Effects of grazing strategy on grassland bird nesting on native grassland pastures of the Mid-South USA (#73034)

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Effects of grazing strategy on grassland bird nesting on native grassland pastures of the Mid-South USA

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Understanding how livestock grazing strategies of native warm season grasses (NWSG) can impact grassland bird nesting can provide insight for conservation efforts. We compared the effects of rotational grazing (ROT), patch-burn grazing (PBG) with control treatments for bird species nest success and nest-site selection on NWSG pastures at three Mid-South research sites. We established 14, 9.7-ha NWSG pastures and randomly assigned each to either ROT or PBG and monitored avian nest-site selection and nest success, 2014–2016. We collected nesting and vegetation data in 2014, before treatment implementation, as an experimental pre-treatment control. We implemented treatments across all research sites in spring 2015. We used a step-wise model selection framework to estimate treatment effect for ROT or PBG on avian daily survival rate (DSR) and resource selection function (RSF) in the context of a temporal scale and within-field variables. Daily survival rates were 0.93% (SE = 0.006) for field sparrow (*Spizella pusilla*), 0.96% (SE = 0.008) for red-winged blackbird (*Agelaius phoeniceus*), and 0.92% (SE = 0.01) for indigo bunting (*Passerina cyanea*). Model support for PBG treatment and vegetation height were influential for field sparrow DSR; however, ROT and vegetation height were important red-winged blackbird DSR, and DSR for indigo bunting did not differ among treatments. Combined RSF models indicated nest-site selection for all species was positively related to vegetation height and only weakly associated with other within-field variables. We provide evidence that ROT and/or PBG effects vary by species for DSR for these 3 grassland-facultative birds, and vegetation characteristics affected their nest-site selection in the Mid-South USA. A lack of disturbance in Mid-South grasslands can lead to higher

successional stages (i.e., mix shrub-grassland), but ROT, PBG, and unburned/ungrazed areas can create a mosaic of vegetation that appears to offer the opportunity to simultaneously maintain livestock production and grassland bird nesting habitat.

Effects of Grazing Strategy on Grassland Bird Nesting on Native Grassland Pastures of the Mid-South USA.

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Abstract

Understanding how livestock grazing strategies of native warm season grasses (NWSG) can impact grassland bird nesting can provide insight for conservation efforts. We compared the pre and post treatment effects of rotational grazing (ROT) and patch-burn grazing (PBG) for bird species nest success and nest-site selection on NWSG pastures at three Mid-South research sites. We established 14, 9.7-ha NWSG pastures and randomly assigned each to either ROT or PBG and monitored avian nest-site selection and nest success, 2014–2016. We collected nesting and vegetation data in 2014, before treatment implementation, as an experimental pre-treatment. We implemented treatments across all research sites in spring 2015. We used a step-wise model selection framework to estimate treatment effect for ROT or PBG on avian daily survival rate (DSR) and resource selection function (RSF) at the temporal scale and within-field variables. Daily survival rates were 0.93% (SE = 0.006) for field sparrow (*Spizella pusilla*), 0.96% (SE = 0.008) for red-winged blackbird (*Agelaius phoeniceus*), and 0.92% (SE = 0.01) for indigo bunting (*Passerina cyanea*). Model support for PBG treatment and vegetation height were influential for field sparrow DSR; however, ROT and vegetation height were important red-winged blackbird DSR, and DSR for indigo bunting did not differ among treatments. Combined RSF models indicated nest-site selection for all species was positively related to vegetation height and only weakly associated with other within-field variables. We provide evidence that ROT and/or PBG effects vary by species for DSR for these 3 grassland-associated birds, and vegetation characteristics affected their nest-site selection in the Mid-South USA. A lack of disturbance in Mid-South grasslands can lead to higher successional stages (i.e., mix shrub-grassland), but some combination of ROT, PBG, and unburned/ungrazed areas can provide adequate nesting habitat on small pasture lands (~1.8-7.8 ha) for various grassland-associated

38 birds and potentially offer the opportunity to simultaneously maintain livestock production and
39 grassland bird nesting habitat.

