received the most intensive grazing pressure of all treatment strata, had the lowest visual obstruction (median = 0.88 decimeters) and the lowest percent cover of grass (median = 32.50%). Forb cover was highest at the SLSB (median = 18.54%) and PBG1 (median = 17.39%) strata, and lowest at the PBG0 (median = 11.57%) stratum. Percent cover of bare ground was highest at the IESB stratum (median = 30.73%) and was low at the PBG2 (median = 1.46%) and PBG1 (median = 7.17%) strata. Percent cover of litter was low overall across all treatment strata (median = 0.63%). The greatest litter depth was found on PBG2 (median = 3.67 mm). Little litter was present on any areas that were burned within the previous year.

We used general linear models with random effects of year, survey round, and property owner to test for differences in vegetative characteristics by treatment strata. A model containing effect of burn treatment was the top model for each vegetation metric measured in our study (Table 2.2). Models testing for differences in visual obstruction, percent cover of grass, percent cover of forb, percent cover of bare ground, percent cover of litter and litter depth by treatment type contained nearly all of the support (w_i = ~1.0) compared to models with no effects of treatment. Differences in shrub cover between treatment strata were less pronounced (w_i = 0.95, P = 0.01). Woody plants are relatively scarce in tallgrass prairie managed with regular fire, and average shrub cover averaged <1% throughout the site.

Line Transects

We completed 432 unique line transect surveys over the three-year study period. We observed 74 bird species in our sample and recorded a total of 9,232 detection clusters after dropping records of flyovers where no perpendicular distance was recorded. The five most abundant species in our surveys were Dickcissels (n = 3,000 clusters), Eastern Meadowlarks (n = 2,007 clusters), Grasshopper Sparrows (n = 1,922 clusters), Brown-headed Cowbirds (n = 450 clusters) and Upland Sandpipers (n = 368 clusters). Henslow's Sparrows were relatively rare (n = 163 clusters), but we modeled survey data for this species as it is a grassland bird of conservation concern in Kansas. Detections of these six species accounted for 86% of all birds recorded in our line transect surveys (7,910 of 9,232 detection clusters).

Model Selection

Effect of year influenced probability of detection for all species. For Upland Sandpipers, an equally parsimonious model (ΔAIC = 0.78, w_i = 0.44) included the effect of survey round on detection probability. For all species, the best fit model for density contained the effect of stratum and received a majority of support within each candidate model set. Thus, densities of all six species differed among the five habitat strata: IESB, PBG0, PBG1, PBG2 and SLSB (Table 2.3).

Detection

We estimated survey strip half-width for each species (Figure 2.5). Large-bodied birds with conspicuous vocalizations such as Upland Sandpipers (Figure 2.5A) and Eastern Meadowlarks (Figure 2.5E) could be detected further from the line transect than smaller birds (143.3 m and 137.8 m, respectively). Henslow's Sparrows are small-bodied, secretive songbirds with a quiet song. Estimated survey strip half-width was short for the species at 67.3 m (Figure 2.5B) . Grasshopper Sparrows are similar in size to Henslow's Sparrows and we were able to detect this species to a median distance of 70.7 m (Figure 2.5C). Estimated strip half-width for Dickcissels was 95.5 m (Figure 2.5D), whereas estimated strip half-width for Brown-headed Cowbirds was 122.4 m (Figure 2.5E).

Density

The effects of fire and grazing on grassland bird densities differed among our six study species (Figure 2.6). Upland Sandpipers are often associated with bare ground and shorter vegetation during the breeding season. The species was most commonly encountered on the SLSB (0.15 birds/ha), PBG0 (0.13 birds/ha), and IESB (0.09 birds/ha) strata. Upland Sandpipers were relatively uncommon on the PBG2 (0.05 birds/ha) and PBG1 (0.07 birds/ha) strata which contained denser vegetation and a deeper litter layer (Figure 2.6A).

Henslow's Sparrows are specialist species that require thick vegetation and a dense litter layer to build their nest and are generally not found on areas that have been recently burned (<13 months). Henslow's Sparrows were only found on patch-burned pastures (Figure 2.6B). The species was found at highest densities on the PBG1 (0.52 birds/ha) and PBG2 strata (0.49 birds/ha). Henslow's Sparrow detections on the PBG0 stratum (0.27 birds/ha) are likely due to the close proximity of unburned habitat in adjacent patches. Although the two IESB pastures were not burned in 2012 or 2013 and the SLSB pasture was not burned in 2013, Henslow's Sparrows were completely absent from these treatment strata.

Grasshopper Sparrows prefer to nest in grasslands of intermediate height with a clumped vegetation structure and were relatively uncommon in the PBG0 stratum (0.78 birds/ha). Highest densities of Grasshopper Sparrows were found on the PBG1 stratum (1.29 birds/ha), but the species was also commonly found in the IESB (1.15 birds/ha), PBG2 (1.09 birds/ha) and SLSB strata (1.27 birds/ha; Figure 2.6C).

Dickcissels are habitat generalists and were the most commonly encountered species in our field study (Figure 2.6D). Although the species will use heavily grazed and burned areas, lowest densities were found on the PBG0 strata (0.93 birds/ha) which received the most intensive grazing pressure of all habitat strata. Higher densities of Dickcissels were found on the unburned PBG1 (1.25 birds/ha) and PBG2 (1.36 birds/ha) strata. Dickcissel density was highest on the SLSB strata (2.01 birds/ha), which received relatively light grazing pressure and was burned only 2 out of the 3 years of our study due to drought conditions.

Eastern Meadowlarks generally prefer grassland habitats with higher vertical vegetation density and less bare ground. The PBG2 stratum, which had not been burned for two years, had the highest density of Eastern Meadowlarks (0.72 birds/ha; Figure 2.6E). High densities of meadowlarks were also found on the PBG1 (0.59 birds/ha) and SLSB (0.65 birds/ha) strata. Eastern Meadowlarks were present on IESB and PBG0 strata, but at lower densities (0.45 and 0.44 birds/ha, respectively).

Brown-headed Cowbirds tended to avoid heavily grazed areas and few birds were detected on the PBG0 (0.10 birds/ha) and IESB strata (0.09 birds/ha; Figure 2.6F). The species was found at the highest density on the SLSB stratum (0.21 birds/ha).

Discussion

Chase County and Greenwood County contain large tracts of native tallgrass prairie. The vast majority of the tallgrass prairie in these two counties is under private ownership and is intensively managed for livestock production with prescribed fire (Mohler and Goodin 2012). Although some grassland bird species will utilize grasslands that are intensively managed, some sensitive species will be absent from these areas or only found at low densities. Overall, we found greater vegetative heterogeneity on patch-burned pastures as compared to annually burned and heavily grazed pastures. Increased vegetative heterogeneity on patch-burned pastures coupled with more residual vegetation and a deeper litter layer provided habitat for Henslow's Sparrows, and coincided with higher densities of sensitive species of grassland songbirds such as

Eastern Meadowlarks, Grasshopper Sparrows, and Dickcissels.

Vegetation Surveys

Results of our vegetation surveys show that fire-grazing interactions can be used as a management tool to restore heterogeneity on privately owned native rangelands. Although uniform grazing has long been a central paradigm of rangeland management (Holechek et al. 2010), this strategy may not provide adequate habitat for many species of grassland birds. Our data support previous studies on patch-burn grazing that show significant differences in plant community composition between pastures managed with patch-burn grazing and pastures managed with intensive early stocking or season-long stocking coupled with annual burning (Fuhlendorf and Engle 2004). Patch-burned pastures have a high degree of vegetative structural heterogeneity which can provide habitat for a greater number of native grassland bird species than a management based on even utilization of forage by livestock (Fuhlendorf and Engle 2006).

The vegetative differences between patch-burned pastures and annually burned and grazed pastures were evident despite the fact that the annually burned pastures were not burned every year as planned due to drought conditions. Although the IESB pastures were only burned one out of the three years of our field study, visual obstruction values remained low (1.0 decimeters). The PBG2 stratum, which was also burned only one out of the three study years, had a much higher average visual obstruction (2.13 decimeters). Differences in vegetative structure are likely due to differences in cattle stocking density between the two management systems, as well as preferential grazing by cattle on the burned patch of patch-burned pastures (PBG0) which leaves more residual vegetation on unburned patches. If an entire pasture is left unburned, cattle will graze the pasture more evenly than they would in a patch-burned pasture where only a portion is burned, leading to a more homogeneous vegetation structure across the entire pasture.

Line Transects

Results of our line transect surveys for bird densities were consistent with previous studies on patch-burn grazing and grassland birds (Fuhlendorf et al. 2006, Coppedge et al. 2008). Patch-burned pastures contained a gradient of habitat patches created by the uneven utilization of forage by cattle. Pastures that are completely burned or not burned at all are generally more homogeneous in terms of vegetation structure since there are no burned areas available for cattle to preferentially graze. Although evenly grazed pastures provide adequate nesting and brood-rearing habitat for some generalist species and bare ground specialists, birds requiring tall grass and accumulated litter such as Henslow's Sparrows may not be present on these areas (Herkert 1998). Patch-burned and grazed pastures provided a gradient of habitat structures ranging from burned and heavily grazed areas with abundant bare ground to areas with thick residual vegetation and a dense litter layer. Vegetative heterogeneity created within a pasture via the interaction of fire and grazing therefore provides habitat for a greater number of grassland bird species, even though some species may only utilize one or two patches within a patch-burned pasture.

Upland Sandpipers were regularly seen flying overhead but were less often encountered on the ground where perpendicular distance from the line transect could be recorded. Upland Sandpipers utilize short grass habitat interspersed with patches of bare ground (Dechant et al. 1999b, Sandercock et al. 2015). The species had the highest estimated density in the PBG0 patch, but were rarely encountered in unburned areas. Although the species utilizes patches of taller vegetation for nest construction and concealment, nests are usually in close proximity to patches of bare ground and shorter grass for brood-rearing.

We found that Henslow's Sparrows were completely absent from pastures intensively managed to promote even forage utilization via the use of annual prescribed fires and heavy stocking rates. Henslow's Sparrows build nests near the ground in dense litter and standing dead vegetation (Cully and Michaels 2000), often incorporating dead vegetation into an overhead dome or arch to aid in concealment. Although the IESB pastures used in this study were not burned in 2012 or 2013 and the SLSB pasture was not burned in 2013, we recorded zero detections for Henslow's Sparrows on these strata. The absence of the species on some unburned areas indicates that changes in fire frequency alone may not influence the availability of useable habitat for Henslow's Sparrows, particularly during drought years when vegetation production is low or if the stocking rate of cattle is high.

