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# Survival of grasshopper sparrows (Ammodramus savannarum) during two important life stages in grassland managed with fire and grazing

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Survival of grasshopper sparrows (*Ammodramus savannarum*) during two

important life stages in grassland managed with fire and grazing


by


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## CHAPTER 1. GENERAL INTRODUCTION

Tallgrass prairie in the eastern United States has been classified as critically endangered (Noss et al. 1995). Throughout most of its original extent, < 0.10 % remains and many persisting remnants occur in small and isolated parcels (Samson & Knopf 1994). Not surprisingly, obligate grassland birds have undergone precipitous population declines and some forecast grassland birds are the next major conservation crisis (Brennan & Kuvlesky 2005).

Land use change in the form of row-crop agriculture has been a major reason for the decline of the tallgrass ecoregion (Smith 1990). However, more recently the intensification of agricultural practices, and management that creates homogenous habitat structure, has further degraded remaining grasslands (Vickery et al. 1999, Fuhlendorf & Engle 2001). Practices such as fence-line to fence-line plowing, early haying, over-grazing, and intensive early grazing have all contributed to grassland loss or degradation (Churchwell et al. 2008). Management that increases heterogeneity and re-couples the historic disturbances that shaped pre-settlement tallgrass prairie landscapes may be a beneficial alternative to many current management practices.

Patch-burn grazing uses a fire and grazing interaction to promote heterogeneity across the landscape (Fuhlendorf & Engle 2001). Through the use of discrete fire and the resulting focal grazing, patch-burn grazing creates a shifting mosaic of habitat that varies spatially and temporally (Fuhlendorf & Engle 2001, Fuhlendorf & Engle 2004). The resulting habitat resembles the structure of historic grasslands and can be exploited by multiple grassland birds, in contrast to the few that can inhabit grasslands under homogenizing-current managements (Fuhlendorf et al. 2006).

Grasshopper Sparrows (*Ammodramus savannarum*) are a continental species of concern as a result of habitat loss and are listed as a Species of Greatest Conservation Need in Iowa (Panjabi 2005, Zohrer 2005). Current grassland practices in Iowa manage for tall, rank grasslands such as Conservation Reserve Program (CRP) set-asides, or they are heavily grazed and have too little vegetation for nesting structure. The fire-and-grazing interaction creates a gradient of habitat types that can benefit nesting grassland birds like Grasshopper Sparrows and Eastern Meadowlarks (*Sturnella magna*) that prefer mid-level grassland structure for nesting habitat (Lanyon 1995, Vickery 1996).

Most of the work examining the effectiveness of patch-burn grazing in managing for grassland birds has occurred at the Tallgrass Prairie Preserve in Oklahoma. The Tallgrass Prairie Preserve is a large tract of grassland, with a much different spatial extent at which grassland is found than in corn-belt states farther east like Iowa (Fuhlendorf et al. 2006, Churchwell et al. 2008, Coppedge et al. 2008). In contrast to previous work, our study examined Grasshopper Sparrow survival during two life stages in response to patch-burn grazing in a highly fragmented, agricultural landscape. Our findings provide information on the effectiveness of patch-burn grazing in a landscape that has not been studied previously and could influence future land-manager choices in this landscape.

**THESIS ORGANIZATION**

This thesis is composed of two papers written for publication in scientific journals. Chapter 1 contains a general introduction of my research and why it merits investigation. Chapter 2 evaluates the effectiveness of patch-burn grazing at creating nesting habitat that is beneficial to Grasshopper Sparrows and other factors that are associated with nest survival in

that species. Chapter 3 investigates survival of Grasshopper Sparrows during the postfledging stage with use of radio telemetry. Chapter 4 contains general results from my research. Data acquisition, statistical analysis, and preparation of the text were the responsibility of the candidate, while editorial advice and guidance were given by Dr. James R. Miller.

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# CHAPTER 2. EFFECTS OF FIRE AND GRAZING ON GRASSHOPPER SPARROW NEST SURVIVAL IN A FRAGMENTED LANDSCAPE

A paper to be submitted to the Journal of Wildlife Management

Torre J. Hovick, James R. Miller, Stephen J. Dinsmore, David M. Engle, Diane M. Debinski, and Samuel D. Fuhlendorf

**Abstract:** Patch-burn grazing is a management framework that promotes heterogeneity in grasslands, similar to the structure grasslands birds evolved inhabiting. Published studies on patch-burn grazing have been conducted on large, contiguous grasslands and only one of these studies has investigated the reproductive success of grassland birds. We assessed the effects of patch-burn grazing (grazing, one third of the pasture burned annually) compared with a more traditional graze-and-burn treatment (grazing, entire pasture burned every third year) on nests of grasshopper sparrows (*Ammodramus savannarum*) in fragmented grasslands. We modeled grasshopper sparrow nest survival as a function of multiple biological and ecological factors. Constant daily survival rates were greater in patch-burn grazing pastures than in graze-and-burn pastures (patch-burn grazing rate $\bar{x} = 0.930$, burn-and-graze rate $\bar{x} = 0.907$). Multiple factors were significant in survival models including year, stage of nest, a negative effect of nest age, and a negative effect of cool-season grass abundance within five meters of the nest. Our findings represent grassland bird survival in small-scale, fragmented grassland similar to many found throughout the corn-belt region of the United States. Results showed that survival rates were the highest in pastures managed with patch-burn grazing, but multiple factors influenced grasshopper sparrow survival. Results emphasize the importance of researchers using multiple covariates when examining

nest survival to inform land managers and to increase ecological understanding of nest survival in grassland birds.

*Key Words:* cattle grazing, daily survival rate, grasshopper sparrow, heterogeneity, Iowa, nest predators, nest success, patch-burn grazing, prescribed fire, tallgrass prairie

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## INTRODUCTION

Grasslands are one of the most endangered ecosystems in the world (Noss et al. 1995). Nearly 80% of prairie in the United States has been converted to other land uses (Samson & Knopf 1994). In the Tallgrass Ecoregion, < 4% of tallgrass prairie persists that existed at the time of settlement (Samson and Knopf 1994) and in the eastern states of this region < 0.01% remains (Smith 1990). Not surprisingly, grassland birds are declining at a greater rate than any other habitat-reliant group of birds (Brennan and Kuvlesky 2005).

Native grasslands have experienced widespread conversion to cropland and in many protected areas native grasslands have experienced a decoupling from historic disturbances, resulting in encroachment by woody vegetation (Samson & Knopf 1994, Fuhlendorf & Engle 2001). Lack of management, such as fire suppression and the removal of large herbivores, can make grassland unsuitable for multiple grassland bird species (Fuhlendorf et al. 2006). In addition, agricultural practices aimed at increasing livestock production have also been identified as negatively affecting grassland bird populations (Fuhlendorf et al. 2006, With et al. 2008). These include cross-fencing pastures, annual burning, intensive early grazing and over-stocking, and the elimination of forbs – all of which have a homogenizing effect on grassland habitats (Churchwell et al. 2008). Collectively, these practices result in decreased habitat heterogeneity at landscape scales (Fuhlendorf et al. 2006).

Fuhlendorf and Engle (2004) recommend the use of fire and grazing in tandem to promote heterogeneity sufficient to accommodate the full spectrum of grassland-dependent wildlife. Fuhlendorf et al. (2009) contend that grazing and fire do not operate independently and in many cases their interaction is more important than the independent effects would predict. Patch-burn grazing is a management framework that relies on a fire-and-grazing interaction to create heterogeneity across grasslands. This is accomplished by applying discrete fires to grassland and allowing grazing animals to freely select from burned and unburned portions of the landscape (Fuhlendorf & Engle 2001, Fuhlendorf et al. 2009). Free-ranging grazers focus on recently burned areas, decreasing the probability of future fires and allowing fuel to accumulate in areas with more elapsed time since fire. This process creates a spatially shifting mosaic of habitat types with varying structure dependent on the time since fire and grazing (Fuhlendorf et al. 2009).

To date, most published studies on the effects of patch-burn grazing on grassland birds have been conducted on The Nature Conservancy's Tallgrass Prairie Preserve, a large (~15, 000 ha), contiguous grassland in Oklahoma. There, researchers have reported an increase in the diversity of grassland-bird species in pastures treated with patch-burn grazing compared with those under traditional agricultural management (Fuhlendorf et al. 2006, Coppedge et al. 2008). In the only study to investigate nest success under patch-burn grazing, Churchwell et al. (2008) reported that nesting success was greater for dickcissels (*Spiza americana*) in one and two year post-burn patches of patch-burn grazed pastures than in traditionally treated pastures.

In contrast to northern Oklahoma, most of the remaining grassland in the Midwest occurs in the form of small, privately held pastures and hayfields, and grassland with public ownership in this region is usually isolated (Herkert et al. 1995). Treating grasslands of this nature with patch-burn grazing could result in areas that are perceived as smaller patches by grassland birds,

exacerbating the negative effect of fragmentation that exist. Fragmentation negatively affects grassland birds by reducing survival and increasing predation and parasitism rates by Brown-headed Cowbirds (*Molothrus ater*) (Johnson & Temple 1990). Previous work on fragmented grassland have supported a decrease in nest survival and grassland-bird density as a result of small patch sizes caused by fragmentation (Herkert 1994, Helzer & Jelinski 1999, Johnson & Igl 2001, Davis 2004). It is essential that patch-burn grazing is examined in a fragmented landscape to determine how nesting grassland birds respond.

We examined the effect of patch-burn grazing on nest success in a fragmented landscape in southern Iowa, USA. We focused on the grasshopper sparrow (*Ammodramus savannarum*), a continental species of concern which has declined by >69% across the Midwest (Herkert 1994, Panjabi 2005). Our objective was to model grasshopper sparrow nest survival in experimentally altered grasslands treated with patch-burn grazing and a more traditional treatment as a function of multiple biological and ecological parameters. That is, we intended to identify variables associated with nest survival.

**METHODS**

*Study area*

Our study was conducted on 9 pastures in Ringgold County, Iowa, ranging from 22.5-37 ha (Fig. 1). Pastures were under the jurisdiction of either the Iowa Department of Natural Resources, The Nature Conservancy, or privately-owned. This region lies within the Dissected Till Plains physiographic region, originally shaped by the Pre-Illinoin glacial advances some 500,000 years ago (Prior 1991). Mean annual precipitation for the area ranges from approximately 90-100 cm annually (NCDC 2008). About 80% of the region remains in

native and non-native grasslands, although woodlands and row-crop fields are common in drainages and river bottoms. On average, the landscape (within 1 km) surrounding research pastures is comprised of 12% row-crops, 62% grassland, and 24% woody vegetation (F. Pillsbury, unpublished data). Dominant native herbaceous species include rough dropseed (*Sporobolus clandestinus*), sedges (*Carex* spp.*),* and Baldwin's ironweed (*Veronica baldwinii*) (McGranahan 2008). Tall fescue (*Lolium arundinaceum*), an exotic forage species, was present on all pastures and was the dominant grass species on most (McGranahan 2008). Other common exotics included black medick (*Medicago lupulina*) and Kentucky bluegrass (*Poa pratensis*).

In 2007, research pastures were assigned to either the patch-burn grazing treatment (n = 5) or a graze-and-burn treatment (n=4). All pastures were stocked with cattle at 1.1 to 1.5 animal units per month (AUM) per acre and fenced on the perimeter. One third of each of the patch-burn pastures was burned annually and the graze-and-burn pastures were burned completely in the third year of the study to prevent encroachment of woody vegetation. An escaped fire burned two-thirds of a patch-burn grazed pasture in 2009.

*Data Collection*

We searched for nests from 0600 to 1200 (CST) from 14 June through 15 July in 2008 and 15 May through 25 July in 2009. Most nests were located by systematic rope-dragging (Higgins et al. 1969, Galligan et al. 2006) in which a flag was placed at one end of a 30-m rope every 50 m to ensure complete and systematic coverage of research pastures. In the event of a flush, we searched the area extensively. If a nest was not found and the flushed bird showed signs of nesting (i.e., insistent chipping, flailing wing display, short-circular

flights), the location was marked as a probable nest site and searched again within 3d by walking and using flushing sticks (Winter et al. 2003). We located few nests by observing parental behavior and through incidental flushes because these methods were less effective and more time consumptive (Kershner 2004). No nest searches were conducted during rain events (Martin and Geupel 1993).

When we located nests, the Universal Transverse Mercator (UTM) coordinates were recorded, eggs were candled to determine age (Lokemoen and Koford 1996), and flagging was placed 5-m north and 5-m south of the nest to aid in relocation. Nest-site flagging was placed low in the vegetation to reduce visual cues to aerial predators. We subsequently visited nests every 3 days, with more frequent visits near stage transitions to determine ages and outcome accurately. During each nest visit, we recorded the date, time, and number and stage of eggs/nestlings, including brown-headed cowbirds (Ralph et al. 1993). We considered a nest to be successful if ≥1 conspecific young fledged. Fledging was confirmed by parental behavior (i.e., alarm calls & feeding).

We measured vegetation features at each nest 25 days after the calculated nest initiation dates, which is the nesting period for grasshopper sparrows, (Vickery 1996). This standardized vegetation measurements and reduced biases stemming from failed nests. We quantified abundance of warm-season grasses, cool-season grasses, tall fescue, forbs, bare ground, litter, and woody vegetation using a 0.5-m$^2$ quadrat, classifying percent cover using the midpoints of the following categories: 0-5, 6-25, 26-50, 51-75, 76-95, and 96-100 % (Daubenmire 1959). Tall fescue was measured separately from other cool-season grasses, given its dominance on research pastures (McGranahan 2008) and because it is an invasive species that has been associated with poor feeding, nesting, and roosting habitat for grassland

birds (Barnes et al. 1995). Quadrats were centered over the nest bowl and microhabitat measurements were taken 5-m away from the nest in each cardinal direction. Vegetation structure was quantified by recording the height at which a Robel pole was 50% obscured while standing at a distance of 4 m and viewing at 1 m above ground (Robel 1970).