40 **Introduction**

41 Grassland bird populations in North America have experienced a ~45% decline since the
42 1970s (Rosenberg et al., 2019). Habitat loss, fragmentation, and degradation through fire
43 suppression, and inappropriate grazing management are contributing causes of these declines
44 (Green et al., 2005; White et al., 2000). Much of the eastern United States has experienced
45 reforestation due to fire suppression, which has also reduced grassland habitat. Remaining
46 grasslands within the eastern United States have been converted to non-native grass species (tall
47 fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.], orchard grass [*Dacytlis glomerata* – L.],
48 bermudagrass [*Cynodon dactylon* – (L.) Pers.]) focused primarily on livestock production
49 (Derner et al., 2009; Tilman, 1999). These conversions have led to alterations in vegetative
50 structure and composition of Mid-South (the region south of glacial influence, north of the Gulf
51 Coastal Plain, west of the Appalachians, and east of the Great Plains; (Barrioz et al., 2013),
52 grasslands (Auken, 2000; Briske et al., 2011; Hayes and Holl, 2003; Willcox et al., 2010). In
53 turn, these changes have been linked to reduced nesting success and shifts in nest-site selection
54 for grassland bird populations (Coppedge et al., 2008; Davis, 2005).

55 To mitigate the loss of grassland habitat at a large scale, "working-lands conservation"
56 efforts promote sustainable grazing practices on private lands to benefit agricultural production
57 and grassland bird populations (Keyser et al., 2019; Kremen and Merenlender, 2018; Monroe et
58 al., 2016). Under a working-lands model, native warm-season grass pastures managed with,
59 rotational grazing (ROT) or patch-burn grazing (PBG) could improve grassland bird breeding

habitat and contribute to conservation efforts in eastern systems (Lituma et al., 2022). Grazing management that relies on the systematic shifting of cattle (*Bos tarus*) at temporal and spatial scales (ROT) can achieve uniform utilization of forage within a given pasture while creating heterogeneous vegetation structure among pastures (Briske et al., 2011; Holling, 1978). However, research comparing ROT with other land management strategies (i.e., continuously grazed) has produced variable results concerning grassland bird nesting success. Studies have reported reduced (Temple et al., 1999; Kerns et al., 2010), increased (Kerns et al., 2010), and highly variable (Perlut and Strong, 2011) nest success for ROT versus idle or continuously grazed pastures. This conflicting information suggests nest success under ROT are species and/or region-specific for grassland-associated birds. Using ROT also indicates that impacts on structure and plant species composition will determine benefits among grassland-associated birds (Perlut and Strong, 2011; Sliwinski et al., 2019; Soderstrom et al., 2001; Temple et al., 1999).

Pyric-herbivory (i.e., periodic fires and large ungulate grazing) mimics the historical natural disturbances under which North American grassland ecosystems evolved (Fuhlendorf et al., 2009). Grazing management based on pyric herbivory, PBG, utilizes prescribed burns to create a mosaic of burned and unburned areas across a gradient of spatial and temporal scales within grasslands (Fuhlendorf et al., 2009). Selective grazing of recently burned areas results in increased vegetation structural and compositional heterogeneity (Allred et al., 2011; Augustine and Derner, 2015). Researchers have reported increased(Churchwell et al., 2007; Davis et al., 2016), similar (Erickson, 2009; Holcomb et al., 2014), and highly variable (Doxon, 2009; Skagen et al., 2018) grassland-associated bird nest success when compared to traditional grazing. It is important to examine PBG effects given the highly variable response for grassland bird nest survival and the lack of empirical data in the eastern USA.