Grasshopper Sparrows were relatively common across our study site and were encountered on all treatment strata. We found the highest densities of Grasshopper Sparrows on the PBG1 stratum, which supports previous studies showing that the species prefers to nest in grassland habitats with a moderate level of burning and grazing (Dechant et al. 1998). As the species sometimes incorporates dead grass into a domed roof structure over the nest cup to aid in concealment, residual dead vegetation left on the landscape when pastures are unburned or lightly grazed may provide better nesting habitat for the species. Grasshopper Sparrows were encountered on the IESB and SLSB strata, indicating that these widespread management practices may create adequate nesting habitat for the species. However, burned and heavily grazed areas, such as the most recently burned patch of patch-burned pastures and burned pastures managed with intensive early stocking, supported lower densities of the species as compared with unburned areas or burned areas with lower stocking rates.

Dickcissels, which are habitat generalists (Dechant et al. 1999a), were found in relatively high numbers on every habitat strata in our study although they tended to avoid the most heavily grazed PBG0 stratum. Dickcissels build an open-cup nest on or close to the ground and do not generally incorporate live grass or standing dead vegetation in the construction of the nest. Results of this study indicate that both a patch-burn grazing management and traditional management practices such as IESB and SLSB can provide useable habitat for Dickcissels, although burning coupled with high grazing intensity may reduce habitat suitability and lead to lower densities of the species.

Eastern Meadowlarks, which prefer to nest in grasslands with a dense vegetation structure (Hubbard et al. 2006, Frey et al. 2008), were most commonly encountered in the PBG2 stratum. The PBG2 treatment stratum had not burned for two years and was lightly grazed, allowing for the accumulation of residual dead vegetation and litter. Like Henslow's Sparrows and Grasshopper Sparrows, Eastern Meadowlarks often incorporate standing vegetation into the nest to create a roof over the nest cup to provide better concealment from predators. Eastern Meadowlarks were found on every habitat strata but showed variation in densities depending on intensity of fire and grazing. The lowest densities of Eastern Meadowlarks were found in the PBG0 and IESB strata, indicating that annual fire coupled with heavy grazing may not create suitable nesting habitat for the species. Although the IESB pastures used in this study were not burned in 2012 and 2013, densities of Eastern Meadowlarks were still lower than on unburned patches within the patch-burned pastures. Therefore, fire frequency may not be the only factor influencing abundance of the species, particularly in years of low forage production or when stocking rates are high.

We estimated relatively low densities of Brown-headed Cowbirds on all survey strata even though the species was commonly encountered during our surveys. As with Upland Sandpipers, low estimated densities may be due to the fact that Brown-headed Cowbirds were rarely seen perched on the ground or in the grass, and most of our detections were flyovers. It was not possible to record a perpendicular distance for birds flying overhead, and flyover records were not used in our analyses and did not contribute to abundance estimates. Brown-headed Cowbirds lay their eggs in the nests of other species and are mobile and non-territorial, and we could not assume that birds seen flying overhead were utilizing the habitat being surveyed.

Overall, a patch-burn grazing management can have a positive impact on some species of declining grassland birds due to the greater amount of litter and residual dead vegetation left on the landscape. Species that utilize bare ground and short grass during parts of the breeding season, such as Upland Sandpipers and Greater Prairie-Chickens, may also benefit from patch-burn grazing as the most recently burned patch can provide brood-rearing, lekking and foraging habitat as well as taller grass in close proximity for nesting. Future work should examine barriers to implementation of patch-burn grazing for private landowners, as well as examining effects of scale, patch size, and cattle stocking rate on grassland bird densities on managed rangelands.

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Table 2.1. Burning and stocking information for managed rangelands in Chase and Greenwood counties, Kansas, 2011-2013.

2011 Burning and Stocking Information

Pasture	Area (Hectares)	Burn Treatment	Pasture Burned	Burn Date	Cow Type	Stocking Rate (ha/head)	Cattle In	Cattle Out
Schoolhouse	440	PBG	East patch	Early Apr	Steer	1.1	Late Apr	No data
Bell	376	PBG	South patch	12-Apr	Steer	1.8	Late Apr	Oct
Tower	392	PBG	North/South patch	1-Apr	Steer	1.7	Late Apr	Oct
Highland	419	IESB	Yes	5-Apr	Steer	0.9	15-Apr	20-Jul
Nation	587	IESB	Yes	1-Apr	Steer	0.8	15-Apr	15-Jul
Huber	583	SLSB	Yes	25-Mar	Steer	1.6	20-Apr	15-Sep

2012 Burning and Stocking Information

Pasture	Area (hectares)	Burn Treatment	Pasture Burned	Burn Date	Cow Type	Stocking Rate (ha/head)	Cattle In	Cattle Out
Schoolhouse	440	PBG	West patch	10-Apr	Steer	2.1	Late Apr	No data
Bell	376	PBG	East patch	30-Mar	Steer	1.6	4-Apr	3-Aug
Tower	392	PBG	West patch	30-Mar	Steer	1.9	4-Apr	3-Aug
Highland	419	IESB	No	Unburned	Steer	0.9	9-Apr	11-Jul
Nation	587	IESB	No	Unburned	Steer	1.6	15-Apr	17-Jul
Huber	583	SLSB	Yes	1-Apr	Heifers	1.6	25-Apr	30-Aug

2013 Burning and Stocking Information

Pasture	Area (hectares)	Burn Treatment	Pasture Burned	Burn Date	Cow Type	Stocking Rate (ha/head)	Cattle In	Cattle Out
Schoolhouse	440	PBG	Middle patch	4-Apr	Steer	2.1	Late Apr	No data
Bell	376	PBG	North patch	28-Apr	Steer	2.1	30-Apr	1-Aug
Tower	392	PBG	East patch	28-Apr	Steer	2.1	30-Apr	2-Oct
Highland	419	IESB	No	Unburned	Steer	1.1	29-Apr	26-Jul
Nation	587	IESB	No	Unburned	Steer	1.6	15-May	4-Oct
Huber	583	SLSB	No	Unburned	Steer	2.0	27-Apr	6-Sep

Table 2.2. Model selection for candidate models for effects of burn treatment on vegetation characteristics on managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

Model	df	AIC_c	ΔAIC_c	w_i
VOR				
Burn Treatment	8	1778.0	0.0	1.0
Constant	4	1987.9	197.7	0.0
% Grass				
Burn Treatment	8	6198.4	0.0	1.0
Constant	4	6281.9	95.8	0.0
% Forb				
Burn Treatment	8	5457.7	0.0	1.0
Constant	4	5491.3	41.7	0.0
% Bare				
Burn Treatment	8	5925.4	0.0	1.0
Constant	4	6171.7	257.1	0.0
% Shrub				
Burn Treatment	8	4019.8	0.0	0.95
Constant	4	4025.5	5.9	0.05
% Litter				
Burn Treatment	8	4823.1	0.0	1.0
Constant	4	4865.2	46.71	0.0
Litter Depth				
Burn Treatment	8	4073.2	0.0	1.0
Constant	4	4240.0	167.2	0.0

Notes: Model parameters: df = degrees of freedom, AIC_c = Akaike's Information Criterion corrected for small sample size, ΔAIC_c = difference in AIC value from model with lowest AIC value, and w_i = model weight within candidate set. Random effects included year of study (2011-2013), survey round (1-3), and property owner.

Table 2.3. Model selection for candidate models for detection and density of grassland birds on line transect surveys in managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

Detection	**Density**	**K**	**AIC**	**ΔAIC**	$w_{i \leq}$
Dickcissel					
Year	Stratum	9	9146.28	0.00	1.00
Stratum	Stratum	11	9160.55	14.27	0.001
Round	Stratum	9	9189.06	42.78	0.001
Year	Round	7	9206.39	60.10	0.001
Constant	Stratum	7	9238.43	92.15	0.001
Grasshopper Sparrow					
Year	Stratum	9	5441.50	0.00	0.98
Year	Year	7	5449.65	8.15	0.002
Round	Year	7	5476.55	35.06	0.001
Stratum	Year	9	5478.14	36.65	0.001
Constant	Year	5	5485.99	44.49	0.001
Eastern Meadowlark					
Year	Stratum	9	7946.27	0.00	1.00
Year	Year	7	7999.06	52.80	0.001
Year	Round	7	8004.20	57.93	0.001
Year	Constant	5	8020.03	73.76	0.001
Stratum	Stratum	11	8065.96	119.69	0.001
Brown-headed Cowbird					
Year	Stratum	9	2897.23	0.00	1.00
Year	Year	7	2911.27	14.03	0.001
Constant	Stratum	7	2914.44	17.21	0.001
Stratum	Year	9	2915.86	18.63	0.001
Stratum	Stratum	11	2916.65	19.42	0.001
Upland Sandpiper					
Year	Stratum	9	2427.30	0.00	0.55
Round	Stratum	9	2428.08	0.78	0.44
Constant	Stratum	7	2431.71	4.41	0.01
Stratum	Stratum	11	2435.05	7.75	0.001
Stratum	Round	9	2450.42	23.12	0.001
Henslow's Sparrow					
Year	Stratum	7	858.19	0.00	0.96
Stratum	Year	7	865.92	7.74	0.02
Constant	Year	5	867.84	9.65	0.01
Year	Constant	5	868.03	9.85	0.001
Round	Year	7	870.81	12.62	0.001

Figure 2.1. Map of Kansas showing location of study site in Chase County and Greenwood County, 2011-2013.