We quantified distances to woody edges, fencelines, and permanent water bodies from each nest bowl using the measure tool in ArcGIS 9.2 (Environmental Systems Research Institute, Redlands, California), and overlaying UTM coordinates from each nest on 2-m resolution true color digital orthophotos from August of 2005 (U.S. Department of Agriculture 2005).

*Data Analysis*

We used SAS 9.2 (SAS Institute Inc., Cary, North Carolina) to examine clutch sizes among treatments (i.e., graze-and-burn pastures, patch-burn grazing current-yr burn, patch-burn grazing 1-yr post-burn, and patch-burn grazing 2-yr post-burn) using a 2-way analysis of variance (ANOVA) with a split-plot design and to compare rates of parasitized and non-parasitized nests across treatments in both years of the study. Patches within patch-burn pastures were considered to be the experimental unit because each patch had a unique treatment imposed by the fire-grazing interaction (Churchwell et al. 2008). We report comparisons of parasitized and non-parasitized clutch sizes as means and standard errors.

Daily nest survival was estimated using the nest survival model in program MARK (White and Burnham 1999). Program MARK uses a maximum-likelihood estimator and the use of a logit function to derive daily survival probabilities (Dinsmore et al. 2002). This approach enables researchers to incorporate nest survival variables of interest including nest

age, timing of nesting events, and vegetation characteristics (Dinsmore & Dinsmore 2007), which earlier methods such as the Mayfield estimator were unable to do. Furthermore, program MARK is menu driven and does not require programming experience by the user (Dinsmore et al. 2002). For purposes of comparison, we report constant (Mayfield) daily survival rates that were calculated in program MARK, but our primary focus is indentifying variables associated with nest survival.

We included biological and ecological parameters in MARK models generated *a priori* on the basis of previous grassland-bird research and prior knowledge. We divided nesting data into 20 groups generated from combinations of year, nesting stage, and treatments. Nests found early in the nesting cycle and surviving multiple stages could be included in multiple groups, but we censored nests on the last day of observation for the first stage and initiated it on that day for the second stage when including nests in more than one group (Dinsmore & Dinsmore 2007). To standardize nest ages across both years, we set 14 May as day one and sequentially numbered days through 15 August.

We used a hierarchical modeling scheme to explain nest survival (Winter et al. 2006, Dinsmore & Dinsmore 2007). A multi-stage approach allowed us to reduce the overall model set and the final modeling stage included the most variables explaining nest survival. At each stage, all models were identified using Akaike's Information Criterion, adjusted for small sample sizes (AIC$_c$: Burnham and Anderson 1998). Only the model with the lowest AIC$_c$ score from each stage was used as a base model for adding variables in the next. If adding variables in one stage did not increase the parsimony of the model (i.e., lower the AIC$_c$ score with the addition of variables), then base model from the previous stage was used in the next

stage. After all modeling was complete we used the general approach of Burnham and Anderson (2002) for making inference from the model set.

In the first stage of modeling, we incorporated temporal patterns within and between years. Within year variation in survival may result from timing of nest initiation for birds with nesting experience compared to those without, seasonal weather patterns, shifts in food resources, and changes in the predator community (Wiebe & Martin 1998, Dinsmore et al. 2002). Similarly, patterns across years can influence survival due to extraordinary weather events, cyclical increases in predator or prey abundance, resource availability, and changes in landscape composition (Rotenberry & Wiens 1989, Grant et al. 2005).

In the second stage of modeling, we added variables for treatment and the effect of nest-stage to the best models from the first stage. Variables included the incubation and nestling stages for each year, plus the egg-laying stage in 2009. We coded for treatment and stage effects by using 0 and 1 in the design matrix to represent the respective groups. We examined nest-stage effects because survival may decrease during the nestling stage due to increases in parental activity around the nest site (Conway & Martin 2000).

In the third modeling stage, we investigated the effect of nest age within each nesting stage, regular nest visits (coded 1 for visit days, 0 for not), and brown-headed cowbird parasitism. We chose these varaibles because they have all been used to describe changes in survival rates (Temple & Johnson 1990, Dinsmore & Dinsmore 2007), and to show that precautions taken during data collection prevented any negative effect on nesting survival.

In the fourth stage, we explored the effect of nest placement relative to three specific edge types; woody vegetation, fence-lines, and permanent water bodies. These edges have been associated with mesopredator abundance and we believed they could act as corridors,

making nests in close proximity more vulnerable to opportunistic predation events. Grassland

bird nesting survival decreased within 50 m of shrubby edges in Missouri (Winter et al.

2000).

We added variables describing the microhabitat and then those related to the nest

bowl in the final two modeling stages.

**RESULTS**

In 2008 and 2009 we found a total of 327 Grasshopper Sparrow nests (77 in 2008, 250 in

2009). Mean daily survival rates were greater in all patch-burn grazing patches compared to

graze-and-burn pastures (Table 1). The highest average survival rate was in the 1-year post-

burn patches (0.9305) and the current-year burn patches (0.9300; Table 1). Overall, the

probability of a nest surviving the 20-day nesting period (incubation and nestling stages) was

23.1% in patch-burn grazing pastures and 14% in graze-and-burn pastures. Clutch sizes

differed between parasitized and non-parasitized nests across all research patches (i.e.,

experimental units) ($F_{1, 310} = 105.09$, $P < 0.001$); average clutch size for parasitized nests was

2.42 (SE = 0.12) and non-parasitized nests was 3.92 (SE = 0.07). Rates of parasitism were

not different across research patches ($F_{3, 310} = 0.78$, $P = 0.50$) (Table 2), and the clutch sizes of

non-parasitized nests were not significantly different across research patches ($F_{3, 178} = 1.09$, $P

= 0.35$) (Table 2).

Nests failed as a result of predation, abandonment, and trampling. We did not monitor

nests to identify predators, but we did observe raccoons (*Procyon lotor*) and striped skunks

(*Mephitis mephitis*) in pastures regularly. On four separate occasions, we witnessed an

eastern garter snake (*Thamnophis sirtalis*) attempting to eat nestlings. Most cases of

abandonment followed repeated losses of an individual egg from a nest, presumably by small reptiles or rodents rather than larger predators, which would consume the entire clutch (Maxon & Oring 1978, Davison & Bollinger 2000). Cattle trampling was responsible for the failure of five nests (<1.6%). We did not attribute any nest failures to weather.

We included 323 nests with known fates in a maximum-likelihood analysis in the nest survival model of program MARK. Our results indicate that the nest survival of grasshopper sparrows was influenced by year, nesting stage, age of nest, and cool-season grass abundance within 5 m of the nest (Table 3). Evidence of a year effect on survival was strong in the best model. Compared with 2009, survival in 2008 was substantially greater ($\beta_{2008} = 0.59$ on a logit scale, SE = 0.18, 95% CI was -0.96, -0.22). Similarly, nest stage had a strong effect on survival ($\beta_{stage} = 2.16$ on a logit scale, SE = 0.38, 95% CI was 0.38, 1.42). Nest survival was greater during the nestling stage than during incubation and decreased significantly with time during each stage ($\beta_{age} = -0.12$ on a logit scale, SE = 0.02, 95% CI was -0.17, -0.08). For example, a nest in the incubation stage had a greater probability of surviving a one-day-interval on the first day of incubation than on the final day. Similar to the age effect, cool-season grass abundance within 5 m of the nest had a negative effect on daily nest survival ($\beta_{cool\_season\_5} = -0.01$ on a logit scale, SE = 0.004, 95% CI was -0.02, -0.002). No habitat measurements at the nest bowl were significant, but warm-season grass abundance and tall fescue abundance were included in the most competitive models (Table 3).

We used our best model to create predictive graphs based on year (2008 & 2009), stage of the nest (incubation & nestling), age of the nest (1-11 for incubation, 1-9 for nestling), three levels of cool season grass abundance in the microhabitat (minimum, mean, and maximum), and the average recorded warm-season grass abundance at the nest site (Fig.

2 & Fig. 3). These graphs highlight the effect of changes in cool-season grass abundance on the predicted daily survival rates of grasshopper sparrow nests.

**DISCUSSION**

Research published on patch-burn grazing has been on large, contiguous tracts of grassland (Fuhlendorf and Engle 2004, Fuhlendorf et al. 2006, Churchwell et al. 2008, Coppedge et al. 2008), but this is the first study to investigate its effects on nest survival in a highly fragmented system. Our data suggest that grasshopper sparrows will have greater survival in patch-burn pastures than in pastures with a more traditional treatment. Higher daily survival rates in patch-burn pastures likely results from increased spatial heterogeneity and a decrease in cover as a result of focal grazing.Patch contrast was not as evident as expected in this study (McGranahan et al., unpublished data), but patch-burn grazing effectively created vegetation structure suitable for nesting grasshopper sparrows. Previous work related a decrease in grasshopper sparrow nest survival to increased vertical cover and found that grasshopper sparrows were most abundant in fields with moderate vegetation height (Patterson & Best 1996). Similarly, Whitmore (1981) observed a reduction in grasshopper sparrow densities as vegetation density increased and a concomitant decrease in bare ground occurred.

Fragmentation stemming from intensive agricultural practices, woody encroachment, high road density, and urbanization has been blamed, in part, for major declines in grassland bird populations (Askins 2000, Perkins et al. 2003, Brennan & Kuvlesky 2005). Some fear that using patch-burn grazing management will increase the effects of fragmentation in grasslands that are already exposed to these problems. Fragmentation creates edges that may

act as travel corridors for mesopredators which can increase the predation rates for nests near edges (Fritzel 1978, Winter and Faaborg 1999). Our results did not provide support for an effect of proximity to any edge on daily survival rates. We attribute this lack of support to two main factors. First, the area surrounding pastures is highly fragmented by roads, fence-lines, woody draws, and small woodland areas, which makes most nests close to edges. On average, the distance from nests to the nearest edge was 58.25 m, and the greatest distance from a nest to any edge was 133 m. This is much less than the 190 m Renfrew and Ribic (2003) recorded predators traveling away from woody edges to grassland bird nests in southern Wisconsin. Perkins et al. (2003) also documented grassland nest predators known to prefer edges occurring as far as 400 m from woody edges. Grassland predator communities may be highly complex, with multiple species responsible for nest predation events (Pietz & Granfors 2000, Skagen et al. 2005). If predation events are associated with small mammals or snakes, distances of nests from edges may have no relationship with survival rates.

Small mammals and snakes could increase mortality rate during the incubation stage than during the nestling stage, and the size of grasshopper sparrow eggs makes them more susceptible to egg predators than grassland birds with larger eggs (Davison & Bollinger 2000). We found that nests had greater survival rates during the nestling stage than the incubation stage. Grassland-bird studies have reported greater survival during the nestling stage than the incubation stage (Lorenzana et al. 1999, Giocomo et al. 2008). This is likely a result of the abundance of egg-predators that are commonly found within grasslands (Pietz & Granfors 2000). Weatherhead and Blouin-Demers (2004) report that 6 out of 8 studies that identified nest predators with cameras identified snakes to be the most numerous. Shochat et al. (2005) reported 79% of predators in Oklahoma to be reptilian and suggested this as reason

for greater mortality in ground nesting birds when compared to shrub and tree nesters. We believe small snakes and rodents account for the majority of predation events during the incubation stage and consequently daily survival rates are greater when nests advance to the nestling stage.

Cowbirds commonly parasitized nests in our study area (24% of all nests in 2008, 28% in 2009) and parasitized nest had significantly lower clutch sizes than those that were not. Parasitism rates have been attributed to multiple factors that include proximity to woody edges, vegetation structure, host vulnerability and proximity to livestock (Fondell & Ball 2004). Patten (2006) examined different combinations of grazing and burning treatments on grasslands in Oklahoma and found no difference in parasitism rates, likely due to the large scale of research pastures and relatively few perching sites for cowbirds to use across all treatments. In the Flint Hills, parasitism rates were as high in CRP fields as in grazed pastures and rates of parasitism were 2-5 times greater in the northern Flint Hills than further south (Rahmig et al. 2008), indicating a possible regional effect as oppose to a response of grassland structure. Density measure of cowbirds in our research pastures were higher in more traditionally treated pastures than in patch-burn graze pastures (Pillsbury et al., unpublished data), but rates of parasitism did not differ across treatments. This result suggests that high parasitism rates are a result of high cowbird abundance regionally, and rate was not affected by the pasture treatments.

Survival rate decreased as a result of increased nest age during this study (Fig 2 &3). Multiple studies have included nest age as a variable to explain nest survival and have found a decrease in survival as nests age increases (Winter 1999, Conway and Martin 2000, Shochat et al. 2005). The older a nest is, the more time it is exposed to predators, weather, or

other factors, which increases the risk of failure (Grant et al. 2005). Furthermore, during the nestling stage of nesting, chicks have greater resource demands as they mature and parents are forced to make more visits to the nest on a daily basis (Martin et al. 2000). The increased activity around the nest creates more cues for predators and, in turn, increased mortality. More than 60 years ago, Skutch (1949) reported that increased parental behavior around the nest increases predation on nests.