It is imperative to analyze ROT and PBG management practices across ecosystems (i.e., semi-arid grasslands of the Great Plains and humid, temperate Mid-South grasslands) due to variation in landscape context, precipitation gradients, and bird species-specific responses. Much of the current ROT/PBG peer-reviewed literature originates from the semi-arid Great Plains ecosystem. Furthermore, a direct comparison between ROT and PBG and their effects on grassland birds is needed in the Mid-South USA. In north Mississippi's Black Belt Prairie, ROT management was used to promote NWSG, which resulted in higher nest density for dickcissels due to the increase in habitat structural heterogeneity (Conover et al., 2011; Monroe et al., 2016). Conversely, Harper et al. (2015) found that full-season grazing (early May to late summer) would maintain favorable vegetation structure (vegetation height average pasture = ~40 cm) suitable for grassland birds nesting and brooding habitat in Tennessee. The utilization of PBG in the Mid-South USA could potentially improve grassland bird populations on working lands (Keyser et al., 2019) or, at minimum, provide nesting habitat without sacrificing cattle production.

Understanding the efficacy of ROT and PBG native grassland management on bird reproductive potential can aid working-lands conservation in pasturelands of the Mid-South USA and potentially inform conservation strategies in other regions. Therefore, we evaluated ROT and PBG effects on vegetation characteristics at the within-field scale and determine if these grazing strategies affect grassland-associated avian species reproductive success (DSR and nest success) and nest-site selection on NWSG pastures in the humid temperate Mid-South United States. Additionally, we assessed if grassland bird reproductive efforts during a pre-treatment year (ungrazed and unburned) on the same pastures were affected by subsequent treatments. Finally, we examined the influence of with-in field vegetation characteristics (structure and composition)

on DSR and nest-site selection. We hypothesized that PBG pastures would provide more favorable vegetation characteristics due to an increased heterogeneous structure at the within-field scale for grassland-associated birds resulting in greater reproductive success (DSR and nest success) and selection for nesting locations than pastures managed with ROT or pre-treatments.

Materials and Methods

Study area and site preparation

We conducted our research on three sites: 1) Blue Grass Army Depot (BGAD) in Madison County in east-central Kentucky [37°41'31" N, 84°10'56" W'; elevation, 283 m], 2) Quicksand, Robinson Center for Appalachian Resource Sustainability (QUICK) in Breathitt County in eastern Kentucky (37°25'42" N, 83°10'22" W; elevation, 383 m) and 3) Dairy Research and Education Center (DREC) in Marshall County in south-central Tennessee (35°24'58" N, 86°48'50" W; elevation, 251 m; Fig. 1). The BGAD and DREC sites were located in the Bluegrass and Highland Rim Section of the Interior Lower Plateau (Griffith, 2010; The Nature Conservancy, 2005) while QUICK was located in the North Cumberland Plateau of the Southern Appalachian ecoregions (Griffith, 2010; The Nature Conservancy, 2003). The Interior Lower Plateau consists of irregular plains, open hills, and smooth plains with an elevation between ~200 – 300 m with an average annual precipitation of ~111 cm. The Interior Lower Plateau is generally described as a predominately oak (*Quercus* spp)-hickory (*Cary* spp) forested region with sections of tallgrass prairie (The Nature Conservancy, 2005). The North Cumberland Plateau is characterized by oak-hickory, oak-pine (*Pinus* spp) mixed forest with agriculture pastures and reclaimed surface mines which range from ~365 – 609 m in elevation and annual precipitation of ~88 – 139 cm (Griffith, 2010; The Nature Conservancy, 2003).

Pastures (9.7 ± 0.47 ha each) at each site were converted to NSWG from cool-season grasses during 2012–2013 (Keyser et al., 2015b). Stands were sown with a grass mixture that included 6.7 kg ha^{-1} (pure live seed basis) big bluestem, 3.3 kg ha^{-1} Indiangrass, and 1.1 kg ha^{-1} little bluestem. We established six pastures at BGAD, a property that also included tall fescue pastures, hayfields, and oak-dominated woodlots adjacent to NWSG pastures. We converted four pastures at DREC with similar land use as BGAD. At QUICK, we planted four pastures with the surrounding landscape being a reclaimed surface mine (reclaimed between 2004 – 2012) dominated by tall fescue, sericea lespedeza (*Lespedeza cuneata* [Dum. Cours.]) and stands of various planted hardwoods including autumn olive (*Elaeagnus umbellate* [Thunb.]) and American sycamore (*Platanus occidentalis* {[Fer.).