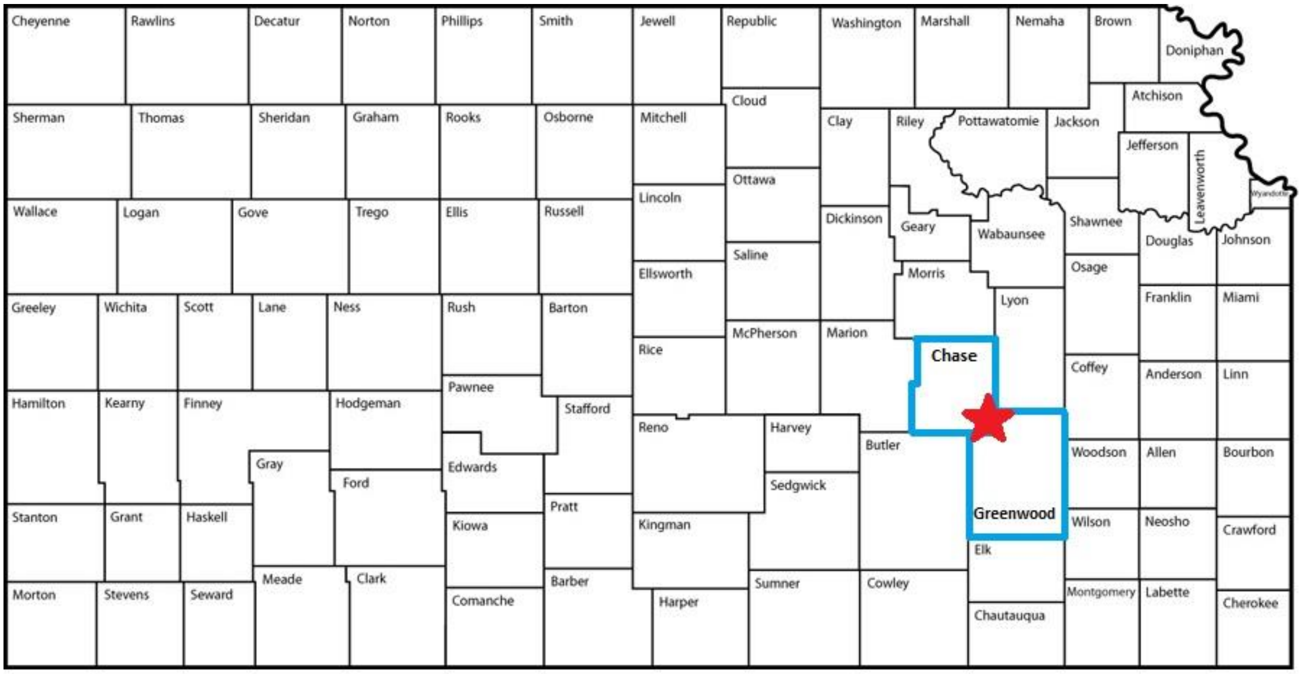


Figure 2.2. Location of six pastures used in the field study. Yellow = patch-burned and grazed (PBG) showing patch divisions; dark blue = intensive early stocked and burned (IESB); light blue = season-long stocked and burned (SLSB), Chase and Greenwood Counties, Kansas, 2011-2013.

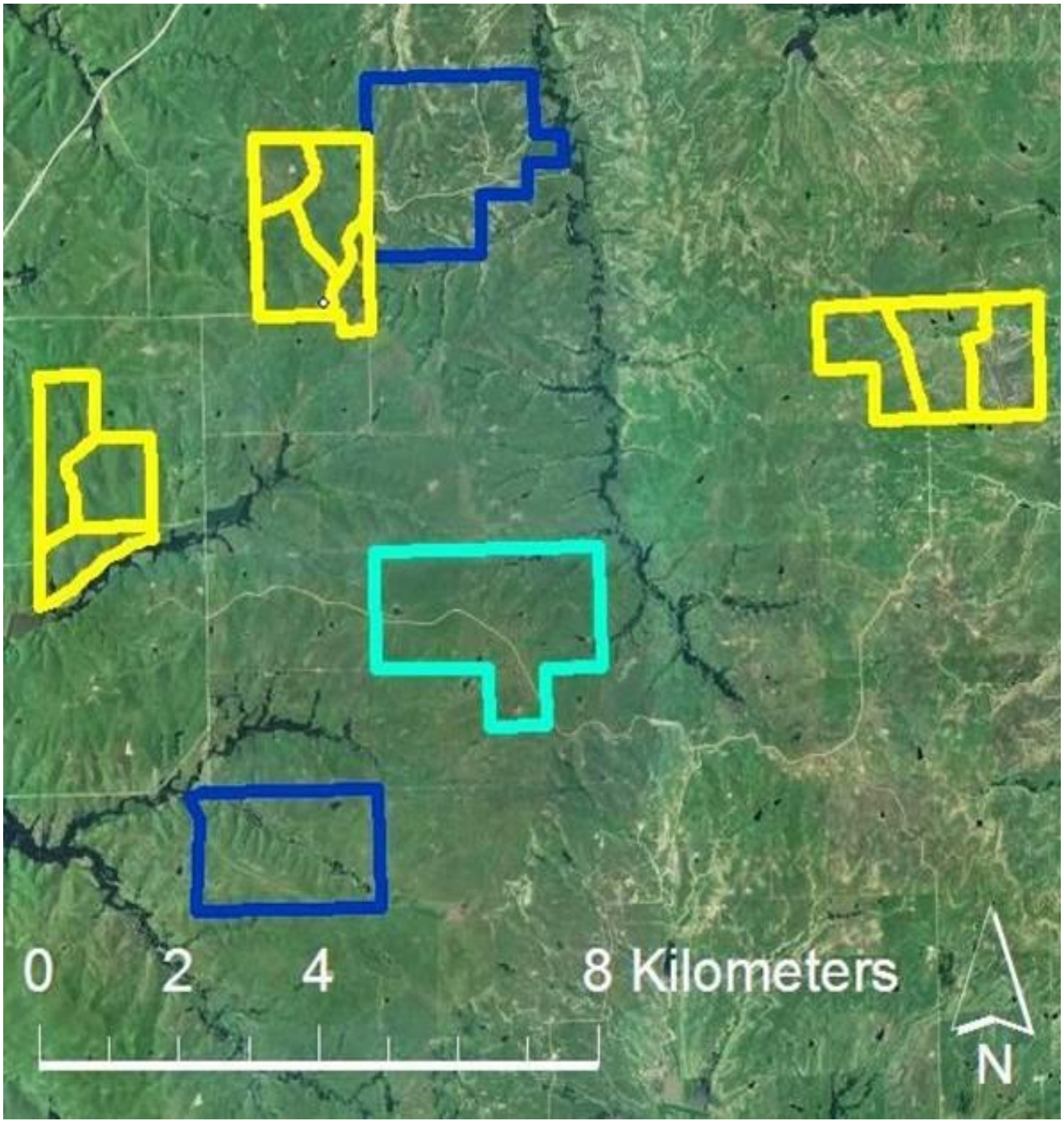


Figure 2.3. Locations of 300-meter line transects on one intensive-early stocked and burned pasture (top) and one patch-burned and grazed pasture, Chase and Greenwood Counties, Kansas, 2011-2013.

Figure 2.4. Vegetation characteristics of managed rangelands in Chase and Greenwood Counties, KS, 2011-2013. Treatment stratum = intensive-early stocking and spring burning (IESB), patch-burn grazing year of burn (PBG0), patch-burn grazing one year since fire (PBG1), patch-burn grazing two years since fire (PBG2) and season-long stocking and annual spring burning (SLSB). Box plots indicate median and interquartile range; whiskers are 95% confidence intervals.

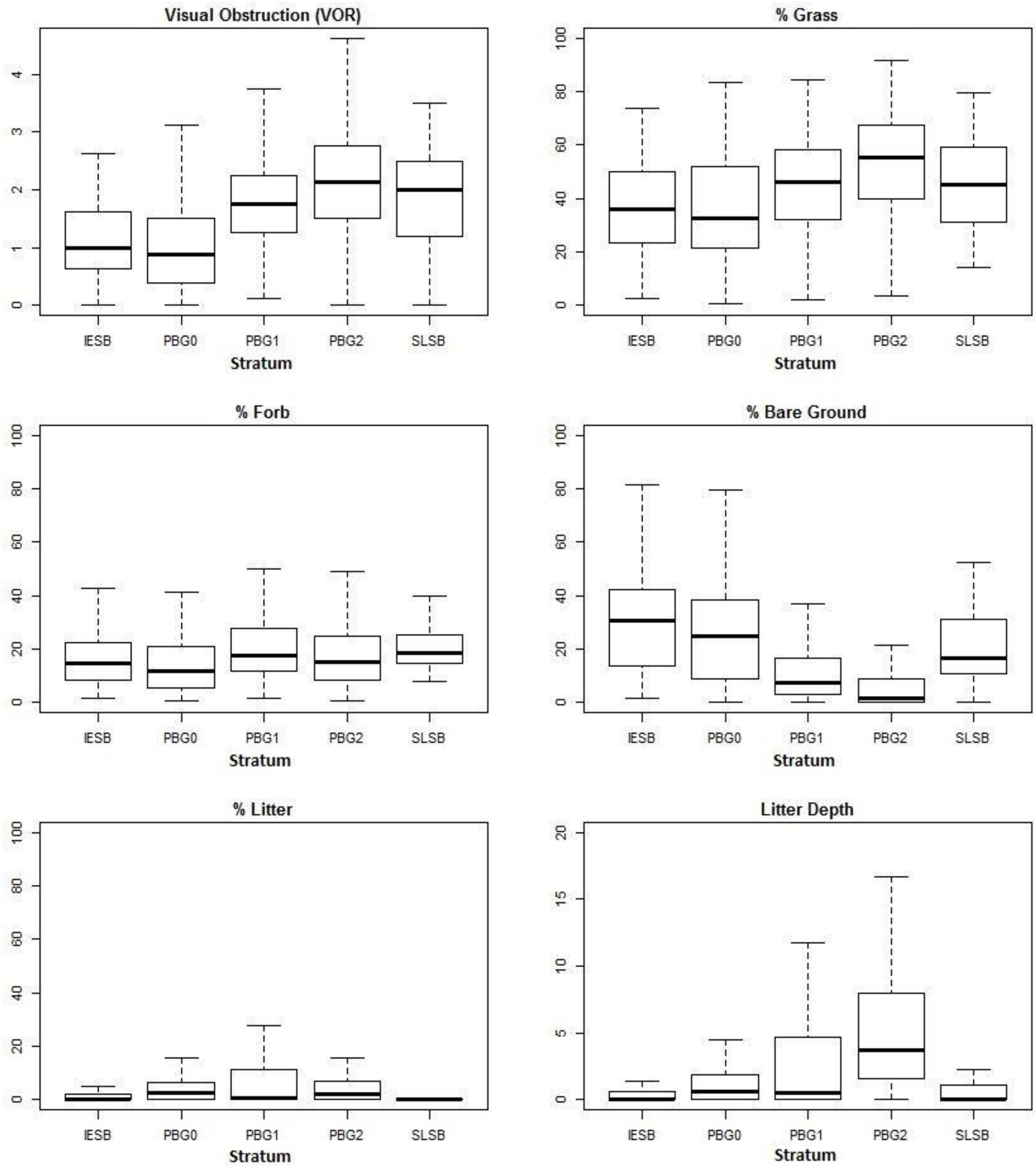


Figure 2.5. Frequency histograms for detection distances of six species of grassland birds in managed rangelands, Chase and Greenwood Counties, KS, 2011-2013. Detections were placed into fifteen 20-meter bins. ESW = estimated strip half-width.