Survival models revealed a decrease in daily survival rates as cool-season grass abundance increased within five meters of the nest site. More generally, survival decreased with greater abundance of total vegetation around the nest site. We offer two explanations for this result. First, an increase in vegetation abundance has a concomitant reduction in bare ground, and grasshopper sparrows are known to primarily forage on bare ground (Vickery 1996). We do not believe food resources are limited by vegetation type in this study (Debinski et al., unpublished data), rather that access to invertebrates is limited by the presence of vegetation. In Oregon, Kennedy et al. (2009) found that, as bare ground decreased, the diets of nesting grassland birds changed; the diet shift was not a result of decreased invertebrate abundance, but presumably due to increased cover, which reduced access to ground dwelling invertebrates. Second, increased vegetation around nest sites may create refuge for predators such as snakes and small mammals, thereby, creating lower survival rates in areas with greater overall vegetation.

**MANAGEMENT IMPLICATIONS**

Survival rates for both treatments were relatively low, and factors other than grassland treatment were more instrumental in predicting grasshopper sparrow survival. Grasshopper

sparrows had lower daily survival rates as nest age increased and survival rates decreased as the amount of cover within five meters of the nest site increased. Spring burning and grazing can reduce cool season grass and vegetation cover, if land managers' goals involve managing for grasshopper sparrows. We would recommend increasing bare ground within grasslands and maintaining bunchgrasses for suitable nesting substrate. Given the need for patchy habitat that grasshopper sparrows require, maintaining regular disturbances such as cattle grazing and prescribed fire is also important.

**ACKNOWLEDGMENTS**

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Table 1. Constant daily survival estimates and standard errors for nests in graze-and-burn and patch-burn grazed (current-yr burn patch, 1-yr postburn patch, and 2-yr postburn patch) pastures in Ringgold County, IA, USA. Mean survival rates are listed in bold for each treatment.

| | Graze-and-burn | | Patch-burn grazing | | | | | |
| | | | Current-yr burn | | 1-yr postburn | | 2-yr postburn | |
| **Stage and year** | DSR | SE | DSR | SE | DSR | SE | DSR | SE |
|---|---|---|---|---|---|---|---|---|
| Incubation 2008 | 0.917 | 0.03 | 0.945 | 0.02 | 0.923 | 0.04 | 0.943 | 0.02 |
| Nestling 2008 | 0.925 | 0.03 | 0.963 | 0.03 | 0.986 | 0.01 | 0.942 | 0.02 |
| Laying 2009* | 0.641 | 0.12 | 0.788 | 0.11 | 0.630 | 0.30 | 0.737 | 0.12 |
| Incubation 2009 | 0.888 | 0.02 | 0.920 | 0.015 | 0.899 | 0.03 | 0.908 | 0.02 |
| Nestling 2009 | 0.896 | 0.02 | 0.892 | 0.02 | 0.914 | 0.03 | 0.917 | 0.02 |
| **Means** | **0.9065** | | **0.9300** | | **0.9305** | | **0.9275** | |

*Due to small sample sizes, laying stage rates were eliminated from mean computations.

Table 2. Clutch size means (SE) for parasitized and non-parasitized nests of grasshopper sparrows in graze-and-burned and patch-burn grazed (current-yr burn patch, 1-yr postburn patch, and 2-yr postburn patch) pastures in Ringgold County, IA.

| | | Patch-burn grazing | | |
| Clutch type | Graze-and-burn | Current-yr burn | 1-yr postburn | 2-yr postburn |
| --- | --- | --- | --- | --- |
| Parasitized | 2.55 (0.21) | 2.24 (0.19) | 2.36 (0.36) | 2.54 (0.18) |
| Non-parasitized | 4.05 (0.07) | 3.86 (0.16) | 4.08 (0.16) | 3.71 (0.13) |
| | | | | |
| **Overall** | 3.30 (0.10) | 3.05 (0.12) | 3.22 (0.20) | 3.12 (0.10) |

Table 3. Models explaining effects of year, temporal trends, management treatments, nest age, nest stage, observer effects, distance to woody edges and fencelines, cool-season grass canopy cover within 5 meters of the nest, all vegetation within 5 meters of the nest, warm-season grass canopy cover at the nest bowl, and tall fescue canopy cover at the nest bowl of nests in Ringgold County, IA.  Stages represent the order at which factors were added to models. The best (i.e., lowest $AIC_c$) two models from each stage are shown.

| Model | $\Delta AIC_c$[a] | $K$[b] | $W_i$[c] | Deviance |
|---|---|---|---|---|
| **Stage 1** | | | | |
| S(year) | 39.23 | 2 | 0.00 | 1057.32 |
| S(null) | 49.46 | 1 | 0.00 | 1069.54 |
| **Stage 2** | | | | |
| S(year+stage) | 29.22 | 4 | 0.00 | 1043.29 |
| S(year+treatment) | 41.60 | 5 | 0.00 | 1053.67 |
| **Stage 3** | | | | |
| S(year+stage+age effect) | 2.86 | 5 | 0.03 | 1014.92 |
| S(year+stage+observer effect) | 31.01 | 5 | 0.00 | 1043.16 |
| **Stage 4** | | | | |
| S(year+stage+age effect+distance to woody veg.) | 4.66 | 6 | 0.01 | 1014.71 |
| S(year+stage+age effect+distance to fenceline) | 4.72 | 6 | 0.01 | 1014.77 |
| **Stage 5** | | | | |
| S(year+stage+age effect+csg_5*) | 1.38 | 6 | 0.06 | 1011.45 |
| S(year+stage+age effect+all_veg_5*) | 2.85 | 6 | 0.06 | 1011.49 |
| **Stage 6** | | | | |
| S(year+stage+age effect+csg_5*+warm_season*)** | 0.00 | 7 | 0.13 | 1008.25 |
| S(year+stage+age effect+csg_5*+fescue) | 0.21 | 7 | 0.12 | 1009.26 |

*Abbreviations: csg_5 = cool season grass measured within five meters of the nest site,

all_veg_5 = sum of all vegetation types measured within five meters of the nest site,

warm_season = warm season grass canopy coverage at the nest site.

**Best model has an $AIC_c$ score of 1022.0890

[a] Akaike's information criterion adjusted for small sample sizes. Numbers are based on differences from the best overall model.

[b] The number of parameters used in each model.

[c] Model weight.

FIGURE LEGENDS

Figure 1. Map of research sites in Ringgold County, IA, USA.

Figure 2. Daily survival rates in 2008 as a function of nest age and cool-season grass abundance in the microhabitat from the best MARK model. Incubation (A) and nestling (B) stages for grasshopper sparrow nests in pastures treated with fire and grazing. Lines represent the minimum, mean, and maximum amount of cool-season grass abundance measured within 5 m of nest sites in Ringgold County, IA, USA.

Figure 3. Daily survival rates in 2009 as a function of nest age and cool-season grass canopy cover (%) in the microhabitat from the best MARK model. Incubation (A) and nestling (B) stages for grasshopper sparrow nests in pastures treated with fire and grazing. Lines represent the minimum, mean, and maximum amount of cool-season grass abundance measured within 5 m of nest sites in Ringgold County, IA, USA.

Appendix A. Model set for grasshopper sparrow survival in Ringgold County, IA, USA.
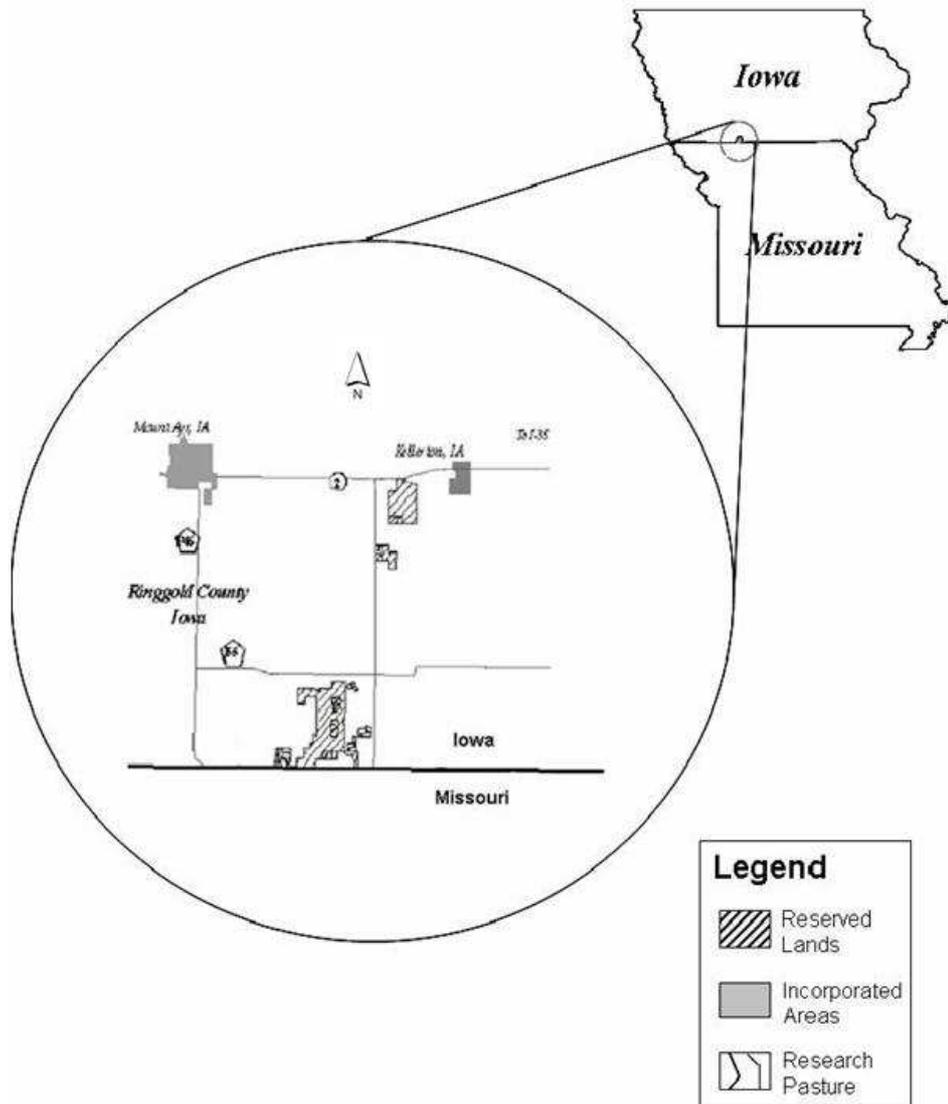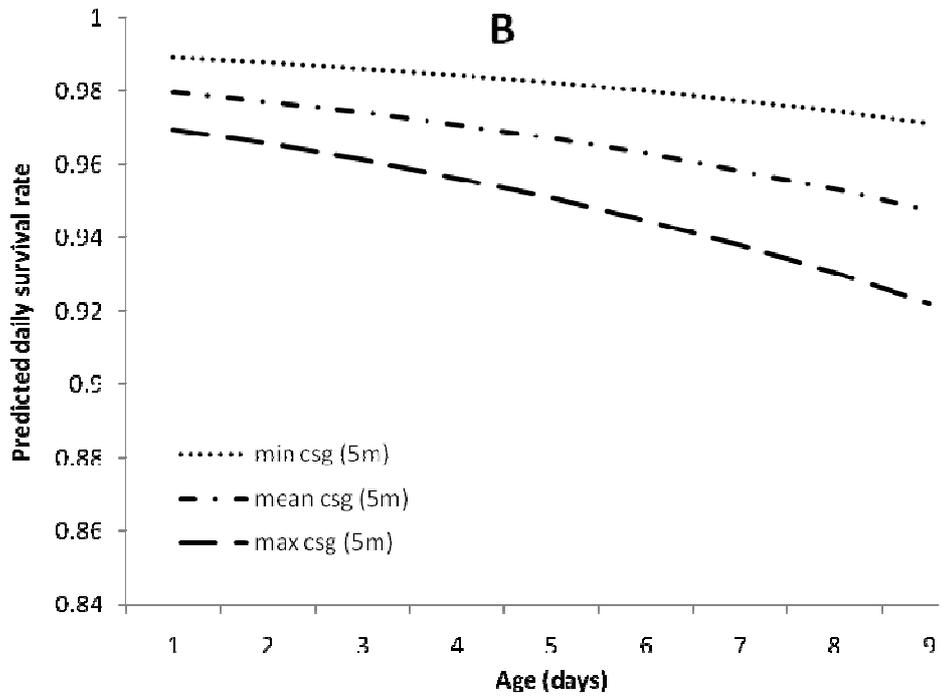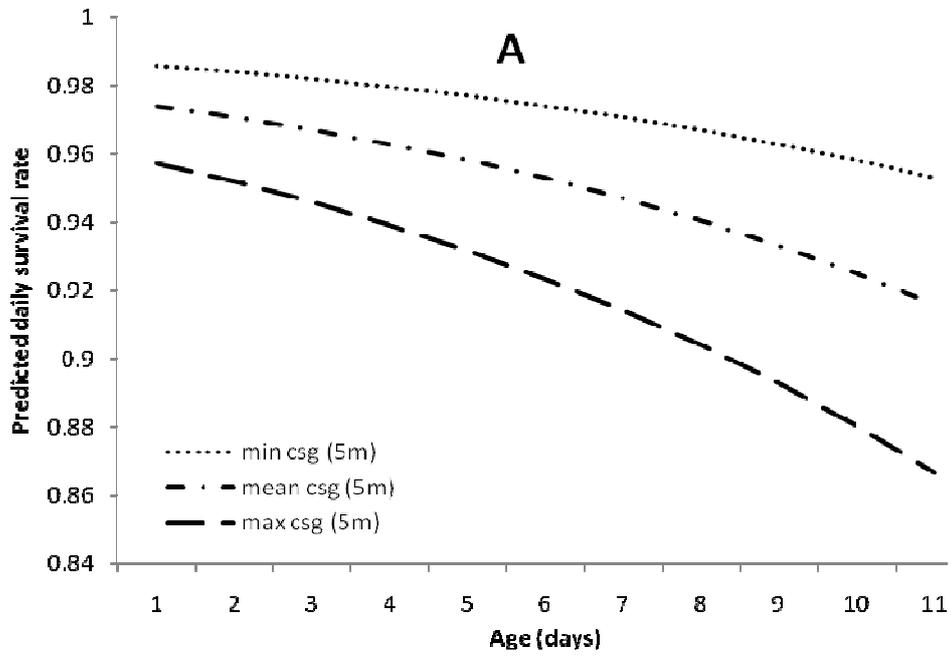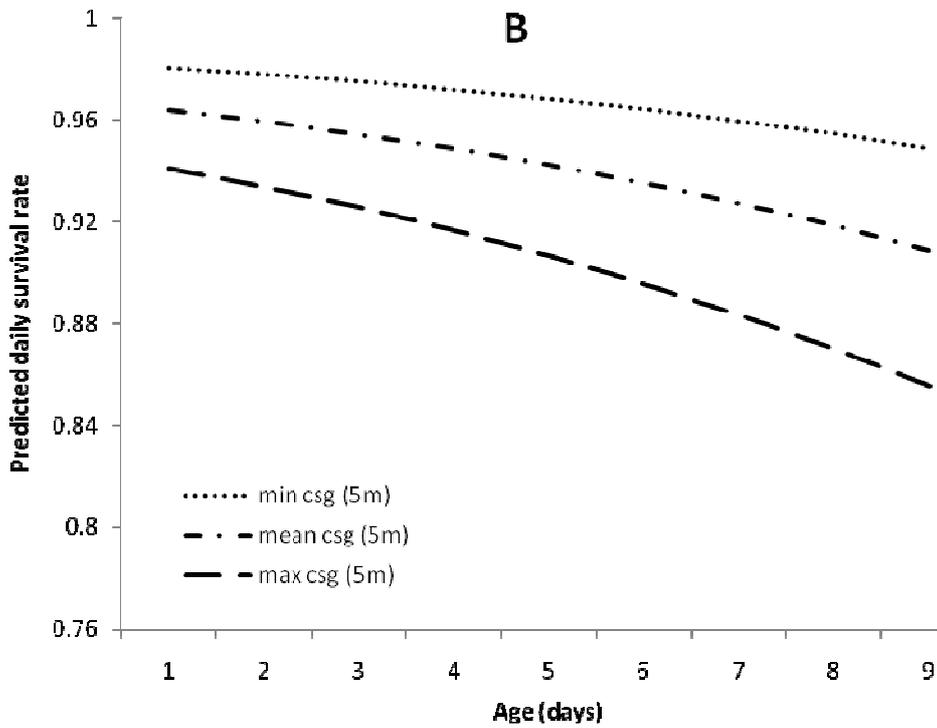
Figure 1.