Treatments and management protocol

We divided each pasture (n = 14) into thirds (3.2-ha paddocks) using temporary fencing (ROT pastures only) with permanent fence enclosing each pasture. We randomly selected half of the pastures at each site for PBG treatments and implemented prescribed burns on a different paddock each year, 2015 – 2016. We used ~3-m disked lines as fire breaks around all burn pastures and all prescribed burns were conducted in early to mid-April of each burn year. Rotationally grazed pastures were not burned during this study. Pastures were not grazed or burned for either treatment during 2014 to allow them to complete establishment and to collect pre-treatment data.

We utilized an initial stocking density of cattle based on previous NWSG research in the Mid-South and adjusted rates across sites based on pasture conditions and site productivity (Keyser et al., 2015a). On the less productive mine site (QUICK), stocking density was 260 – 350 kg ha^{-1} while at BGAD it was 500 – 600 kg ha^{-1}, and at DREC 620 – 700 kg ha^{-1}. We

stocked pastures ~2 – 5-weeks post-burn for all sites. We used yearling heifers or due to a lack of availability of heifers (QUICK only), steers for grazing purposes. Cattle grazed freely throughout PBG pastures. We rotated cattle on ROT pastures among the three paddocks based on residual vegetation height (target = 35 – 45 cm); in practice, we moved cattle approximately once every 4 – 7-days. We provided all cattle with water, shade, and trace mineral salt blocks for all pastures and across all 3 sites. Cattle occupied each pasture from mid-May until late August each year, 2015 – 2016. Animal care adhered to University of Tennessee-Institutional Animal Care and Use protocols No. 2258-0414 and No. 2258-0417.

Nest searching and monitoring

We searched for grassland-associated bird nests beginning from early May to late July across all research sites, 2014 – 2016. We located grassland bird nests using a combination of systematic point counts and behavioral observations of adults (Martin and Geupel, 2016; Winter et al., 2003). We searched each pasture every 3 – 4 days for potential grassland bird nests. Once a nest was located, we recorded the Universal Transverse Mercator (UTM) coordinates, species, parental activity, and nest contents (eggs or nestlings). We attached 10 cm orange vinyl flagging 5 m north of a nest to facilitate relocation. We monitored each nest every 2 – 3-days to determine fate (abandoned, successful, or failed nest) by recording the nest contents and parental activity. We categorized a successful nest as those with ≥1 nestling fledged. We determined fledging by observing parental behavior (i.e., adult alarm call or chick feeding calls) or visual confirmation of young near the nest (feces on the rim, flushed young near the nest). We determined a nest failure if eggs were missing, there were broken egg fragments in the nest, and if behavioral cues (absent parents, absent fledglings) indicated failure.

Nest measurements

We collected vegetation measurements at all active nests within two weeks of completion (young fledged or failed). We measured nest substrate height (cm), nest height (measure to the rim of the cup; cm), litter depth (cm), and used a Daubenmire frame to estimate percent cover of grass, forbs, bare ground, and litter for each active nest location. We recorded VOR using a Robel pole in each cardinal direction (N, S, E, or W) 4-m from the center of each nest bowl (Robel et al., 1970).

Pasture Vegetation measurements

We also conducted vegetation samples in each pasture during May, June, and July 2014-2016. We utilized previously established fixed avian point count locations, hereafter vegetation points, spaced >150 m apart within each pasture ($n = \leq 5$ points/pasture). We measured within-field vegetation variables (the same ones previously mentioned for nest sites) along a 25-m transect in a randomly selected cardinal direction (Elzinga et al., 1999), starting at each vegetation point center. Vegetation metrics were recorded every 5-m alternating between the left and right side of the transect line.