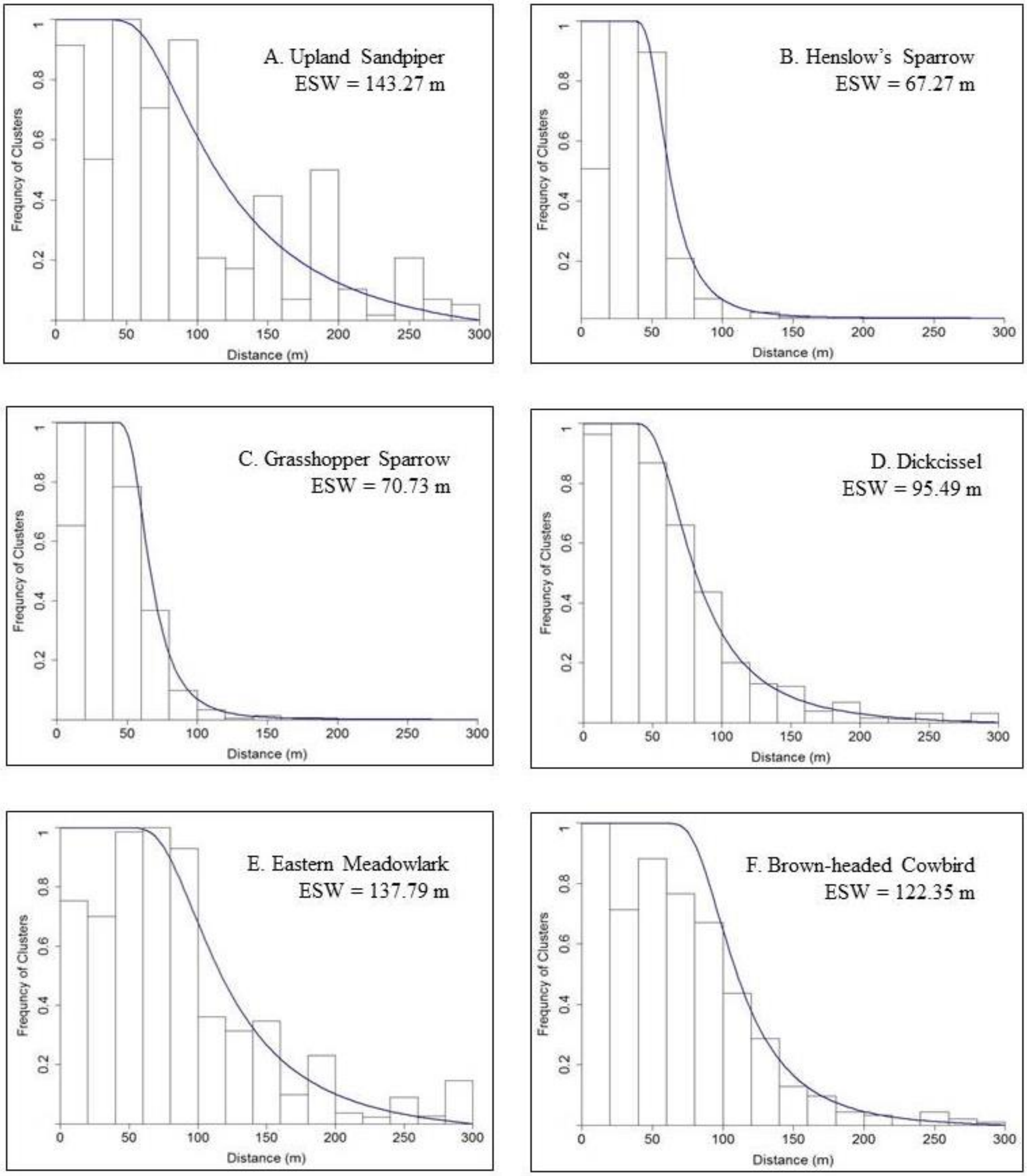
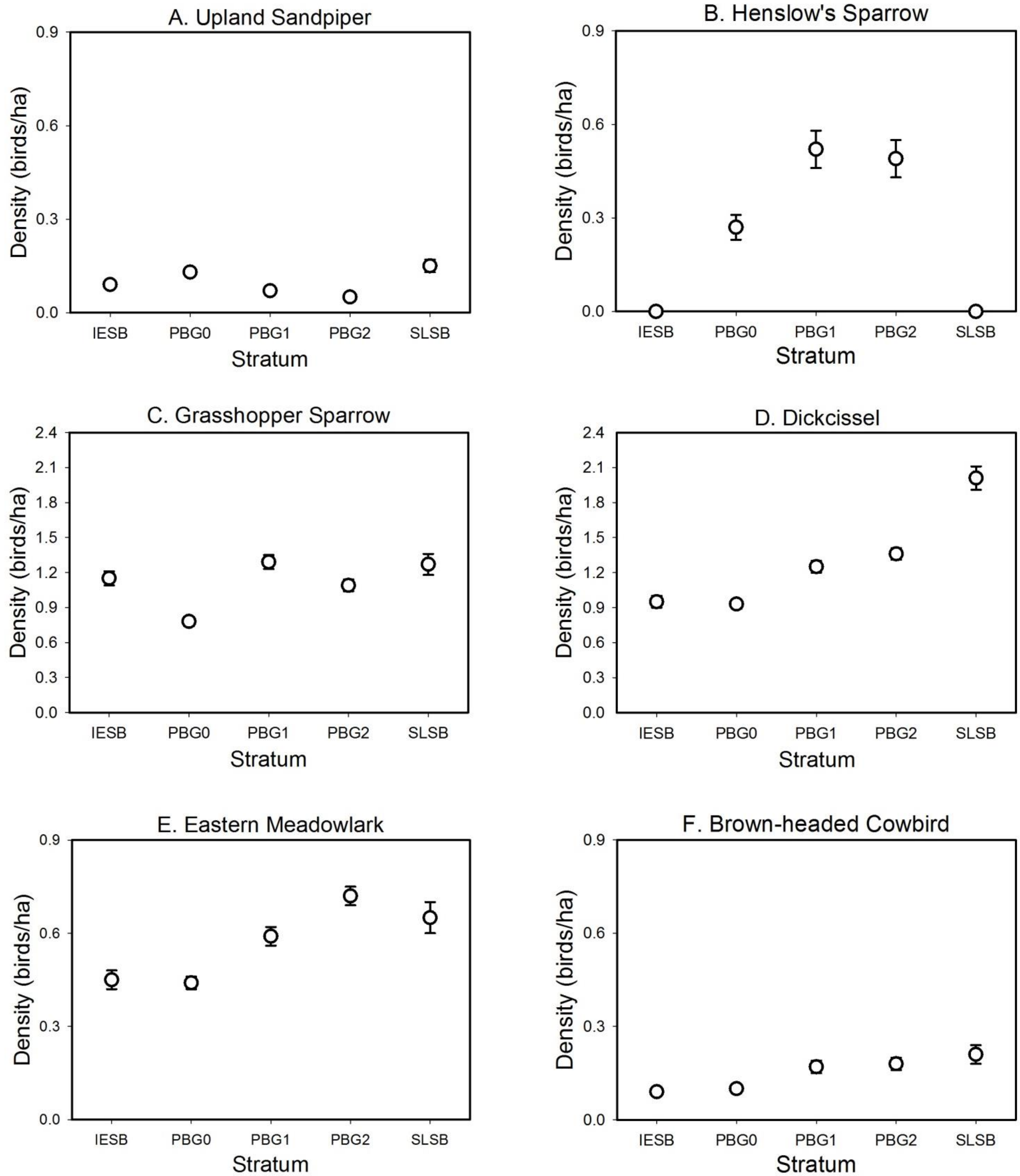


Figure 2.6. Densities (± SE) of six species of grassland birds in managed rangelands, Chase and Grenwood Counties, KS, 2011-2013. Treatment strata = intensive-early stocking and spring burning (IESB), patch-burn grazing year of burn (PBG0), patch-burn grazing one year since fire (PBG1), patch-burn grazing two years since fire (PBG2) and season-long stocking and annual spring burning (SLSB).



Chapter 3 - Effects of prescribed burns and grazing management on the nest survival of four species of grassland songbirds

Abstract

The timing, frequency, and intensity of burning and grazing events on tallgrass prairies can influence the reproductive performance of grassland songbirds. A heterogeneity-based management system, such as patch-burn grazing, may be more beneficial to grassland songbirds than management practices such as intensive early stocking and annual spring burning which promote homogeneous utilization of forage by cattle. We examined nest success of grassland songbirds and rates of nest parasitism by Brown-headed Cowbirds (*Molothrus ater*) on a patch-burned and grazed pasture versus an intensive early stocked and burned pasture. Nest survival of four species was similar between rangeland management treatments, but varied by year during our three-season field study. The probability of parasitism by cowbirds for Dickcissels (*Spiza americana*) and Grasshopper Sparrows (*Ammodramus savannarum*) varied among years and between treatments, with overall lower rates on annually burned pastures and during drought years. Probability of parasitism was low overall for Eastern Meadowlarks (*Sturnella magna*) and did not differ by year or treatment. For Dickcissels and Grasshopper Sparrows, there was a significant reduction in host clutch size in parasitized versus unparasitized nests. Overall, reproductive performance of grassland songbirds in managed rangelands was low. Patch-burn grazing improved rangeland conditions but did not increase nest survival, possibly due to wide-ranging and highly mobile nest predators and cowbirds. Further study is needed to determine underlying factors for variation in nest success and parasitism rates for grassland birds, particularly on private lands which make up the vast majority of remnant tallgrass prairies.

Introduction

Prairies are disturbance-driven systems that are inherently patchy in nature. The North American tallgrass prairie evolved under natural burning and grazing processes driven mainly by lightning strikes and large grazing animals such as the Plains Bison (*Bison bison*), which had an estimated population of 30-60 million animals throughout the Great Plains prior to European settlement (McHugh 1972, Flores 1991). The fire-grazing interaction, also referred to as pyric herbivory, created a shifting mosaic pattern across the landscape in which different structural habitats were constantly being replaced and renewed by periodic fire and grazing (Fuhlendorf and Engle 2001). Many North American grassland bird species have shown significant population declines over the past 50 years (Herkert et al. 1996, Peterjohn and Sauer 1999, Brennan et al. 2005), mainly due to the intensification of agricultural practices on remaining prairies and a subsequent reduction in heterogeneity among rangelands (With et al. 2008). Ecological changes to a disturbance-regulated system via alterations to the fire regime or changes to the timing and intensity of grazing can have widespread and long-term implications for the tallgrass prairie and its associated flora and fauna.

Rangeland management practices based on intensive-early stocking and annual spring burning (IESB) were widely adopted in the Flint Hills during the 1980s. This management system aims to maximize livestock production by burning entire pastures each spring and double-stocking burned areas with cattle early in the growing season (Smith and Owensby 1978). IESB facilitates an even distribution of cattle across the landscape and homogeneous utilization of available forage. The result is a landscape without the patchiness that would have been present prior to the 1800s (Fuhlendorf et al. 2006).