Figure 2.

Figure 3.
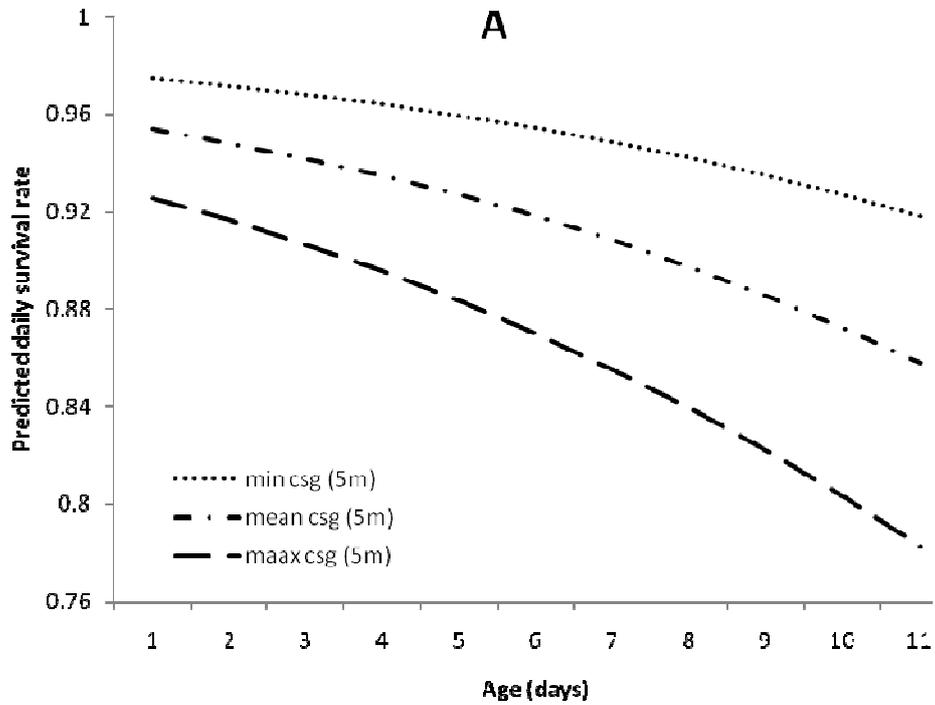
Appendix A.

| Model | AICc | Δ AICc | W$_i$ | P | Deviance |
|---|---|---|---|---|---|
| {S(year+stage+age_effect+all_csg_5+warm)} | 1022.09 | 0.00 | 0.13 | 7.00 | 1008.04 |
| {S(year+stage+age_effect+all_csg_5+fescue)} | 1022.30 | 0.21 | 0.12 | 7.00 | 1008.25 |
| {S(year+stage+age_effect+all_csg_5+veg_total)} | 1022.96 | 0.87 | 0.09 | 7.00 | 1008.91 |
| {S(year+stage+age_effect+all_csg_5+forbs)} | 1023.20 | 1.11 | 0.08 | 7.00 | 1009.15 |
| {S(year+stage+age_effect+all_csg_5)} | 1023.48 | 1.39 | 0.07 | 6.00 | 1011.45 |
| {S(year+stage+age_effect+all_live)} | 1023.51 | 1.43 | 0.07 | 6.00 | 1011.48 |
| {S(year+stage+age_effect+fescue_5)} | 1024.11 | 2.03 | 0.05 | 6.00 | 1012.08 |
| {S(year+stage+age_effect+all_csg_5+VOR)} | 1024.26 | 2.17 | 0.04 | 7.00 | 1010.21 |
| {S(year+stage+age_effect+all_csg_5+csg)} | 1024.42 | 2.33 | 0.04 | 7.00 | 1010.37 |
| {S(year+stage+age_effect+all_csg_5+all_csg)} | 1024.53 | 2.44 | 0.04 | 7.00 | 1010.48 |
| {S(year+stage+age_effect+all_csg+woody)} | 1024.79 | 2.70 | 0.03 | 7.00 | 1010.74 |
| {S(year+stage+age_effect)} | 1024.94 | 2.85 | 0.03 | 5.00 | 1014.92 |
| {S(year+stage+age_effect_robel_5)} | 1025.16 | 3.07 | 0.03 | 6.00 | 1013.12 |
| {S(year+stage+age_effect+all_csg+bare_ground)} | 1025.38 | 3.29 | 0.03 | 7.00 | 1011.33 |
| {S(year+stage+age_effect+all_csg_5+litter)} | 1025.46 | 3.37 | 0.02 | 7.00 | 1011.41 |
| {S(year+stage+age_effect+forbs_5)} | 1026.04 | 3.95 | 0.02 | 6.00 | 1014.00 |
| {S(year+stage+age_effect+dist_wood)} | 1026.38 | 4.29 | 0.02 | 6.00 | 1014.34 |
| {S(year+stage+age_effect+wsg_5)} | 1026.49 | 4.40 | 0.01 | 6.00 | 1014.45 |
| {S(year+stage+age_effect+csg_5)} | 1026.64 | 4.55 | 0.01 | 6.00 | 1014.60 |
| {S(year+stage+age_effect+woody_5)} | 1026.75 | 4.66 | 0.01 | 6.00 | 1014.71 |
| {S(year+stage+age_effect+dist_fence)} | 1026.81 | 4.72 | 0.01 | 6.00 | 1014.77 |
| {S(year+stage+age_effect+bare_5)} | 1026.92 | 4.83 | 0.01 | 6.00 | 1014.88 |
| {S(year+stage+age_effect+dist_water)} | 1026.95 | 4.86 | 0.01 | 6.00 | 1014.92 |
| {S(year+stage+age_effect+nearest_edge)} | 1026.95 | 4.86 | 0.01 | 6.00 | 1014.92 |
| {S(year+stage+age_effect+litter_5)} | 1026.95 | 4.87 | 0.01 | 6.00 | 1014.92 |
| {S(year+stage)} | 1051.32 | 29.23 | 0.00 | 4.00 | 1043.30 |
| {S(year+stage+observer_effect)} | 1053.19 | 31.10 | 0.00 | 5.00 | 1043.16 |
| {S(year+stage+parasitism)} | 1053.31 | 31.22 | 0.00 | 5.00 | 1043.28 |
| {S(year)} | 1061.32 | 39.24 | 0.00 | 2.00 | 1057.32 |
| {S(year+treatment)} | 1063.69 | 41.61 | 0.00 | 5.00 | 1053.67 |
| {S(.)} | 1071.54 | 49.46 | 0.00 | 1.00 | 1069.54 |
| {S(T)} | 1073.45 | 51.37 | 0.00 | 2.00 | 1069.45 |
| {S(TT)} | 1075.44 | 53.35 | 0.00 | 3.00 | 1069.42 |

# CHAPTER 3. POSTFLEDGING SURVIVAL OF GRASSHOPPER SPARROWS IN FRAGMENTED GRASSLAND MANAGED WITH FIRE AND GRAZING

A paper to be submitted to Condor

Torre J. Hovick, James R. Miller, Rolf R. Koford, David M. Engle, and Diane M. Debinski

**Abstract**: More accurate survival estimates are needed after nestling fledge to understand population dynamics during this vulnerable time period. The postfledging period is the time when chicks learn to fly, forage, and hide from predators. We monitored postfledging survival, cause-specific mortality, movement, and habitat use of Grasshopper Sparrows (*Ammodramus savannarum*) in grassland managed with fire and grazing. We attached radio transmitters to 50 nestlings from 50 separate broods in 2009 and modeled survival in response to climatic, biological, and ecological variables. The factor most influencing postfledging survival was age. There were weak effects of parasitism, forb abundance within five meters of the nest site, and vegetation height within five meters of the nest site. The majority of chicks (74%) died within three days of attachment and mesopredators were responsible for the greatest number of mortalities (48%) with exposure being the second greatest (28%). Postfledging movements increased rapidly for the first 4 days after leaving the nest and flights >10 m occurred, on average, 9 days after fledging. Newly fledged birds occurred in areas with lots of bare ground most commonly, and frequently used tall vegetation as refuge. Managing vegetation for a mix of bare ground that can be used for feeding that is adjacent to areas of dense litter for seeking refuge may be beneficial to newly fledged Grasshopper Sparrows.

*Key Words*: tallgrass prairie, grasshopper sparrow, postfledging, survival, prescribed fire, grassland, fragmentation, grazing, Iowa.

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**INTRODUCTION**

Grassland birds have declined more in recent decades than any other avian group in the United States (Peterjohn and Sauer 1993, Knopf 1994, Vickery et al. 1999, Sutter and Ritchison 2005). Habitat loss and degradation, coupled with conversion of agricultural grasslands and Conservation Reserve Program lands (CRP) to row-crops, have contributed to these declines (Vickery 1996, Vickery and Herkert 2001). This underscores the importance of enhancing habitat on remnant prairies and restored grasslands (Fletcher and Koford 2002, Fletcher and Koford 2006) and understanding survival demographics for all life stages to monitor accurately and predict population trends (Knutson 2006).

To assess habitat quality, avian ecologists typically estimate population trends using point count data (Van Horne 1983). Count data provide information on abundance but do not accurately reflect habitat quality, particularly if a given area is serving as a population sink or ecological trap (Bock and Jones 2004). As a more accurate measure of habitat quality, Garshelis (2000) and Johnson (2007) recommend collecting demographic information such as nest survival. Many nesting studies have been conducted to understand factors affecting nest success (Johnson 2007). Under some conditions, however, daily nest survival may not correlate with population growth, and annual productivity and survival during various life stages may be more robust measures of habitat quality (Knutson et al. 2006).

The stage after nestlings fledge, or the postfledging period, is of critical importance for grassland birds because fledglings generally experience extremely high mortality rates

(Anders 1998, Lang et al. 2002, Kershner et al. 2004, Berkeley et al. 2007). During this period, fledglings remain dependent on parental care while they learn to fly, feed on their own, and hide from predators (Kershner et al. 2004, Yackel Adams et al. 2006). Despite fledgling vulnerability at this time and the potential importance of the postfledging life stage in the decline of grassland birds, few studies have focused on it (Berkeley et al. 2006). This is likely due to the logistical challenges of monitoring birds during a stage when they can be especially cryptic and difficult to relocate (Vega Rivera et al. 1998, Suedkamp Wells et al. 2007), although these challenges have been somewhat reduced by advances in radio telemetry.

Creating heterogeneous patches across grasslands can create greater habitat diversity, which can be exploited by grassland birds for nesting and brood rearing. Fuhlendorf and Engle (2001) proposed a fire-and-grazing interaction to promote heterogeneity of grassland through the use of patch-burn grazing. Patch-burn grazing creates heterogeneity through the application of discrete fires and the resulting focal grazing of large herbivores (cattle in most agricultural areas) (Fuhlendorf and Engle 2001, Fuhlendorf et al. 2009). Resulting structural diversity has potential to increase survival for postfledging Grasshopper Sparrows by creating areas open enough for foraging while maintaining enough structure in other areas for refuge.