Statistical analysis

For data analysis we selected nests of those species that nest in grasslands and pasturelands, are of conservation concern [i.e., species listed on the Birds of Conservation Concern List; (U. S. Fish and Wildlife Service, 2008)], and had >30 nests (a number that permitted models to converge properly) (Moineddin et al., 2007; Smith et al., 1997). Before fitting models, we assessed explanatory variables multicollinearity by calculating variance inflation factors (VIF) with the VIF function in the R package car, version 3.5.0 (Fox and Weisberg, 2018). We created a linear regression model with all response variables and removed variables with VIF values >5 (James et al., 2014). We used the nest survival model function built

on a logistic regression framework in the RMark package in Program R (version 3.6.2 R Core Team, 2019) to estimate DSR for selected grassland-associated bird nests (Dinsmore et al., 2002; Laake, 2013; White and Burnham, 1999). We grouped nests by species across all sites to increase sample size. We used a step-wise modeling approach (Mundry and Nunn, 2009; Whittingham et al., 2006) to determine the influence of site, treatment, and/or within-field variable effects on DSR for each selected grassland-associated bird species individually. We used Akaike's Information Criterion corrected for small sample sizes (AIC_c) to evaluate model performance and identify competitive models (≤ 2.0 AIC_c) (Anderson, 2008; Burnham and Anderson, 2002). We considered variables with β-values with a 95% confidence interval that did not overlap zero to be important in explaining the variability in top models (Arnold, 2010). We created model subsets for DSR with an additive step-wise process, by modeling 1) year, 2) research site, 3) treatment method, and 4) within-field variables as covariates for each selected bird species and each subset. We also incorporated a site by year interaction for each species. We created a combined model set using the top competing model from each subset of models consisting of all variables of importance to determine effects on nest survival. For modeling DSR prediction, we only included variables that met our selection criteria from combined model sets. If treatment effects (ROT/PBG/Pre-treatment) were documented, we ran *post hoc* analyses to assess potential for within-field variable effects. We calculated the probability of nest success from initiation to fledge (nesting cycle; DSR raised to the power of nesting duration in days for each individual species) (Rotella, 2012). Average nest duration in days was based on species-specific nesting information (Cornell Lab of Ornithology, 2019). We present DSR and overall nest success as mean ± SE.

We examined treatment and within-field variable influences on nest-site selection using resource selection function (RSF) with a generalized linear mixed model approach with a binomial distribution and a logit link (Bates et al., 2015; Boyce et al., 2002) for grassland-associated birds with large enough sample sizes to allow for proper model performance. We used the glmer function in the lme4 package (Bates et al., 2015) in Program R (version 3.6.2 R Core Team, 2019) to compare RSF for nest sites utilized vs available habitat (i.e., vegetation points sampled in association with point counts) for each pasture across all research locations. We used an unpaired, used vs. unused framework for the RSF analysis (Manly et al., 2002; Milligan et al., 2020). This approach allows for a more comprehensive and robust comparison than a nest site paired with a single random point. We followed the previous step-wise modeling approach and model selection criteria described above for DSR. Model subsets for RSF were 1) treatment (ROT, PBG, and Pre-treatment), 2) within-field covariates, and 3) site as a random effect. Significant RSF estimates obtained from the combined model were either a positive score, indicating "use" of a resource in larger proportion than what is available, or a negative RSF score indicating "underuse" concerning available resources (i.e., treatment, within-field variable) (Boyce et al., 2002).

Means and standard errors for all vegetation metrics were calculated for each site, year, and between ROT and PBG pastures. Coefficient of variation (CV) of the vegetation height was estimated to determine structural heterogeneity within pastures and calculated as the standard deviation of the vegetation height divided by the mean X 100 for (Bowman, 2001; Chanda et al., 2018; Pearson, 1895).