An intensive early stocking management system may provide adequate habitat for grassland species that use disturbed areas and short vegetation. However, sensitive species that are dependent on taller vegetation or a well-developed litter layer for parts of their life cycle, such as Greater Prairie-Chickens (*Tympanuchus cupido*; McNew et al. 2015, Winder et al. 2016) and Henslow's Sparrows (*Ammodramus henslowii*; Reinking 2005, Powell 2006), are often absent from prairies that are annually burned and heavily grazed. A fire and grazing system that promotes heterogeneity, such as patch-burn grazing, may therefore be more beneficial for tallgrass prairie wildlife than a management system based on promoting homogeneity. Under a patch-burn grazing system, a different portion of each pasture, usually one-third, is burned each year on a rotational schedule. Cattle have access to both burned and unburned patches on which to graze and will spend the majority of the time grazing on the most recently burned patch. The fire-grazing interaction creates a shifting mosaic of habitat patches that include recently burned and heavily grazed areas alongside unburned areas that receive relatively light grazing pressure. The resulting vegetative heterogeneity provides habitat for more species of grassland wildlife than management practices such as intensive early stocking and annual burning which promote even forage utilization and a homogeneous landscape (Fuhlendorf and Engle 2001, Coppedge et al. 2008).

The relationship between fire-grazing interactions and the reproductive output of grassland birds is poorly understood. Some studies have found that patch-burn grazing can have positive effects on the nest survival of habitat generalists such as Dickcissels (Churchwell et al. 2008, Davis et al. 2016), but other studies of the effects of burning and grazing treatments and grassland bird fecundity have shown mixed results. For example, Grasshopper Sparrows nesting in small fragmented prairies showed no difference in nest survival between areas managed with patch-burn grazing and areas managed with traditional burning and grazing methods (Hovick et al. 2012). Nest-site selection and nest survival by Upland Sandpipers was influenced by fire frequency, but not by grazing activity on managed rangelands (Sandercock et al. 2015). Patch-burn grazing has been shown to stabilize nest survival rates of Eastern Meadowlarks from year to year, but average nest survival may not be significantly different on patch-burned pastures as compared with annually burned and grazed pastures (Hovick and Miller 2016), or may be lower on patch-burned pastures (Davis et al. 2016).

We studied nest survival and parasitism by Brown-headed Cowbirds for four species of grassland songbirds over three years in a patch-burned pasture and an intensive early stocked pasture managed by private landowners. Unburned sites have more accumulated plant biomass, which provides cover for ground-nesting birds. Therefore, we predicted that nest survival would vary with time since burning and would be higher overall in pastures managed with patch-burn grazing. We also predicted that nest parasitism by Brown-headed Cowbirds would be lower in pastures managed with patch-burn grazing due to more residual vegetation and better nest concealment.

Methods

Study Site

From 2011-2013, we searched for nests of grassland songbirds on two privately-owned pastures, one in Chase County and one in Greenwood County, Kansas. The pastures were less than 15 kilometers apart and were similar in size (419 hectares and 440 hectares for the IESB and PBG pastures, respectively). Pasture burning is an important management practice for increasing livestock production in the Flint Hills, and Chase County and Greenwood County are intensively managed with prescribed fire. On average, 56% of grasslands in Chase County and 40% of grasslands in Greenwood County are burned every year (Mohler and Goodin 2012).

The climate in Chase and Greenwood counties is moderately humid, with an average annual rainfall of 900 millimeters that occurs mainly during the growing season from April to October. Late summer droughts in July and August are not uncommon. Winters are generally mild, although the temperature may fall below freezing for a few days at a time. Average annual snowfall is around 250 millimeters (Byers et al. 1914, Goodin et al. 1995).

The main soils in Chase and Greenwood County include well-drained cherty or silty clay loam underlain by limestone. The topography in this region of the Flint Hills consists of rolling hills where elevation ranges from a low of 275 meters along the Verdigris River to a high of around 500 meters along some of the ridges and hilltops (Byers et al. 1914, USDA Soil Conservation Service 1974).

Our study pastures were dominated by native warm-season bunchgrasses including Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium)*. Common forbs included ragweed (*Ambrosia* spp.), common yarrow (*Achillea millefolium*), goldenrod (*Solidago* spp.), ironweed (*Vernonia baldwinii*), blue wild indigo (*Baptisia australis*), and milkweeds (*Asclepias* spp.). Shrubs and trees are relatively uncommon in tallgrass prairies that are managed with fire, but small patches of prairie were dominated by eastern redcedar (*Juniperus virginianus*), rough-leaved dogwood (*Cornus drummondii)*, buckbrush (*Symphoricarpos orbiculatos*), and smooth sumac (*Rhus glabra*).

The patch-burned pasture has been managed under this system since 2008 and thus had undergone one full burn rotation before our field study began. The pasture was stocked with steers from mid-April through mid-July at a stocking rate of 1.05-2.09 hectares/head (2.6-5.16

acres/head) and was burned as scheduled in 2011, 2012, and 2013, with a different third being burned each year for one complete burn rotation over the course of this study. The intensive early stocked pasture was generally burned every year by the landowner and was stocked with steers from mid-April through mid-July at a stocking rate of 0.85–1.05 hectares/head (2.1–2.6 acres/head). The pasture was burned completely in 2011, but was not burned in 2012 or 2013 due to drought conditions causing an inadequate fuel load to carry a fire. Pasture conditions with low fuel loads during drought years were similar to the short vegetation in burned pastures. Burns were conducted on both pastures in March or early April depending on landowner preference. Burning and stocking rates for the IESB pasture (Highland) and PBG pasture (Schoolhouse) were representative of private lands in the region (Table 2.1).

Study Species

We focused on four grassland songbird species of conservation concern: Lark Sparrow (*Chondestes grammacus*), Grasshopper Sparrow (*Ammodramus savannarum*), Dickcissel (*Spiza americana*), and Eastern Meadowlark (*Sturnella magna*). These four species of songbirds can nest sympatrically in the same pasture, sometimes even within a few feet of each other, but often select a slightly different microhabitat which includes their preferred vegetation characteristics. Nests of all four species are regularly parasitized by Brown-headed Cowbirds (*Molothrus ater*).

Lark Sparrow nests are generally located in drier sites with sparse ground cover such as sites associated with burning, moderate to heavy grazing, or poor or eroded soils. Their open-cup nests are usually on the ground, often placed at the base of a forb (Dechant et al. 1999a). Litter layer and bare ground exposure are important as nest-site selection criteria for Lark Sparrows (Lusk et al. 2003). Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -0.78% per year for Lark Sparrows, but a population increase of 2.10% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

Grasshopper Sparrows prefer to nest in grazed grasslands of intermediate height with a clumped vegetation structure and occasional patches of bare ground (Blankespoor 1980, Vickery 1996). The species has been observed nesting in native prairies, pastures, hay fields, and occasionally in crop fields such as corn and oats (Dechant et al. 1998). Nests are generally placed low to the ground and may incorporate nearby standing vegetation to form a roof over the nest cup for concealment. Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -2.52% per year for Grasshopper Sparrows, and a decline of -4.08% per year in the Eastern tallgrass prairie region that includes our study area (Sauer et al. 2017).

Dickcissels are habitat generalists and have been observed nesting in fallow fields, hayfields, fencerows, hedgerows, road rights-of-way, waterways, stubble fields, planted cover such as Conservation Reserve Program fields, grazed prairies, ungrazed prairies, and idle prairies (Dechant et al. 1999b). The species prefers somewhat dense vegetation cover, moderate to tall vegetation, a moderately deep litter layer, and a strong forb component with many elevated song perches (Harmeson 1974, Patterson and Best 1996). Dickcissels build open-cup nests that are usually located at the base of a forb or within a few feet of the ground. Breeding Bird Survey data collected between 1966-2015 show a survey-wide decline of -0.36% per year for Dickcissels, and a decline of -1.0% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

Eastern Meadowlarks nest in pastures, meadows, hay fields, or other grassland habitat; less often in cultivated fields (Roseberry and Klimstra 1970). In Kansas tallgrass prairies, Eastern Meadowlarks tend to select nest sites with higher vertical vegetation density (Hubbard et al. 2006, Frey et al. 2008) and with greater litter depth, less bare ground, and increased distance from large patches of bare ground. Eastern Meadowlark nest sites have been associated with greater amounts of standing dead vegetation, deeper litter, and taller vegetation (Warren and Anderson 2005). The species may build an open-cup nest in dense grass, but often nearby standing vegetation is used to form a domed roof over the nest cup for concealment. Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -3.28% per year for Eastern Meadowlarks, and a decline of -2.28% per year in the Eastern tallgrass prairie region (Sauer et al. 2017).

The Brown-headed Cowbird is an obligate brood parasite that was once restricted to open grasslands in central North America but has expanded its geographic range following the clearing of forests and other human land-use changes (Mayfield 1965, Rothstein et al. 1980). Over 170 host species have been reported as being parasitized by Brown-headed Cowbirds (Lowther et al. 1993, Rivers et al. 2012), including all four focal species in this study. Although Brown-headed Cowbird nestlings generally hatch and fledge alongside the host young, their presence in the nest can decrease fecundity for the host species (Jensen and Cully 2005a, Kosciuch and Sandercock 2008). Additionally, Brown-headed Cowbirds may remove host eggs or even destroy broods of songbird young to induce the host species to renest (Hoover and Robinson 2007). Brown-headed Cowbirds are not a species of conservation concern, but Breeding Bird Survey data collected from 1966-2015 show a survey-wide decline of -0.7% per year, and also a decline of -0.5% per year in the Eastern tallgrass prairie region (Sauer et al. 2014). Brown-headed Cowbirds are primarily of interest for their potential negative effects on the reproductive performance of host species.

Field Methods

Songbird nests were located by walking through the pastures and flushing incubating birds from the nest and by behavioral observations of nesting birds. Dates and times of nest-searching were recorded by each observer to ensure equal search effort between pastures and within each patch of the patch-burned pasture. We searched for nests every day during the ~70-day field season from late May through early August in 2011-2013.

When a nest was located, a colored rock was placed at least 5 meters from the nest. Colored rocks were used for nest marking instead of flagging because rocks were generally left undisturbed by cattle. A handheld GPS unit was used to record the location of the nest in UTM coordinates. A compass bearing was taken from the rock towards the direction of the nest. Data collected at the time of discovery and at subsequent nest visits included the bird species, number of host eggs or nestlings, number of cowbird eggs or nestlings, age-class of nestlings, behavior of the parent birds, and any distinguishing characteristics about the nest or local habitat features to facilitate re-location. Nestlings were categorized in one of 5 age-classes each time they were observed: age class 0 = eyes closed, no down present on body (0-2 days); age class 1 = eyes closed, down present on body (3-4 days); age class 2 = eyes open, pinfeathers present (5-6 days); age class 3 = some wing feathers emerging from sheaths (6-7 days); age class 4 = wing feathers fully emerged from sheaths (8-9 days). Young Dickcissels begin to grow down and pinfeathers approximately 4 days after hatching, and eyes open 4 days before the fledglings leave the nest (Long et al. 1965).