We studied postfledging survival of Grasshopper Sparrows (*Ammodramus savannarum*) in grassland that we experimentally altered with the use of a fire-and-grazing interaction. Mimicking historic disturbance such as fire and grazing, through the use of prescribed fire and cattle grazing, could benefit postfledging grassland birds by creating structural diversity that can be exploited for foraging and refuge. Grasshopper Sparrows are a

species of concern in the Eastern Tallgrass ecoregion according to Partners in Flight (Panjabi et al. 2005) and have experienced population declines near 78% across the United States since the 1960s (Sauer et al. 2008). Our objectives were to 1) identify cause-specific mortality and timing of mortality as a function of fledgling age, 2) quantify postfledging daily movements and habitat use, and 3) model survival rates as a function of ecological and biological factors.

**METHODS**

*Study Sites*

We examined grassland management on eight pastures from 22.5-37 ha in Ringgold County, IA, USA (Fig. 1). Pastures were under the jurisdiction of the Iowa Department of Natural Resources, The Nature Conservancy, or privately-owned. Five of the pastures were managed with a patch-burn grazing treatment, and three of the pastures were managed with a graze-and-burn treatment. One third of each patch-burn pasture (hereafter, a patch) was burned annually beginning in 2007, whereas the graze-and-burn pastures were burned in their entirety in 2009. This fire return interval was necessary to maintain grassland, and for consistency across treatments. One patch in one patch-burn pasture was burned in consecutive years as a result of an escaped fire. All pastures were grazed at 1.1 to 1.5 animal units per month per acre and had an exterior fence.

Dominant native grassland species included rough dropseed (*Sporobolus clandestinus*), sedges (*Carex* spp*.),* and Baldwin's ironweed (*Veronica baldwinii*) (McGranahan 2008). Tall fescue (*Lolium arundinaceum*), an introduced forage species from Europe, was present on all pastures and was the dominant grass species on most

(McGranahan 2008). Other common exotic species included black medick (*Medicago lupulina*) and Kentucky bluegrass (*Poa pratensis*). Precipitation totals averaged 15.3 cm per month (May-Aug) during the study period with the greatest amounts occurring in June and August.

*Nest searching*

In 2009, we conducted nest searches between 15 May and 25 July from 0600 to 1200 (CST) on days with no precipitation. We located nests using the rope-drag method (Higgins et al. 1969, Galligan et al. 2006), incidental flushes, and observations of parental behavior (Kershner et al. 2004). To ensure complete coverage, we flagged one end of each rope-drag as we made systematic passes through pastures and did return drags along the flagged line. Upon flushing a bird, both draggers searched the vicinity of the flush. If the nest was not found, the location was marked as a probable nest site and searched again within three days by walking and using flushing sticks (Winter et al. 2003).

We recorded the Universal Transverse Mercator (UTM) coordinates of each nest using a Trimble Geo*XT* ® Global Positioning System (GPS). We candled eggs to determine their age (Lokemoen & Koford 1996) and subsequently monitored nests every three days, with more frequent visits near the time of hatching and fledgling. During each nest visit, we recorded the date, time, number and stage of eggs/nestlings, and the number and age of Brown-headed Cowbird (*Molothrus ater*) eggs/nestlings (Ralph et al. 1993).

*Vegetation measurements*

Each time a bird was relocated, we quantified vegetation structure and composition using a
0.5-m$^2$ quadrat and a 2.5-m Robel pole centered on the relocation site. Within the quadrat, we
estimated classes of canopy cover (%) of tall fescue, warm-season grasses, cool-season
grasses (including tall fescue), forbs, legumes, bare ground, litter, and woody vegetation. Tall
fescue was estimated separately because it is an invasive species and has been associated
with poor brood rearing in other grassland bird species (Barnes et al. 1995). These
measurements were subsequently classified using the midpoints of the following intervals: 0-
5 (3), 6-25 (16), 26-50 (38), 51-75 (63), 76-95 (86), and 96-100 (98) (Daubenmire 1959).
Visual obstruction (VOR) was recorded at a distance of 4 m and a height of 1 m above
ground, recording the height at which the pole was 50% obscured by vegetation (Robel
1970). We used extreme caution when relocating fledglings and if a given bird did not flush,
we the bird's location and measured the vegetation features the next day. This reduced the
stress imposed on young fledglings by limiting the time we spent in the area. With the use of
these same protocols, we measured microhabitat features at a distance of five meters from the
nest in each cardinal direction.

*Radio attachment & tracking*

We attached radio transmitters to nestlings near the time of fledging, typically on day 8
(Vickery 1996), to reduce negative effects of inducing fledging prematurely (Berkeley et al.
2007). On the day of attachment, we measured culmen length, wing chord, mass, and tarsus
length for each nestling. We attached transmitters using glue and figure-eight leg harnesses
(Rappole & Tipton 1991, Suedkamp Wells et al. 2007) to one randomly selected nestling per
nest to ensure independence among marked individuals (Kershner et al. 2004, Cohen &

Lindell 2004, Berkeley et al. 2007). We placed transmitters just above the rump of each selected nestling with the whip-tail pointing towards the tail of the chick and the transmitter resting on the synsacrum (Rappole and Tipton 1991). We used series A2412 transmitters (Advanced Telemetry Systems, Isanti, MN) weighing ~0.26g, or <3% of the mass of a Grasshopper Sparrow fledgling (>10.5g, Vickery 1996; >12g, T.J.H. unpublished data). Battery life was expected to be 30 days. At the time of attachment, we placed a U.S. Geological Survey band to the right leg and a unique combination of plastic, UV-resistant Darvic bands (Avinet, Dryden, New York) to the left leg to assist in accurate identification of nestlings upon re-sighting. Nestlings were returned to the nest after handling, which took <5 minutes, and covered with a bird bag until they were calm. All protocols were approved by Iowa State's Institutional Animal Care and Use Committee (Protocol #: 4-09-6720-Q).

After fledging, individuals were tracked daily until we obtained evidence of the bird's death, the juvenile left the area, or the transmitter battery expired (Anders 1997, Kershner 2004, Berkeley 2007). If a signal was not heard at the time of relocation, we walked the entire pasture perimeter and searched adjacent fields by driving roadways and listening for a signal. Under ideal conditions signals could be heard at a distance of ~ 300 m. Relocation times were randomly selected from three different time intervals (06:00-11:00, 11:00-16:00, and 16:00-21:00). Interval allocation was never the same for consecutive days, which prevented biasing habitat use measurements (e.g., regular relocation at the hottest or coldest time of the day).

*Determining cause-specific mortality*

We determined cause-specific mortality for each fledgling using the methods of Suedkamp Wells et al. (2007). We reasoned that mesopredators such as raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), red foxes (*Vulpes vulpes*) or farm cats were responsible if a transmitter was recovered with teeth holes and very little remains. In addition, we attributed mortality to mesopredators when transmissions stopped and birds were < 10 days of age, at which point it was improbable they could have left the study area. We identified snakes as predators when signals led us to a snake and in one case when a fledgling appeared to have been regurgitated. Avian predators such as Loggerhead Shrikes (*Lanius ludovicianus*) or corvids were identified when transmitters were hung in trees or juveniles were plucked with very little meat left on skeletons. Small mammals were considered the likely predator when birds were mostly undamaged with small parcels of tissue eaten, but head and body still intact. Finally, exposure was considered the cause of mortality if dead fledglings were whole and intact.

*Data Analysis*

We categorized fledgling age into three groups on the basis of observed fledgling mobility and studies done on other grassland species (Kershner et al. 2004, Suedkamp Wells et al. 2007). Age classifications were 1-3, 4-8, and 9-14 days. We investigated habitat use as a function of age incorporating raw vegetation measurements taken at each daily-relocation using principle components analysis in the JMP statistical package (Version 8.0.1; SAS Institute, Cary, NC). This was done by creating a file with each fledgling location as a row, each vegetation factor of interest as a column, and a column allocating each location to one of the three age classifications. We used the minimum number of principal components (PCs)

that accounted for ~75% (cumulative percentage) of the variation among habitat use and age. We reduced the dimensionality of the vegetation data using axis loadings from a rotated principal component analysis (PCA). Each PC was interpreted on the basis of the component loadings after we used a varimax rotation, which enhances interpretation by re-distributing the variance and increasing the loadings on variables of importance and decreasing the loadings on variables of less importance.

We used the nest survival model in program MARK to model postfledging survival (White and Burnham 1999) because MARK allows for the inclusion of parameters explaining survival of individuals with known fates and accounts for exposure days. Program MARK operates with a maximum-likelihood framework using the logit function. We examined the first two weeks after fledging because this time period has been identified as the most vulnerable period for postfledging chicks and because relocation becomes difficult after fledglings move great distances with the limited pulse strength of small transmitters (Kershner et al. 2004, Suedkamp Wells 2007). To standardize nest ages across the study period, we set 3 June as day one and sequentially numbered days through 15 August.

Hierarchical modeling decreases the number of models when including many covariates and incorporates factors in an organized, intuitive fashion. At each step, all models were identified using Akaike's Information Criterion, adjusted for small sample sizes (AIC$_c$: Burnham and Anderson 1998). Only the model with the lowest AIC$_c$ score from each step was used as a base model for adding variables in the next. After the final step of modeling, we followed the approach outlined by Burnham and Anderson (2002) for interpreting our model set and considered all models within two AIC units of the best model to be competitive. Model building occurred in 4 steps:

1) We incorporated constant (null), linear (T), and quadratic (TT) time trends. Other studies have reported increased survival throughout the breeding season as a result of greater availability of other prey (Dinsmore &Dinsmore 2007).

2) We added climate variables to the best model from the first step. These included daily minimum and maximum temperatures as well as daily precipitation totals. Young fledglings are unable to thermoregulate for long periods (Yackel Adams et al. 2006). Therefore, we hypothesized that cool, wet nights would decrease daily survival rates, as would extreme heat.

3) We included clutch size, Brown-head Cowbird parasitism (1 if parasitized, 0 if not), morphometric measures, and fledgling age to the best model from step two. Parasitism and clutch size were used as an indirect means of examining resource allocation to nestlings and investigating whether nests with more chicks or the presence of cowbirds decreased the probability of survival. For examining chick condition we used culmen length, wing chord, tarsus length, and mass measurements that were taken at the time of transmitter attachment. We also created a rank of body condition by dividing the mass of the chick with the transmitter attached by the greatest mass of any chick in the clutch (Yackel Adams et al. 2006). Body condition, whether by rank or using mass alone, has been related to fledgling survival in previous studies (Krementz et al. 1989, Yackel Adams et al. 2006, Suedkamp Wells 2007).

4) Finally, we added the effect of treatment and nine habitat measurements taken from the microhabitat to the best model from step three. Measurements of the microhabitat were averaged across four quadrats and we believe they represented

habitat used by fledglings in the first few days after leaving the nest, and they could give insight into fledgling survival as an indirect consequence of resource availability to foraging parents during the nesting period.

**RESULTS**

We attached 50 transmitters to pre-fledging Grasshopper Sparrows representing 50 broods between 28 May and 5 August, 2009. Chicks weighed 12.0 g (SE ± 0.26) at the time of attachment. We determined that 37 birds successfully fledged and 10 survived the first two weeks after fledging. In total, we tracked individuals for 217 days with an average survival of 6.8 (SE ± 1.21) days.

We assigned fates to 47 birds. The fate of three individuals was unknown due to battery failure or a detached transmitter. Predation was the leading cause of mortality for postfledgings and was responsible for 63% (22/35) of all deaths. The majority of predation events were attributed to mesopredators (48%). Other predators included small mammals (~11%), snakes (~6%), and one death resulted from cattle trampling. The second leading cause of mortality was exposure, which was responsible for >26% of deaths. Most of these occurred within the first three days of fledging. The source of mortality could not be identified in six cases and two fledglings died of unnatural causes. The timing of death varied, with the majority occurring during the first three days after attachment (74.3% or 26/35; Fig. 2). Six birds died between 4 and 8 days and three birds died after 9 days.

Daily movements of fledglings increased for the first 4 days after fledging and then became relatively stable for the remainder of the 14-day interval (Fig. 3). The maximum distance recorded for a fledgling movement was 135 m and the shortest was <1 m. Average

daily distances from the nest site was 37.5 m (SE ± 3.11). On average, fledglings first took flight 4 days after leaving the nest (range: 1-7). Initial flights averaged 7 m and fledglings averaged flights >10 m at 9 days (range: 4-12).

The first four principal components explained 73.6, 76.4, and 76.9 % of the variation in habitat-use measurements for age groups 1, 2, and 3, respectively. Vegetation variable loadings were very similar for all three age classes according to PCA, suggesting that habitat use did not vary by age (Table 1). Fledglings of all ages used bare ground often and were rarely located in areas of with high litter abundance. Similarly, fledglings of all ages used areas of high mean forb and cool-season grass abundance with little fescue or warm-season grass (Table 1).