Results

Daily survival rate and nest success rate

We located and monitored 350 nests across all 3 sites during the breeding seasons of 2014 – 2016. Grassland-associated bird nests represented a range of 1 species at QUICK (2016) to 11 at DREC (2014). Three grassland-associated avian species met the selection criteria for data analysis [field sparrow, $n = 153$; red-winged blackbirds (*Agelaius phoeniceus*), $n = 33$; and indigo bunting (*Passerina cyanea*), $n = 41$]. Only 2 nests of red-winged blackbirds were found in PBG pastures (2015 QUICK and 2016 BGAD) following the 2014 pre-treatment period. Thus, parameters for this species and treatment were inestimable. Estimated VIF values ranged between 1.01 and 1.22, indicating an absence of multicollinearity for all within-field variables for DSR and RSF. Site-by-year interaction models were not incorporated into combined model analysis due to poor model performance ($\Delta AIC_c > 2.0$). Based on top models, DSRs were 0.93 (SE = 0.006) for field sparrow, 0.96 (SE = 0.008) for red-winged blackbird, and 0.92 (SE = 0.01) for indigo bunting. Field sparrow DSR was lowest on PBG pastures and differed from ROT and pre-treatments, while ROT and pre-treatment DSR were similar (Fig. 2). Red-winged blackbird DSR differed among ROT and pre-treatment (Fig. 3). Based on the ΔAIC_c and combined model DSR beta estimates, ROT and PBG negatively affected red-winged blackbird and field sparrow, respectively (Table 1). Indigo bunting DSR was not influenced by site, treatment, or vegetation metric. *Post hoc* analysis indicated vegetation height was positively associated with DSR for red-winged blackbird and field sparrow (Table 1). However, the 95% confidence intervals for the β estimate for red-winged blackbirds and field sparrow overlapped zero, indicating a weak effect for vegetation height, yet vegetation height was associated with the top models for each species.

Nest success, the overall probability of a nest surviving the nesting cycle (incubation to fledging), was highest for red-winged blackbirds (50% ± 9%, based on 22 ± 5-day nesting cycle) followed by field sparrow (38% ± 5%, 15 ± 10-day nesting cycle), and lowest for indigo bunting

(22% ± 0.06%, 19 ± 5-day nesting cycle). The relationship to treatments for nest success was similar to that for DSR for all three species (Fig. 2).

Nest-site selection

None of these three bird species' nest-site selection was influenced by ROT or PBG treatments. Combined model analysis indicated all three bird species selected nesting locations based on vegetation height and within-field vegetation metrics. Field sparrow nest site selection was positively influenced by vegetation height (β = 0.03, 95% CI = 0.02 – 0.03; Fig. 3) and negatively impacted by % grass (β = -2.50, 95% CI = -4.36 – -0.64) and % bare ground (β = -2.50, 95% CI = -4.36 – -0.64). Combined RSF model estimates indicated indigo bunting selected nest-sites based on vegetation height (β = 0.03, 95% CI = 0.02– 0.04; Fig. 3), % forb (β = 0.02, 95% CI = 0.00 – 0.04) but avoided sites with more grass (β = -0.03, 95% CI = -0.05 – -0.01) and bare ground (β = -0.08, 95% CI = -0.16 – -0.00) (AICc <2.0, ∑ AICcw_i = 1.0, Table 2). Red-winged blackbird selected nest sites based on vegetation height (β = 3.55, 95% CI = 2.77 – 4.82, Table 2; Fig. 3) but was negatively associated with litter depth (β = -2.50, 95% CI = -4.36 – -0.64) (AICc <2.0, ∑ AICcw_i = 1.0, Table 2). A pre- and post-treatment effect was not supported for any species in the combined models indicating a lack of nest-site selection between pre-treatment and treatment pastures (ROT or PBG).

Within-field habitat

A total of 4,464 vegetation samples were collected across all 3 study sites. Mean vegetation height across all sites and treatments declined following the implementation of ROT and PBG management (Table 3). Sample means for within-field habitat variables differed among sites and treatments (Supplemental Table1). Mean vegetation height on each site differed for ROT and PBG as well as between years (Fig. 4). The coefficient of variation for vegetation

height varied minimally between ROT and PBG for each site as well as between years (Table 4). Vegetation height maximum and minimum varied for each site and years from a maximum of 225-cm at DREC to a minimum of 0-cm observed at all sites based on random vegetation samples. All VIF estimates for vegetation variables were <5.