We visited each nest every 2-3 days until the young either fledged or the nest failed. A nest was considered *successful* if at least one host or cowbird young survived to fledging age. The duration of the nestling stage, presence of fecal matter in or around the nest, or presence of agitated adult birds were indicators that a nest had successfully fledged. A nest was considered to have *failed* if the nest contents disappeared before the expected fledging date, if the nest was abandoned, or if broken eggs, torn nest, a predator, or other sign at the nest site indicated that the nest contents had been destroyed. We recorded cause of failure for all nests that were unsuccessful.

Statistical Analyses

Nest Survival

We modeled daily nest survival of songbird nests with the RMark package in Program R (Laake 2013, R Core Team 2015) as an interface to the nest survival procedure of Program Mark (ver. 7.1, Colorado State University, Ft. Collins, CO). We created encounter histories for all nests monitored in 2011-2013 where we had complete information for dates of monitoring and nest fate. Encounter histories included the date of initial nest discovery (*i*), the last date a nest was known to be active (*j*), the date that the nesting attempt was completed (*k*), the fate of the nest (*f*, 0 = successful and 1 = failed), and the number of nests with the encounter history (*n*). The last two dates were set to be equal if a nest was successful ($j = k$), but bracketed the period of loss if a nest failed ($j < k$).

We modeled daily nest survival with a set of *a priori* models that included an intercept-only model, single factor models, additive models with main effects (+), and factorial models with main effects and an interaction term (×). Model factors included species (Dickcissel, Grasshopper Sparrow, Eastern Meadowlark and Lark Sparrow), year of study (2011-2013), rangeland treatment (intensive early stocking vs. patch-burn grazing), and rangeland patch (intensive early-stocking vs. year of fire, one year post-fire, or two years post-fire within the patch-burn grazing treatment). We used estimates of daily nest survival (S_d) to calculate period survival of a nest for a 24-day exposure period (S_p) based on 2 days for egg-laying, 13 days for incubation, and 9 days for brood-rearing (e.g., Dickcissels, Sandercock et al. 2008). We used the delta method to derive an expression to calculate the variance of period survival (Powell 2007). The estimates of period survival correct for losses prior to nest discovery and are expected to be lower than unadjusted estimates of apparent nest survival based on the percentage of successful nests in our sample that were observed to fledge young.

Cowbird Parasitism

We used logistic regression models to compare probability of parasitism by species and burn treatment, and analysis of variance to test for differences in the number of host eggs in parasitized and unparasitized nests for three species: Dickcissel, Grasshopper Sparrow, and Eastern Meadowlark. Due to sparse sample sizes, we censored all nests found in the PBG year of burn patch (n = 9) and nests of Lark Sparrows (n = 18) from our analyses of cowbird parasitism.

We used generalized linear models and analysis of variance (ANOVA) to compare clutch size among species and burn treatments. We used the maximum number of host and cowbird eggs observed in each nest as an index of clutch size. We tested whether the presence of parasitic eggs in a nest had an effect on the number of host eggs in the nest and if the relationship varied among burn treatments or by host species. All analyses were conducted with base functions of Program R.

Results

Nest Survival

We located a total of 340 songbird nests during our 3-year field study (Table 3.1). We spent > 500 hours each field season searching for nests. Search effort was similar between the two pastures (265 hours/season in the IESB pasture vs. 245 hours/season in the PBG pasture), and among the three patches of the patch-burned pasture (74-89 hours/patch/season). More nests were found in the intensive early stocked pasture (n = 230) than in the patch-burned pasture (n = 110). Sample sizes per year ranged from 90 nests located in 2011, 112 nests located in 2012, and 138 nests in located 2013. The largest sample of nests was found for Dickcissels with 189 nests. Smaller numbers of nests were monitored for Grasshopper Sparrows with 82 nests, Eastern Meadowlarks with 51 nests, and Lark Sparrows with 18 nests. We also monitored a small number of nests of non-target species including Upland Sandpipers (*Bartramia longicauda*), Common Nighthawks (*Chordeiles minor*), Mourning Doves (*Zenaida macroura*), Red-winged Blackbirds (*Agelaius phoeniceus*), Orchard Orioles (*Icterus spurius*), and Brown Thrashers (*Toxostoma rufum*), but sample sizes were small and were not included in any analyses. Apparent nest survival was low overall and varied among species (23.2% - 32.8%), with different patterns of annual variation in each species.

The top model for survival across all songbird nests was a model with a constant daily nest survival rate (Table 3.2). A model with effect of species was unsupported (ΔAICc = 2.91; w_{i} = 0.08), indicating that nest survival did not differ by species. The daily survival estimate for all species pooled across all treatments was relatively low at S_d = 0.920 ± 0.005. Period nest survival for a 24-day exposure period was low at S_p = 0.136 ± 0.018. A model containing the effect of year was the second best fit and was equally parsimonious (ΔAICc = 0.88), but the constant model received 1.6x more support (i.e., w_i/w_j = 0.38/0.24). Predicted period nest survival was highest in the first year of the study (2011: S_p = 0.197) and lower in the two subsequent years with drought conditions (2012, 2013: S_p = 0.114, 0.124, Table 3.3). The third best model was also parsimonious (ΔAICc = 1.98) and included the effect of treatment comparing daily survival of nests in an intensive early stocked and burned pasture versus nests in a patch-burned pasture. The daily survival estimate for birds nesting in the patch-burned pasture was S_d = 0.919, whereas the estimate for birds nesting in the intensive-early stocked and annually burned pasture was slightly higher at S_d = 0.921 for all years combined. In both pastures, songbird nests were expected to have a low probability of surviving until fledging (S_p = 0.133 - 0.138). A model with the effect of patch produced estimates of daily survival separately for all habitat strata but received relatively little support (ΔAICc = 4.69). Unexpectedly, the highest rate of daily and period nest survival was found in the year of burn in the patch-burn grazing treatment (PBG0: S_p = 0.255 vs. 0.111 - 0.138 for the other treatments). However, relatively few nests were found in the PBG0 patch (n = 9) and the high estimate of period survival also had the lowest precision (SE(S_p) = 0.142 vs. 0.022 - 0.044 for the other habitat strata).

Nests of grassland songbirds were unsuccessful for a variety of reasons. In this study, a majority of nest failures were due to predation (79%, n = 189 of 240). We were unable to distinguish among nest predators, but common species observed in the study area included corvids, snakes, rodents, and mesocarnivores. On one occasion, we observed a prairie kingsnake (*Lampropeltis calligaster*) curled up inside the nest of a Grasshopper Sparrow, with agitated parents nearby. One Lark Sparrow nest failed when the 2-3 day old nestlings were consumed by ants. A small number of nests failed due to abandonment (14%, n = 34 of 240) or trampling by cattle (5%, n = 12 of 240). About 2% (n = 5 of 240) of nests failed due to weather events, usually when the nest was flooded after a heavy rain.

Cowbird Parasitism

After censoring a handful of nests found in the year-of-burn patch (PBG0) and Lark Sparrow nests, a total of 313 nests were used for analyses of cowbird parasitism. The proportion of parasitized nests ranged from 0.224 to 0.576 across our study species (Table 3.4).

A logistic regression model containing all three species with fixed effects of species and treatment with year as a random effect revealed significant differences in the probability of parasitism by species ($P < 0.001$) and burn treatment ($P < 0.001$). A model with additive or interactive effects of both species and burn treatment received the highest AIC weight (0.972). The model with the next highest AIC weight (0.026) contained effects of species, burn treatment, and an interactive effect. The null model and models containing only species and only burn treatment were unsupported (AIC weights <0.003, ΔAIC > 11).

The probability of parasitism for Dickcissels varied among years ($P = 0.006$) and by treatment ($P = 0.003$), with the highest parasitism rate seen in 2011 (74.5%) and lower rates during the drought years of 2012 (55.4%) and 2013 (45.3%, Table 3.5). There was no support for an interactive effect among treatment and year for Dickcissels. Probability of parasitism for Grasshopper Sparrows and Eastern Meadowlarks was variable, possibly due to small sample sizes for these species. For Grasshopper Sparrows, a test for effect of burn treatment and year on probability of parasitism was weakly non-significant ($P = 0.06$ to 0.09), indicating that burn treatment and year had a marginal effect on the probability of parasitism for this species. Probability of parasitism was relatively low overall for Eastern Meadowlarks (20% of nests parasitized) and did not differ by year ($P = 0.715$), or by treatment ($P = 0.199$).

For Dickcissels, there was a significant difference in the number of host eggs per nest in parasitized versus unparasitized nests ($P < 0.001$). Average number of cowbird eggs per parasitized Dickcissel nest was 1.5 ± 0.7, which corresponded to a clutch size reduction of 0.82 host eggs between unparasitized and parasitized nests. Burn treatment also had an effect on number of host eggs per nest ($P = 0.003$). Nests found in the one year since burn treatment (PBG1) had the most host eggs, and nests found in the two year since burn treatment (PBG2) had the fewest, regardless of whether nests were parasitized or not. Host clutch size in the PBG1 patch was 4.0 ± 1.4 eggs for unparasitized nests and 3.5 ± 1.3 eggs for parasitized nests. Similarily, clutch size in the PBG2 patch was 3.8 ± 0.5 eggs for unparasitized nests and 2.1 ± 0.9 eggs for parasitized nests.

Grasshopper Sparrows showed a similar trend to Dickcissels, with parasitized nests having a significantly smaller host clutch size than unparasitized nests ($P < 0.001$). On average, parasitized Grasshopper Sparrow nest contained 1.5 ± 0.6 cowbird eggs and had 1.2 fewer host eggs than unparasitized nests. There was not a significant difference in the number of host eggs per nest of Grasshopper Sparrows between burn treatments ($P = 0.06$), or between years ($P = 0.1$).

Sample size of nests for Eastern Meadowlark was relatively small ($n = 49$ nests). There was no reduction in host clutch size for Eastern Meadowlarks when comparing parasitized and unparasitized nests ($P = 0.09$), and no effect of burn treatment on probability of parasitism ($P = 0.8$; Table 3.6).

Discussion

Chase County and Greenwood County are dominated by privately owned and intensively managed tallgrass prairie and are representative of the Flint Hills ecoregion. Mohler and Goodin (2012) showed that these two counties have some of the most widespread use of prescribed fire in the region, with a high proportion of grasslands burned on an annual basis. Frequent use of fire coupled with heavy grazing can lead to a decrease in vegetative cover on rangelands, which may decrease nesting cover for grassland birds and lead to increased predation pressure. Overall, nest survival of our study species of grassland songbirds was relatively low and rates of cowbird parasitism were high on preferred host species, particularly during drought years of 2012 and 2013. Rangeland management type (intensive early stocking and burning vs. patch-burn grazing) influenced nesting density of grassland songbirds, but had relatively weak effects on nest survival or rates of nest parasitism.