We modeled postfledging survival for 32 fledglings. Several birds died between the time of attachment and the first relocation, making it uncertain as to whether they died after fledging or were killed in the nest and removed. These analyses indicated that fledgling age had the greatest impact on daily survival rates and that parasitism, forb abundance, and vegetation height weakly affected postfledging survival (Table 2). The age effect on survival was significant in all four of the candidate models and positively affected postfledging survival (i.e., as age increased the probability of surviving a one-day interval increased; $\beta_{age\_effect} = 0.13$ on a logit scale, SE = 0.07, 95% CI was 0.002, 0.26). Presence of Brown-headed Cowbirds in nests had a weak positive effect on survival. ($\beta_{parasitsm} = 0.53$ on a logit scale, SE = 0.70, 95% CI was -0.83, 1.88), but estimates had low precision. Forb abundance and vegetation height had a weak negative effect on postfledging survival ($\beta_{forbs} = -0.04$ on a logit scale, SE = 0.02, 95% CI was -0.084, 0.007; $\beta_{veg\_height} = -0.38$ on a logit scale, SE = 0.28, 95% CI was -0.93, 0.17), but confidence intervals overlapped zero and estimates were

imprecise. Cumulative survival rates decreased rapidly over the first 4 days postfledging, became relatively stable from age 5 to 11 days, and then increased for the remainder of the first 2 weeks (Fig. 4). Survival rates were greater in patch-burn pastures (27%) when compared to graze-and-burn pastures (12%).

We used canopy measurements of vegetation variables from our data that influenced grasshopper sparrow survival to create predictive graphs. Graphs of this nature allow land managers to become aware of the repercussions management decisions could have on nesting grassland birds such as grasshopper sparrows. We used the top two candidate models to predict survival rates as a function of their constituent parameters. In the first model, survival rate was a function of fledgling age (1 – 14 days) and 3 levels of forb abundance (minimum, mean, and maximum) recorded within 5 m of the nest site (Fig. 5). In the second model, survival rate was a function of fledgling age and three levels of vegetation height (minimum, mean, and maximum) within five meters of the nest site (Fig. 6).

**DISCUSSION**

To our knowledge, this study is the first to examine survival rates of postfledging Grasshopper Sparrows. Our findings suggest that Grasshopper Sparrows, similar to other grassland-obligate species, have high rates of mortality during the postfledging period. Our survival estimates (9-51% for the first 14 days) were within the range of previously reported in postfledging studies. For comparison, Dickcissel (*Spiza americana*) survival rates were 54% over 29 days in Missouri (Suedkamp Wells 2005), Lark Buntings (*Calamospiza melanocorys*) had 37% survival rates over 21 days in Montana (Yackel Adams et al. 2007), and Dickcissels had survival estimates ranging from 22-33% in the Nebraska (Berkeley et al.

2004). Regional differences in predator communities, research-pasture size differences, and life-history differences in study species make comparisons of survival rates among studies difficult. More work on postfledging grasshopper sparrows in multiple regions and over varying intervals would clarify influences on survival.

Predation by mesopredators was the most common cause of mortality in this study. The great amount of fragmentation in southern Iowa has likely increased the number of mesopredators because they reportedly favor edge habitat adjacent to agricultural fields and wooded areas (Dijak & Thompson 2000). In addition, a lack of top predators has left mesopredator population unregulated (Crookes & Soule 1999). Many more mesopredators were seen on research pastures in 2009 than in 2008 and high predation numbers may have resulted from a spike in mesopredator populations. Alternatively, these rates could reflect the norm, in which case, mesopredators present a major threat to grasshopper sparrows in a fragmented landscape.

Exposure was the second greatest cause of mortality in this study, and was the most unexpected by the researchers. Researchers regularly found unharmed and intact fledglings in the vegetation after cool and wet nights. Survival models did not reflect a negative effect of precipitation on survival, but we believe precipitation poses a major problem for fledglings within the first few days after leaving the nest. During this time, birds rely on parents for food provisioning and are extremely vulnerable to harsh weather conditions that inhibit parents foraging and test weak thermoregulation of fledglings (Anders et al. 1997, Cohen & Lindell 2004, Yackel Adams et al. 2006). Creating vegetation with bare ground for feeding that is adjacent to areas of dense litter for seeking refuge may be beneficial to newly fledged grasshopper sparrows.

In this study, fledglings increased their movements away from the nest during the first 4 days, followed by a stable period of peripheral movements around the nest. This pattern has been associated with spatial dispersion, a strategy to avoid predation (Nolan 1978). Dispersion after fledging is an evolutionary response to predation intended to enhance the prospects for survival of at least some individuals (Green & Cockburn 2001). The subsequent stabilization period was likely due to limited flight capabilities of young Grasshopper Sparrows and their reliance on parental foraging. Parents could be regulating the distance that postfledgings move away from the nest during the first two weeks after fledging. Parents must balance between distances that prevent predators from locating multiple fledglings, with distances that don not exceed the parental energy costs for care (Anthonisen et al. 1997).

Our results demonstrate the vulnerability of postfledging Grasshopper Sparrows immediately after leaving the nest, when mortality rates were highest. Age was the most significant factor associated with postfledging survival and our predictive graphs show how survival rates increased with fledgling age. Age has been associated with survival in Dickcissels, where the cumulative probability of postfledging survival declined rapidly over the first three days before stabilizing (Suedkamp Wells et al. 2007). Similarly, 38 out of 60 Dickcissels died in the first 8 days after fledging in eastern Nebraska (Berkeley et al. 2004). Furthermore, Eastern Meadowlarks (*Sturnella Magna*) experienced 71% mortality rates during the first week postfledging in Illinois (Kershner et al. 2004). Fledglings are most vulnerable immediately after leaving the nest because they are unable to make long flights, rely on their parents for food, and have high energy demands  that can result in thermal stress (Anders et al. 1997, Cohen & Lindell 2004, Yackel Adams et al. 2006).

Vegetation factors such as forb abundance within the microhabitat and vegetation height in the microhabitat were both included in competitive models, and both had negative effects on daily survival rates. Grasshopper sparrows preferentially forage in areas of bare ground and have been shown to have negative relationships with vegetation height and abundance in previous studies (Whitmore 1981, Patterson & Best 1996, Vickery 1996). A nesting study conducted on our research pastures found that Grasshopper Sparrow nest survival was negatively associated with cool-season grass abundance within the microhabitat, and that nesting daily survival rates were reduced with greater herbaceous live cover in the microhabitat of the nest (Hovick et al., unpublished data). Habitat use in this study further reflects grasshopper sparrow affinity for bare ground. The strongest loadings on the first PC of our PCA were high bare ground and low cover for litter.

Parasitism by Brown-headed Cowbirds affected postfledging survival and was included in three of the four candidate models. Generally, parasitism is viewed as negatively affecting host survival, but in this study parasitized nests had a slightly greater rate of fledgling daily survival. This result was unexpected and hard to explain. Grasshopper Sparrow nesting research showed that cowbird parasitism significantly reduced clutch size (Hovick et al., unpublished data), which results in fewer fledglings and may decrease demands on parental energy after birds leave the nest. Modeling did not support smaller clutch sizes having greater survival, but we would argue smaller clutch sizes are generally a result of predators taking eggs or nestling, which eventually leads to mortality for all eggs, nestlings, and fledglings.

Because of the cryptic nature of postfledging Grasshopper Sparrows, we did not compare fates of birds with transmitters to those without transmitters, but we do not believe

transmitters affected survival. We observed Grasshopper Sparrow mobility during

relocations, and at no time did we witness transmitters inhibiting fledgling movements. Radio

tracking did not cause adverse effects in other studies (Rappole & Tipton 1991, Powell et al.

1998, Naef-Daenzer et al. 2001). Moreover, radio-marked Dickcissels had glucocorticoid

levels within normal range after initial handling (Suedkamp Wells 2003). Therefore, we

believe that recorded rates of survival in this study are representative of Grasshopper

Sparrows during the postfledging period in a highly fragmented landscape treated with fire

and grazing.

Assessing habitat quality through nesting survival and postfledging survival gains

greater insight and understanding to how management practices are working than other

measures (i.e., density measures, territory mapping). It is important to consider multiple life

stages of grassland birds when considering management, and nesting alone may be a

misleading indicator of survival (Knutson et al. 2006). Hovick et al. (unpublished data) found

that grasshopper sparrow nest survival ranged from 13-23% in our research pastures. The

addition of survival rates from this study yields an overall probability of a grasshopper

surviving the nesting period (incubation and nestling stages) and successfully surviving the

first two weeks after fledging of < 2 % for graze-and-burn pastures and < 7 % for patch-burn

graze pastures. Current conditions in patch-burn graze pastures resulted in low patch contrast

as a result of heavy first-round stocking rates (McGranahan et al., unpublished data). As

research progress on this project and stocking rates are adjusted, survival rates may be

influenced. Survival was greater in patch-burn graze pastures, but other factors like

fragmentation, landscape context, and predator communities need to be investigated to

further understand why survival estimates are extremely low.

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Table 1.  Principal components of eight vegetation characteristics measured at each postfledging relocation site within a 0.5-m$^2$ quadrat age class. Bold scores are of most importance for ecological interpretation (Hair et. Al 1987). Age group 1 includes fledglings from days 1-3, age group 2 includes fledglings from days 4-8, and age group 3 includes fledglings from days 9-14.

| Parameter | Age group 1 | | | |
| --- | --- | --- | --- | --- |
| | PC1 | PC2 | PC3 | PC4 |
| Fescue | -0.151 | -0.142 | **0.932** | 0.092 |
| Vegetation Height | -0.144 | -0.014 | 0.143 | **0.748** |
| Warm-season grass | -0.073 | **-0.663** | **-0.664** | 0.013 |
| Cool-season grass | -0.037 | **0.835** | -0.125 | 0.196 |
| Forbs | -0.311 | **0.524** | 0.017 | **-0.484** |
| Bare ground | **0.851** | 0.054 | 0.162 | 0.240 |
| Litter | **-0.895** | -0.045 | 0.009 | -0.079 |
| Woody vegetation | -0.183 | 0.155 | -0.045 | **0.658** |
| | Age group 2 | | | |
| Fescue | 0.282 | -0.248 | **0.846** | 0.094 |
| Vegetation Height | 0.252 | -0.011 | -0.205 | **0.786** |
| Warm-season grass | 0.012 | **-0.584** | **-0.764** | 0.026 |
| Cool-season grass | 0.012 | **0.737** | -0.073 | 0.009 |
| Forbs | 0.081 | **0.781** | 0.041 | -0.124 |
| Bare ground | **0.899** | -0.072 | 0.141 | 0.117 |
| Litter | **-0.874** | -0.184 | -0.081 | -0.114 |
| Woody vegetation | 0.001 | -0.113 | 0.312 | **0.793** |
| | Age group 3 | | | |
| Fescue | -0.087 | **-0.520** | 0.010 | **-0.789** |
| Vegetation Height | -0.170 | 0.042 | **0.772** | -0.113 |
| Warm-season grass | -0.148 | -0.315 | 0.000 | **0.880** |
| Cool-season grass | 0.025 | **0.832** | -0.180 | -0.069 |
| Forbs | -0.042 | **0.695** | 0.375 | 0.029 |
| Bare ground | **0.889** | -0.055 | 0.218 | -0.013 |
| Litter | **-0.916** | -0.042 | -0.005 | -0.085 |
| Woody vegetation | -0.029 | -0.003 | **0.807** | 0.097 |

Table 2. Candidate models that best explain postfledging survival of Grasshopper Sparrows
in Ringgold County, IA from 28 May-19 August, 2009. Survival is modeled as a function of
the following covariates: age of fledgling throughout the survival period (age effect), Brown-
headed Cowbird presence in the clutch (parasitize), forb abundance around the nest (forb),
and vegetation height surrounding the nest (Robel).

| Model | $\Delta AIC_c$[1] | $K$[2] | $W_i$[3] | Deviance |
|---|---|---|---|---|
| S(age_effect + parasitize + forb) | 0.00 | 4 | 0.134 | 134.61 |
| S(age effect + parasitize) | 0.61 | 3 | 0.098 | 137.00 |
| S(age_effect + parasitize + Robel) | 0.83 | 4 | 0.088 | 133.67 |
| S(age effect) | 1.49 | 3 | 0.083 | 136.09 |

**AICc for best model = 144.53

[1] Akaikes information criterion adjusted for small sample sizes.

[2] The number of parameters in each model.

[3] Model weight.

 FIGURE LEGENDS

Figure 1. Research sites in Ringgold County, IA with the Iowa Departments of Natural Resource's Kellerton Wildlife Area and Ringgold Wildlife Area outlined and state and county highways adjacent to research pastures shown.

Figure 2. Grasshopper Sparrow mortality as a function of age in pastures treated with fire and grazing in Ringgold County, IA during 2009.

Figure 3. Average (±SE) daily movement distance from the nest bowl of postfledging Grasshopper Sparrows in Ringgold County, IA in 2009.

Figure 4. Cumulative survival probability for the first 14 days after leaving the nest for postfledging grasshopper sparrows in Ringgold County, IA. Survival estimates were derived from the best candidate model (see Table 1 ).

Figure 5. Predicted daily survival rates for postfledging Grasshopper Sparrows as a function of cool-season grass abundance and fledgling age. Lines represent minimum, mean, and maximum cool-season grass abundances recorded at postfledging relocation sites.