Nest Survival

Despite a large sample of nests, we were unable to detect differences in nest survival between a pasture managed with intensive early stocking and a pasture managed with patch-burn grazing. Any variation in reproductive output among songbirds nesting in the different habitat strata was likely determined by differences in bird density (see Chapter 2 – line transect results) and not by differences in reproductive success. Our results indicate that both patch-burn grazing and traditional management strategies can provide suitable nesting habitat for many generalist species of grassland birds. Increased vegetation density may not increase nest survival for some species of grassland-nesting birds (Winter et al. 2005, Hovick et al. 2012), but a patch-burn management can provide habitat for a greater suite of grassland bird species than more intensive management based on annual burning and heavy stocking rates (Fuhlendorf et al. 2006, Coppedge et al. 2008).

A majority of nest losses in my study were due to predation, but identifying nest predators can be difficult under field conditions. Studies using nest cameras have shown that up to 15% of nest fates are incorrectly identified when based solely on the evidence available from periodic nest visits (Pietz and Granfors 2000). We found no effect of rangeland management on probability of nest survival, but effects of fire and grazing on nest predation are variable (Rahmig et al. 2009, Kerns et al. 2010), probably due in part to interactions between habitat characteristics versus different communities of nest predators. For example, Johnson and Temple (1990) predicted that predation rates of five grassland nesting species would increase with increased time since fire, but Shochat et al. (2005) showed that nest success at grazed and burned plots was lower than unburned and ungrazed plots, possibly due to increased predation pressure from reptiles. Our study plots differed in habitat structure (see Chapter 2 – vegetation surveys results), but we found that nest survival was similar among treatments and species. Diverse predator communities, spatial and temporal variation in selection pressures, and other constraints may account for variable relationships between nest survival and nest-site characteristics for grassland songbirds (Davis 2005). Vegetation characteristics at the nest site may influence the local predator community (Dion et al. 2000), with snakes being one of the main nest predators for songbirds nesting in tallgrass prairies (Klug et al. 2010). The most likely predators of nests in our field study were snakes and small mammals such as thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*).

Drought conditions may have also influenced nest survival during my field study. The intensive early stocked pasture used for nest-searching was not burned in 2012 or 2013, which may have resulted in more residual vegetation and a deeper litter layer than would normally be found on pastures managed with intensive early stocking. Drought has usually been shown to negatively affect the reproductive output of grassland birds (George et al. 1992, Zimmerman 1997), but often leads to de-stocking of cattle from privately owned tallgrass prairies. Coupled with a reduction in fire extent and frequency due to landowner decisions, drought may have had an overall positive effect on the nest success of grassland breeding birds with greater amounts of grass cover and litter being left on the landscape, although overall nest survival was still low.

Cowbird Parasitism

Brown-headed Cowbirds are obligate brood parasites that lay their eggs in the nests of many host species of birds and do not provide any parental care to the young (Ortega and Ortega 2009, Rivers et al. 2010). Host parents must allocate time and food resources towards raising cowbird young and generally fledge fewer of their own young from a parasitized nest (Jensen and Cully 2005a, Rivers et al. 2010). Reproductive costs for the host may also include the removal of host eggs by the female cowbird (Lowther 1993, Robinson et al. 1995) and higher predation pressure during the nestling stage (Jensen and Cully 2005b). Some species of songbirds hosts, such as Bell's Vireo (*Vireo belli*), experience complete loss of reproductive effort when parasitic eggs are present in the nest (Kosciuch and Sandercock 2008). Even after fledging, host young reared alongside cowbirds may experience lower survival than young from non-parasitized nests (Peterson et al. 2012).

We found that Dickcissels were a preferred host, with higher rates of parasitism than Grasshopper Sparrows and Eastern Meadowlarks, which is consistent with previous reports from other sites in the Flint Hills ecoregion (Sandercock et al. 2008, Rivers et al. 2012). The results of our study did not show a reduction in cowbird parasitism for birds nesting in a pasture managed with patch-burn grazing compared to birds nesting in an intensive early stocked pasture. Rates of brood parasitism were actually higher on the patch-burned pasture than on the intensive early stocked pasture. Previous studies have shown reduced rates (Eastern Meadowlarks: Hovick et al. 2016; Dickcissels: Churchwell et al. 2008) or no difference (Grasshopper Sparrows: Hovick et al. 2012) in parasitism rates for birds nesting on patch-burned versus annually burned pastures.

One reason for our unexpected result may be due to the timing and frequency of burns on the pastures used in this study. The patch-burned pasture was rotationally burned according to schedule, but the intensive early stocked pasture was not burned in 2012 or 2013 due to extreme drought conditions throughout the Midwest. Conditions between the two treatment types may have been more similar than they would be in a year with more rainfall, which could have affected nest concealment and led to similar rates of parasitism. Rates of parasitism for all species were highest in 2011; the only year during our study in which the intensive early stocked pasture was burned. Even though drought conditions in 2012 and 2013 led to low vegetative production, residual vegetation and litter would likely have been higher than if the pasture had been burned. Burned areas may therefore provide easy access for cowbirds, which may be more likely to discover nests of host species in areas where vegetative cover is low.

More investigations are needed to better understand the relationship between rangeland management strategies on private lands and reproductive output of grassland songbirds. Since patch-burning is a relatively new method of rangeland management, there are few studies investigating how patch-burning influences grassland birds and vegetation characteristics on an extended time scale. Private landowners make management decisions based on weather variables, availability of forage, and price fluctuations in the cattle market which may differ considerably from year to year. Long-term studies on patch-burning may lessen effects of uncontrollable variables and help make more meaningful comparisons between management systems and grassland bird responses. Additionally, effects of patch size are not well understood. Search behavior of nest predators and Brown-headed Cowbirds may be influenced by patch size and distances to patch or pasture edges. Weather variables such as rainfall and drought influence biomass production, potentially affecting nest survival of ground-nesting birds. Understanding how burn frequency, cattle stocking rate, and weather variables interact to causes changes in the vegetation community will ultimately lead to a better understanding of grassland bird population dynamics on managed rangelands.

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Table 3.1. Sample size of nests monitored for four species of grassland songbirds, Chase and Greenwood counties, Kansas, 2011-2013.

Species	Year	Successful	Unsuccessful	Total	Apparent nest success
Dickcissel	2011	23	32	55	41.8%
	2012	18	48	66	27.3%
	2013	21	47	68	30.9%
	Total	62	127	189	32.8%
Eastern Meadowlark	2011	6	6	12	50.0%
	2012	2	11	13	15.4%
	2013	6	20	26	23.1%
	Total	14	37	51	27.5%
Grasshopper Sparrow	2011	7	11	18	38.9%
	2012	4	22	26	15.4%
	2013	8	30	38	21.0%
	Total	19	63	82	23.2%
Lark Sparrow	2011	2	3	5	40.0%
	2012	2	5	7	28.6%
	2013	1	5	6	16.7%
	Total	5	13	18	27.8%
All Species	Total	100	240	340	29.4%

Table 3.2. Model selection for candidate models for daily nest survival (S_d) of four species of grassland songbirds in managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

Models for *S*	**K**	**Dev**	**AIC$_c$**	**ΔAIC$_c$**	w_i
Constant	1	1240.22	1242.22	0.00	0.35
Year	3	1237.10	1243.10	0.89	0.22
Treatment	2	1240.20	1244.19	1.98	0.13
Year + Treatment	4	1236.87	1244.88	2.67	0.09
Species	4	1237.12	1245.13	2.91	0.08
Year × Treatment	6	1233.40	1245.43	3.22	0.07
Patch	4	1238.90	1246.90	4.69	0.03
Year + Patch	6	1235.37	1247.40	5.18	0.03
Year × Patch	12	1229.30	1253.41	11.19	0.00

Notes: Model parameters include K = no. of parameters, Dev = model deviance, AIC$_c$ = Akaike's Information Criterion corrected for small sample size, ΔAIC$_c$ = difference in AIC value from model with lowest AIC value, and w_i = model weight within candidate set. Model factors included year of study (2011-2013), rangeland treatment (intensive early-stocking vs. patch-burn grazing), and rangeland patch (intensive early-stocking vs. 0, 1 or 2 years since fire within patch-burn grazing treatment). Factors were combined in main effects or additive models (+) or factorial models with interaction terms (×).

Table 3.3. Estimates of daily survival (S_d) and period survival (S_p) for a 24-day exposure period for songbird nests in managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

Factor	S_d	**SE(*S*)**	**95%L**	**95%U**	**N**	S_p	**SE(S_p)**	**95%L**	**95%U**
DSR model									
Constant	0.9204	0.0049	0.9101	0.9295	340	0.136	0.018	0.100	0.170
Year model									
2011	0.9346	0.0088	0.9151	0.9498	90	0.197	0.045	0.012	0.291
2012	0.9136	0.0089	0.8945	0.9296	112	0.114	0.027	0.069	0.173
2013	0.9166	0.0079	0.8997	0.9309	138	0.124	0.026	0.079	0.179
Treatment model									
IESB	0.9209	0.0060	0.9082	0.9319	230	0.138	0.022	0.099	0.184
PBG	0.9194	0.0087	0.9007	0.9348	110	0.133	0.030	0.081	0.198
Patch model									
IESB	0.9209	0.0060	0.9082	0.9319	230	0.138	0.022	0.099	0.184
PBG0	0.9446	0.0220	0.8822	0.9749	9	0.255	0.142	0.049	0.544
PBG1	0.9198	0.0128	0.8908	0.9417	50	0.135	0.045	0.062	0.236
PBG2	0.9125	0.0136	0.8820	0.9358	51	0.111	0.040	0.049	0.203

Notes: Estimates of daily nest survival (S) taken from four of the best fit models (Table 3.2). Period survival for a 24-day exposure period estimated as $S_p = S_d^{24}$ where SE(S_p) was calculated from the delta method as $\mathrm{SE}(S_p) = \sqrt{[\mathrm{SE}(S_d)]^2 \times [24 S_d^{23}]^2}$.

Table 3.4. Proportion of parasitized nests by species and burn treatment in managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

Species	Burn Treatment	Proportion Parasitized	No. of Nests
Dickcissel	Annual Burn (IESB)	0.504	133
	PBG 1 year since burn	0.714	28
	PBG 2 years since burn	0.826	23
	All Treatments	0.576	184
Eastern Meadowlark	Annual Burn (IESB)	0.111	18
	PBG 1 year since burn	0.385	13
	PBG 2 years since burn	0.222	18
	All Treatments	0.224	49
Grasshopper Sparrow	Annual Burn (IESB)	0.328	64
	PBG 1 year since burn	0.666	9
	PBG 2 years since burn	0.625	8
	All Treatments	0.395	81

Table 3.5. Proportion of parasitized and unparasitized nests by species and year in managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

Species	Year	Proportion Parasitized	No. of Nests
Dickcissel	2011	0.745	55
	2012	0.554	65
	2013	0.453	64
	All Years	0.576	184
Eastern Meadowlark	2011	0.272	11
	2012	0.250	12
	2013	0.192	26
	All Years	0.224	49
Grasshopper Sparrow	2011	0.555	18
	2012	0.231	26
	2013	0.432	37
	All Years	0.395	81

Table 3.6. Mean number (± SD) of host eggs and parasitic cowbird eggs per nest in managed rangelands, Chase and Greenwood Counties, Kansas, 2011-2013.