Figure 6. Predicted daily survival rates for postfledging Grasshopper Sparrows as a function of vegetation height and fledgling age. Lines represent minimum, mean, and maximum vegetation heights recorded at postfledging relocation sites.
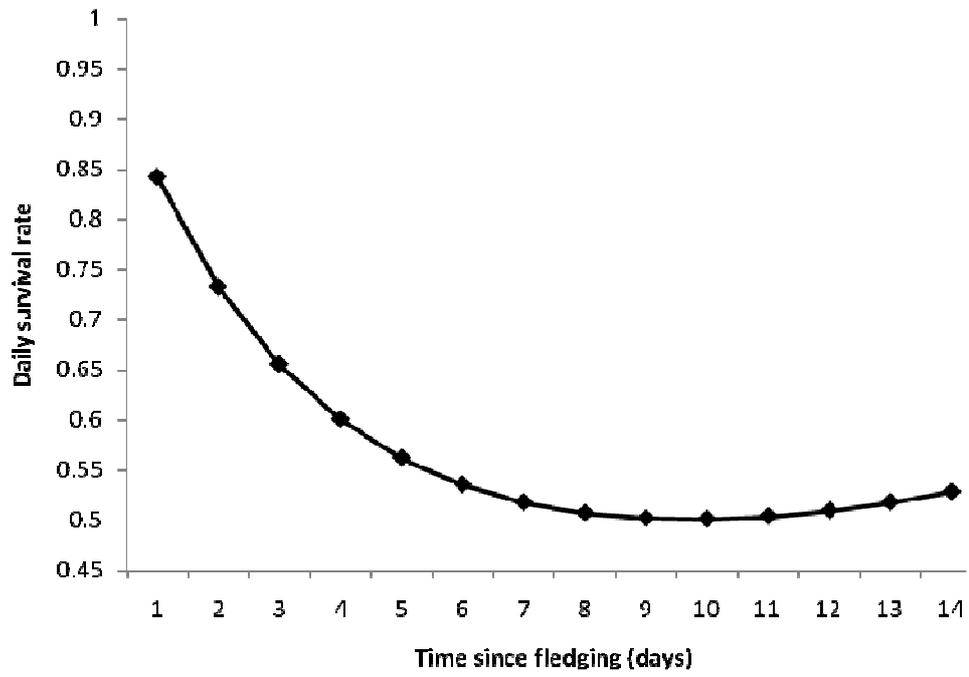
Figure 1.
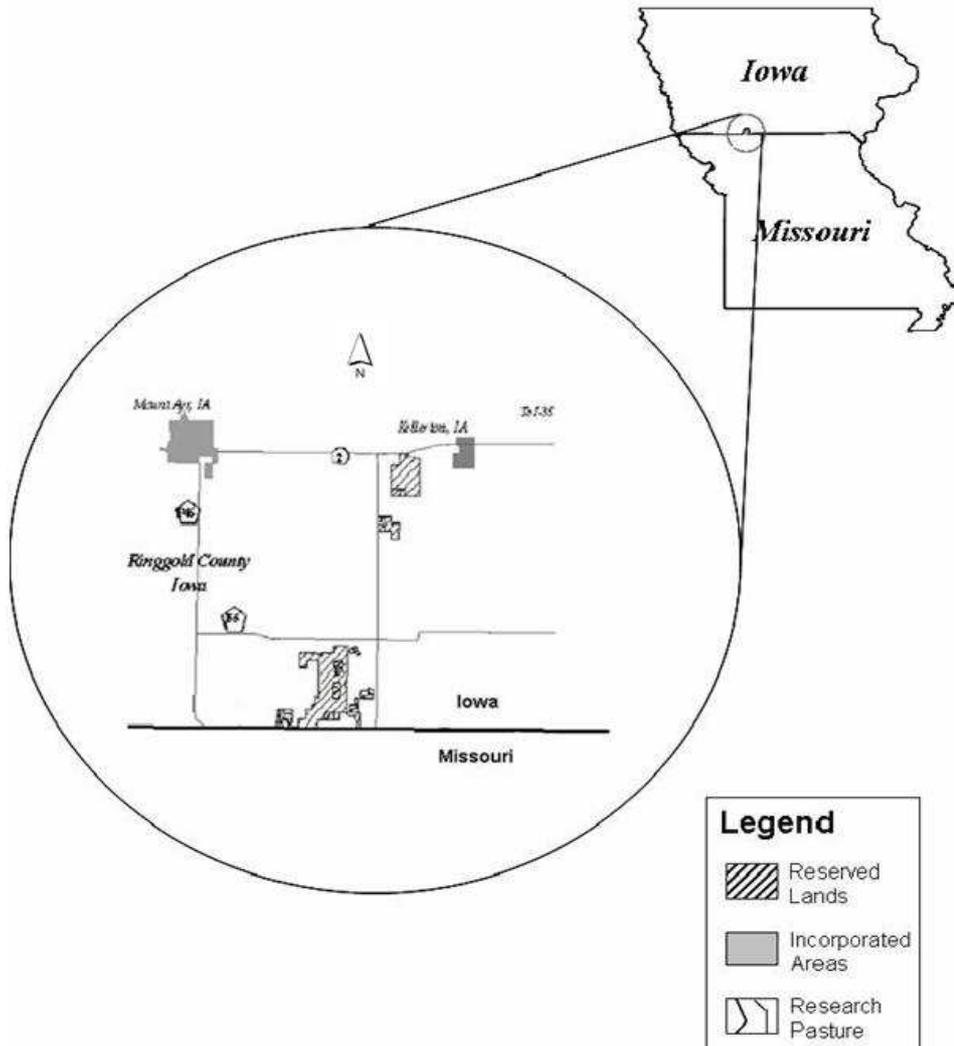
Figure 2.
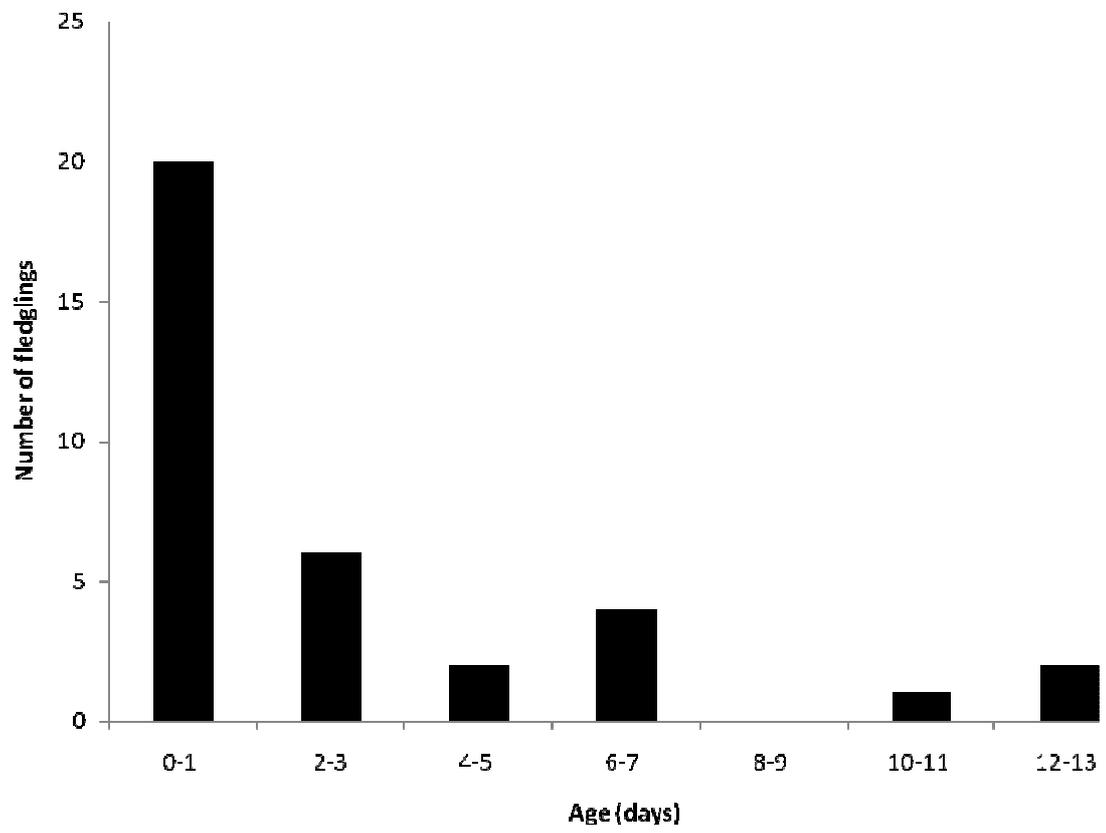
Figure 3.
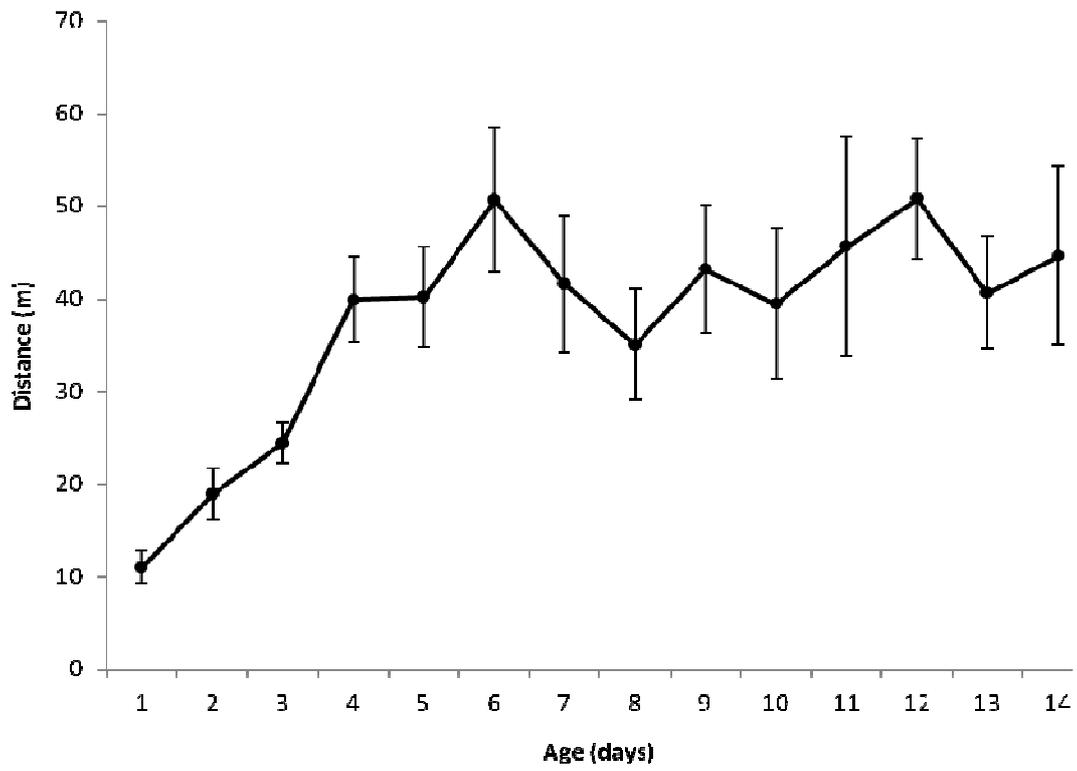
Figure 4.

Figure 5.

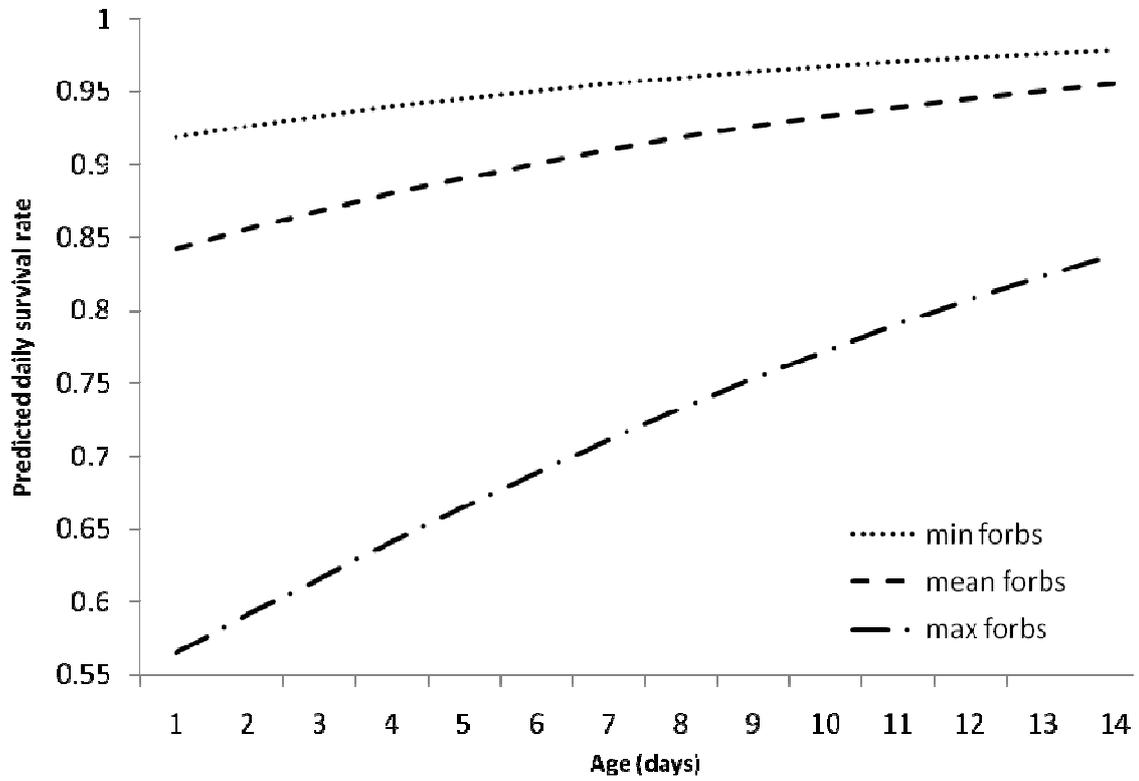Figure 6.
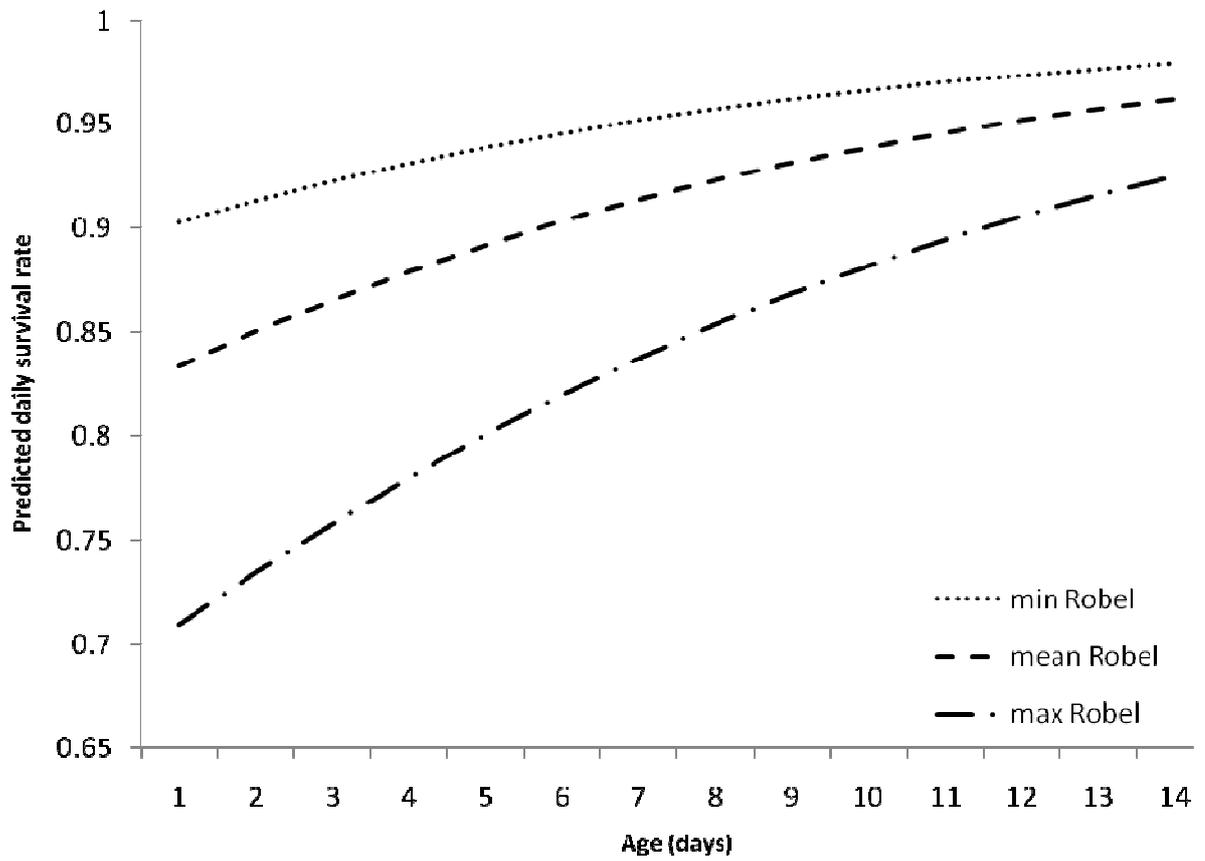
Apendix A.

| Model | AIC$_c$ | Δ AIC$_c$ | W$_i$ | P | Deviance |
|---|---|---|---|---|---|
| {S(age effect+parasitize+forb_5)} | 144.53 | 0.00 | 0.13 | 4.00 | 136.36 |
| {S(age effect+parasitize)} | 145.14 | 0.61 | 0.10 | 3.00 | 139.04 |
| {S(age effect+parasitize+Robel_5)} | 145.36 | 0.83 | 0.09 | 4.00 | 137.19 |
| {S(age effect)} | 145.48 | 0.95 | 0.08 | 2.00 | 141.43 |
| {S(age effect+parasitize+culmen)} | 146.58 | 2.05 | 0.05 | 4.00 | 138.41 |
| {S(age effect +parasitize+treatment)} | 146.91 | 2.38 | 0.04 | 4.00 | 138.73 |
| {S(age effect+parasitize+woody_5)} | 146.93 | 2.40 | 0.04 | 4.00 | 138.76 |
| {S(age effect+parasitize+rank)} | 146.95 | 2.42 | 0.04 | 4.00 | 138.78 |
| {S(age effect+parasitize+wsg_5)} | 147.00 | 2.47 | 0.04 | 4.00 | 138.83 |
| {S(age effect+parasitize+wing chord)} | 147.01 | 2.48 | 0.04 | 4.00 | 138.84 |
| {S(age effect+parasitize+csg_5)} | 147.07 | 2.54 | 0.04 | 4.00 | 138.90 |
| {S(age effect+parasitize+litter_5)} | 147.11 | 2.58 | 0.04 | 4.00 | 138.94 |
| {S(age effect+parasitize+mass)} | 147.12 | 2.59 | 0.04 | 4.00 | 138.95 |
| {S(age effect+clutch)} | 147.12 | 2.59 | 0.04 | 3.00 | 141.02 |
| {S(age effect+parasitize+fescue_5)} | 147.16 | 2.63 | 0.04 | 4.00 | 138.99 |
| {S(age effect+parasitize+bare_5)} | 147.18 | 2.65 | 0.04 | 4.00 | 139.00 |
| {S(age effect+parasitize+all_veg)} | 147.20 | 2.67 | 0.04 | 4.00 | 139.02 |
| {S(age effect+parasitize+tarsus)} | 147.21 | 2.68 | 0.04 | 4.00 | 139.03 |
| {S(age effect+parasitize+veg_variance)} | 147.21 | 2.68 | 0.04 | 4.00 | 139.04 |
| {S(null)} | 148.50 | 3.97 | 0.02 | 1.00 | 146.48 |
| {S(T)} | 149.29 | 4.76 | 0.01 | 2.00 | 145.24 |
| {S(TT)} | 149.52 | 4.99 | 0.01 | 3.00 | 143.42 |
| {S(min temp)} | 149.91 | 5.38 | 0.01 | 2.00 | 145.86 |
| {S(max temp)} | 149.98 | 5.45 | 0.01 | 2.00 | 145.93 |
| {S(precip)} | 150.44 | 5.91 | 0.01 | 2.00 | 146.39 |

## CHAPTER 4. GENERAL CONCLUSIONS

We located and monitored 327 Grasshopper Sparrow nests over both years of this study. We found 77 nest in 2008 and 250 in 2009. Due to conditions beyond our control, nest searching did not start until 14 June in 2008, which reduced the possible number of nest that we could find. Overall, we monitored a total of 103 nests during the incubation stage in pastures receiving a graze-and-burn treatment, 64 nests during the nestling stage in graze-and-burn pastures, 166 nests in the incubation stage in patch-burn graze pastures, and 114 nests in the nestling stage in patch-burn graze pastures.

Results from survival models indicated that multiple factors are significant when determining Grasshopper Sparrow nesting survival. There was a significant effect of year; survival was greater in 2008 than in 2009. The stage of the nesting cycle also significantly influenced daily survival rates. Nests in the nestling stage had a greater probability of surviving a one day interval than nests during the incubation stage. Nest age was determined to be a significant factor associated with daily survival. The older a nest was (within each stage of the nesting cycle) the lower the probability of it surviving a one-day interval. Finally, the amount of cool-season grass in the microhabitat had a significant, negative effect on Grasshopper Sparrow daily survival rates.

Other grassland bird studies have found an effect of year on survival (Winter et al. 2005, Dinsmore & Dinsmore 2007). Patterns across years can influence survival due to extraordinary weather events, cyclical increases in predator or prey abundance, resource availability, and changes in landscape composition (Rotenberry & Wiens 1989, Grant et al. 2005).

Nests had greater survival rates during the nestling stage than the incubation stage in our study. Other grassland bird studies have reported greater survival during the nestling stage than the incubation stage (Giocomo et al. 2008). This may be a result of the abundance of egg-predators that are commonly found within grasslands. Weatherhead and Blouin-Demers (2004) report that 6 out of 8 studies that identified nest predators with cameras identified snakes to be the most numerous. Shochat et al. (2005) reported 79% of predators to be reptilian in northern Oklahoma and reasoned that is why mortality in ground nesting birds was greater than shrub and tree nesters. We believe small snakes and rodents are accountable for the majority of predation events during the incubation stage and consequently daily survival rates are greater when nests advance to the nestling stage.

Until recently, nest survival estimators were unable to determine the effect of covariates such as age (Dinsmore et al. 2002), even though Skutch (1949) reported that increased activity around the nest increases the chance of predation. Since the inclusion of age covariates multiple studies have included nest age as variable to explain nest survival and have found a decrease in survival as nests age increases (Winter & Faaborg 1999, Conway and Martin 2000, Shochat et al. 2005). The older a nest is, the more time it is exposed to predators, weather, or other factors (Grant et al. 2005). Furthermore, during the nestling stage of nesting, chicks have greater resource demands as they mature and parents are forced to make more visits to the nest on a daily basis (Martin et al 2000). The increased activity around the nest creates more cues for predators and, in turn, increased mortality. Nests in this study experienced the same result. Age was a significant factor in all candidate models.

Survival models expressed a decrease in daily survival rates as cool-season grass abundance increased within five meters of the nest site. More generally, survival decreased

with greater abundance of total vegetation around the nest site. We hypothesize two explanations for this result. First, an increase in vegetation abundance has a concomitant reduction in bare ground, and grasshopper sparrows are known to primarily forage on bare ground (Vickery 1996). We do not believe food resources are limited by vegetation type, rather that access to invertebrates is limited by the presence of vegetation. In Oregon, Kennedy et al. (2009) found that as percent bare ground decreased the diets of nesting grassland birds changed; diet shift was not a result of decreased invertebrate abundances, but presumably due to increased cover changing access to ground dwelling invertebrates. Second, increased vegetation around nest sites may create refuge for predators such as snakes and small mammals, thereby, creating lower survival rates in areas with greater overall vegetation abundance.

Nest survival estimates for our study ranged from 13-23 % and are lower than many previous estimates. For example, survival estimates were near 30 % in southern Iowa CRP and agricultural fields (Patterson & Best 1996). In Missouri, the overall probability of nest survival was 32-59 % (McCoy et al. 1999), while in Kansas rates varied from 5-55 % (Rahmig et al. 2008), and in West Virginia rates were 7-47 % (Wray et al. 1982). Estimates from this study are at the lower end of previous estimates, but we believe that our large sample size may make our estimates more representative of overall grasshopper sparrow survival than previous estimates with samples of < 65 nests (Patterson & Best 1996, McCoy et al. 1999, Wray et al. 1982).

In 2009 we monitored Grasshopper Sparrow chicks after they left the nest, during the postfledging stage. We attached 50 transmitters to pre-fledging Grasshopper Sparrows between 28 May and 5 August. For reasons of independence, we attached one transmitter per

nest, totaling 50 separate broods. We assigned fates to 47 birds. The fate of 3 individuals was

unknown due to battery failure or a detached transmitter. We determined that 37 birds

successfully fledged and 10 survived the first two weeks after fledging. In total, we tracked

individuals for 217 days with an average survival of 6.8 (SE ± 1.21), and chicks weighed

12.0 g (SE ± 0.26) at the time of attachment.

Predation was the leading cause of mortality for postfledgings and was responsible

for nearly 63% (22/35) of all mortality. Mesopredators were responsible for the greatest

number of mortalities and exposure was the second greatest cause of mortality (>26%).

Researchers regularly saw raccoons and striped skunks in research pastures. The great

amount of fragmentation in southern Iowa has exacerbated this problem likely due to

raccoons being more abundant along edges adjacent to agricultural fields and streams (Dijak

& Thompson III 2000). Similar to our findings on postfledgings, other work done in southern

Iowa accredited the majority of nest predation to mesopredators (Patterson & Best 1996).

Movements of fledglings increased for the first four days after fledging and then

became relatively stable for the remainder of the 14 day interval. The maximum distance

recorded for a fledgling movement was 135 m and the shortest was < 1 m. Average daily

movement from the nest bowl was 37.5 m (SE ± 3.11) and on average, fledgling took their

first flight at four days of age.

Habitat use as a function of age was described using principal components analysis

(PCA). Fledgling use of the habitat varied little for the three age groups. All PC loadings for

the first component were driven by high bare ground means and low litter means. The second

PC loading was low in means for warm season grass and tall fescue and high in other cool-

season grass and forb canopy cover. PC loadings three and four were similar across age classes with older age classes having higher loading for greater woody vegetation abundance.

Survival analyses indicated that fledgling age had the greatest impact on daily survival rates and that parasitism, forb abundance, and vegetation height weakly affected postfledging survival. Evidence of an age effect on survival was significant in multiple models and age was included in all four of the candidate models. Parasitism had a slight, positive effect on survival that could be indirectly associated with reduced clutch sizes, not caused by predators. Effects of vegetation height and forb abundance were both negative, and similar to the nesting study, we relate this to a concomitant reduction in bare ground which makes foraging more difficult (Kennedy et al. 2009).

Survival rates were greater for nesting and postfledging Grasshopper Sparrows in pastures treated with patch-burn grazing. Patch-burn grazing management can create grassland with increased nesting habitat available to a variety of birds. This is dissimilar to current grassland management practices in Iowa that only include short grass (heavily stocked areas) or tall and rank grasses (CRP fields). Patch-burn grazing has been supported in large landscapes previously and this work provides evidence that it may be a likely management tool in heavily fragmented landscapes as well.

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