		Unparasitized	Parasitized		
Species	**Burn Treatment**	**Mean no. host eggs**	**Mean no. host eggs**	**Mean no. Cowbird eggs**	**Number of nests**
Dickcissel	Annual Burn (IESB)	3.8 ± 1.3	3.0 ± 1.2	1.4 ± 0.7	133
	PBG 1 year since burn	4.0 ± 1.4	3.5 ± 1.3	1.5 ± 0.6	28
	PBG 2 years since burn	3.8 ± 0.5	2.1 ± 0.9	2.0 ± 0.9	23
	All Treatments	3.8 ± 1.3	3.0 ± 1.2	1.5 ± 0.7	184
Eastern	Annual Burn (IESB)	4.1 ± 1.3	3.5 ± 2.1	1.0 ± 0.0	18
Meadowlark	PBG 1 year since burn	3.8 ± 1.5	3.0 ± 0.7	1.4 ± 0.5	13
	PBG 2 years since burn	3.9 ± 1.1	3.3 ± 1.7	1.5 ± 0.6	18
	All Treatments	3.9 ± 1.3	3.2 ± 1.3	1.4 ± 0.5	49
Grasshopper	Annual Burn (IESB)	4.1 ± 1.3	2.8 ± 1.3	1.5 ± 0.6	64
Sparrow	PBG 1 year since burn	4.3 ± 0.6	3.0 ± 1.3	1.7 ± 0.8	9
	PBG 2 years since burn	4.3 ± 0.6	3.4 ± 1.8	1.4 ± 0.5	8
	All Treatments	4.1 ± 1.2	2.9 ± 1.3	1.5 ± 0.6	81

Chapter 4 - Conclusions

Grassland birds are in decline throughout their range, mainly due to loss of habitat and intensification of agricultural practices on remaining grasslands. Although the Flint Hills ecoregion contains large tracts of native tallgrass prairie, private ownership limits the ability of researchers, government agencies and environmental groups to implement management practices that may benefit grassland birds. Overall, patch-burn grazing can be beneficial for grassland birds, particularly for specialist species that need unburned areas for nesting or brood-rearing. Prior to the widespread adoption of intensive early stocking and annual burning in the 1980s, the predominant rangeland management practice in the Flint Hills involved burning pastures every 2-3 years and stocking rangelands with a lower density of steers for a longer duration. Periodic burning and lower stocking rates created a gradient of burning and grazing intensities over a broad spatial scale, which provided habitat for a greater number of grassland species. Declines of grassland birds in the Flint Hills coincide with the decrease in vegetative heterogeneity brought about by the increasing use of heavy stocking rates and annual burning. Patch-burn grazing helps to restore vegetative heterogeneity on a landscape-level scale by providing areas of residual grass cover which may provide greater concealment for ground-nesting birds.

Studies of patch-burn grazing on private working lands have been limited. Controlled studies may not adequately reflect the actions of private landowners who own and make management decisions on the vast majority of remaining tallgrass prairies. Stocking rates on privately-owned patch-burned pastures are often higher than stocking rates on experimental research units or on publically-owned tallgrass prairies, since conservation-minded landowners must balance their wildlife conservation goals with revenues from livestock production. Therefore, results of grassland bird field studies carried out on experimental research stations may not accurately reflect wider trends in grassland bird population demographics if conditions are not similar between privately-owned patch-burned pastures and research-focused patch-burned pastures. One challenge for the adoption of new rangeland management practices is that ranchers may be concerned by the lack of studies carried out on privately-owned working ranch lands. Ranchers may be more likely to switch to a patch-burn grazing management as a way to benefit wildlife if more studies are conducted on privately-owned patch-burned pastures that show livestock revenue remains consistent or even increases under patch-burn management.

Patch-burn grazing can be beneficial to landowners as well as to grassland wildlife. Because patch-burned pastures are not completely burned every year, residual vegetation is left on the landscape that can act as emergency forage for cattle during years of low production. Inadequate forage for livestock can be costly for landowners if supplemental feed must be provided or when cattle have to be removed from rangelands earlier than planned. Studies evaluating livestock production on experimental patch-burned pastures have shown no difference or a slight increase in cattle performance on pastures managed with patch-burn grazing (Limb et al. 2011, Allred et al. 2014, Winter et al. 2014). Other benefits of increased vegetative heterogeneity include a reduction in the number of horn flies on cattle (Scasta et al. 2012) and lowered rates of increase by invasive plants such as sericea lespedeza (*Lespedeza cuneata*; Cummings et al. 2007). If conservation-oriented rangeland management practices such as patch-burn grazing are shown to be economically advantageous when compared to traditional burning and grazing practices, private landowners may be more likely to change their management regimes to one which benefits wildlife in addition to benefitting their ranching operation.

Extreme weather events such as drought are predicted to occur more often due to global climate change. Continued warming is projected to threaten livestock productivity (IPCC 2013), particularly in the Great Plains where annual precipitation is predicted to decrease (Karl et al. 2009). The willingness of landowners to adapt to changing conditions will ultimately determine the level to which livestock production and therefore food security is diminished (McCarthy et al. 2001). Patch-burn grazing may be a way for landowners to mitigate negative effects of uncontrollable weather variables. The increased spatial heterogeneity provided by patch-burn grazing has been shown to stabilize livestock productivity during years with low precipitation (Allred et al. 2014), making patch-burn grazing a potentially viable rangeland management strategy for both livestock producers and conservationists.

Patch-burn grazing has drawbacks as well as benefits. One of the main barriers to landowner participation is the cost and time commitment needed to implement a patch-burn management system. Landowners who patch-burn must cut fire breaks to keep the fire contained within each patch. Maintaining fire breaks can be technically challenging, time-consuming, and may require expensive equipment. Accumulated vegetation and biomass in a patch-burned system leads to hotter and more intense fires, which may be helpful in the control of woody plants. Conversely, fires can be harder to contain in a patch-burn management because of the large amounts of fuel left on the landscape. With traditional management such as intensive early stocking and burning, the entire pasture is burned. Since this is the predominant rangeland management system in the Flint Hills, neighbors often work together to do large, multi-ranch burns that span thousands of hectares. It can be difficult to protect patch-burned pastures from fires started on neighboring ranches. Additionally, patch-burning is a relatively new method which is quite different from long-held rangeland management paradigms which promote even grazing and homogeneous utilization of forage by cattle. Landowners may be hesitant to start patch-burning if the initial start-up costs are too high, they are unsure of what the results will be in terms of their ranch revenues, if none of their neighbors are patch-burning, or if wildlife conservation is not a priority for decisions about rangeland management. Since patch-burn grazing is a long-term management strategy that may not show positive results for a number of years, it may be difficult for landowners to implement.

Fortunately, there are assistance programs available for landowners who are interested in patch-burn grazing. The United States Department of Agriculture's Natural Resources Conservation Service can provide eligible landowners with financial and technical assistance to help offset the costs of implementing a new patch-burn management, and the United States Fish and Wildlife Service's "Partners for Fish and Wildlife" program can provide grants to eligible landowners who are interested in patch-burn grazing. The Audubon Society can enroll interested landowners in their "Conservation Ranching" initiative which helps landowners manage rangelands for grassland birds while providing access to premium grass-fed beef markets. The Audubon Society is currently developing a Conservation Ranching program to be implemented in the Flint Hills within the next 2-3 years. Large-scale implementation of patch-burn grazing or other heterogeneity-based management practices by private landowners in the Flint Hills may ultimately help to slow declines of native birds by creating habitat that better matches the historical conditions under which tallgrass prairie species evolved.

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Appendix A - Values for vegetation characteristics and grassland bird densities

Median values for vegetation characteristics were obtained for all pastures monitored in 2011-2013 (Table A.1). Vegetation characteristics measured include visual obstruction (VOR) in decimeters, percent cover of grass, percent cover of forb, percent cover of bare ground, percent cover of shrub, percent cover of litter, and litter depth. Densities per hectare of six species of grassland birds (Figure A.2) were estimated for all habitat strata using line transect data pooled for all years from 2011-2013. Habitat strata include intensive early stocking and burning (IESB), patch-burn grazing year of burn (PBG0), patch-burn grazing one year since fire (PBG1), patch-burn grazing two years since fire (PBG2), and season-long stocking and burning (SLSB).

Table A.1. Vegetation characteristics (median values) of managed rangelands in Chase and Greenwood Counties, Kansas, 2011-2013.

Burn Treatment	VOR (decimeters)	Percent cover of grass	Percent cover of forb	Percent cover of bare ground	Percent cover of shrub	Percent cover of litter	Litter Depth (mm)
IESB	1.00	36.15	14.48	30.73	0.00	0.00	0.00
PBG0	0.88	32.50	11.57	24.80	0.00	2.40	0.58
PBG1	1.75	46.07	17.40	7.19	0.00	0.42	0.46
PBG2	2.13	55.31	15.32	1.46	0.00	1.88	3.67
SLSB	2.00	45.00	18.54	16.67	0.00	0.00	0.00
All	1.50	43.96	15.21	12.29	0.00	0.63	0.75

Table A.2. Density estimates (birds per hectare) for grassland birds in managed rangelands in Chase and Greenwood Counties, Kansas, 2011-2013.

Species	IESB	PBG0	PBG1	PBG2	SLSB
Dickcissel	0.95 ± 0.05	0.93 ± 0.04	1.25 ± 0.05	1.36 ± 0.05	2.01 ± 0.10
Grasshopper Sparrow	1.15 ± 0.06	0.78 ± 0.04	1.29 ± 0.06	1.09 ± 0.05	1.27 ± 0.09
Eastern Meadowlark	0.45 ± 0.03	0.44 ± 0.02	0.59 ± 0.03	0.72 ± 0.03	0.65 ± 0.05
Brown-headed Cowbird	0.09 ± 0.01	0.10 ± 0.01	0.17 ± 0.02	0.18 ± 0.02	0.21 ± 0.03
Upland Sandpiper	0.09 ± 0.01	0.13 ± 0.01	0.07 ± 0.01	0.05 ± 0.01	0.15 ± 0.02
Henslow’s Sparrow	0	0.27 ± 0.04	0.52 ± 0.06	0.49 ± 0.06	0