Discussion

ROT and PBG management of native warm season grasses can benefit grassland birds by creating breeding conditions that increase nest success for some grassland bird species, though benefits are moderated by species-specific requirements, and ecoregion (Augustine and Derner, 2012; Kerns et al., 2010). However, our research is the first to compare ROT and PBG management effects on grassland bird breeding and nest-site selectionin the Mid-South United States and adds to a limited body of work from outside the Great Plains. We provide evidence that using ROT and/or PBG grazing practices had variable impacts on DSR for 3 grassland-associated birds. These relationships were also influenced by vegetation height for two of these species. With respect to nest site selection, grazing strategy did not receive support in our models. Instead, birds consistently selected for taller vegetation, regardless of grazing treatments, which reduced vegetation height (except for pre-treatment year), litter depth, and forb cover.

Our research provides species-specific results for the 3 grassland-associated bird species we examined during the 3-year study. Field sparrow DSR was lower in PBG treatments than in ROT or pre-treatment, and red-winged blackbird DSR was lower in ROT than pre-treatment; we did not locate any red-winged blackbird nests in PBG pastures. Indigo bunting DSR was unaffected by treatments. *Post hoc* analysis confirmed that DSR differences among treatments for field sparrow and red-winged blackbird were related to vegetation height. Vegetation height

was lower after treatments were implemented, but all three species consistently selected for taller vegetation, including in PBG and ROT pastures.

Although DSR was lower for field sparrow on PBG pastures (93%), it was comparable to what has been reported in Pennsylvania (~93.5%) (Schill and Yahner, 2009). Similarly, red-winged blackbird DSR on ROT pastures was lower (94%) than on pre-treatment year (98%) but was still comparable to DSR reported in the literature (Iowa, ~96%) (Burhans et al., 2002; Murray and Best, 2003). Even thought we did not document a treatment effect indigo bunting DSR, our results were similar to previous reported DSR (~93 - 96%) in the peer reviewed literature (Weldon, 2006).

Vegetation height or cover can be important for DSR for grassland birds. Grassland-associated bird nest site selection has been linked to mean vegetation height across native, restored native, and non-native grasslands in North America (i.e., Illinois, Iowa, West Virginia, and Alberta, Canada) (Fletcher and Koford, 2002; Herkert, 1994; King et al., 2006; Warren and Anderson, 2005). Best (1978) concluded that a reduction in vegetation height in tallgrass prairie systems to <40-cm could allow for increased predation risk for some species.

On our pastures, a reduction in vegetation height following habitat disturbance led to reduced DSR for red-winged blackbird and field sparrow (PBG only), but they continued to select for the tallest vegetation within pastures. Similarly, in Oklahoma, PBG negatively affected field sparrow nest success, which was strongly positively correlated with VOR (Doxon, 2009). It is important to note that due to the incomplete PBG cycle there were sections of 2 years' worth of growth before the last section was burned. This could have led to favorable environmental conditions for field sparrow nesting and increased vegetation structural diversity across the pasture. Field sparrows prefer undisturbed fields with residual grass (i.e., the previous year's

growth) that provides nest substrate and adequate nesting cover (Best, 1978; Sample, 1989; Sousa, 1983) related to greater DSR. Additionally, field sparrows selected for taller vegetation for nesting as the season progresses (i.e., 27-cm in May – 47-cm in July) (Best, 1978). Alternatively, but also in the Great Plains, there was no differences in red-winged blackbird DSR between unburn/ungrazed pastures and burn/grazed pastures in a tallgrass prairie (Zimmerman 1997). In fields burned every 3 - 4 years, red-winged blackbirds nested in taller vegetation than would be expected, given the height of available vegetation after treatments (King et al. 2006).

Indigo bunting DSR was unaffected by ROT or PBG, which highlights the value of including multiple species when assessing the impacts of grazing management. Indigo buntings will create nests in old or biennially burned fields, roadside grasses, and woodland edges (Burhans et al., 2002; Payne, 2006). Burhans et al. (1998) stated that snakes were the principal predator of nests for indigo buntings and vegetation concealment of the nest from below (i.e., reduced vegetation density at ground level) may be the most important factor for this species in Missouri. We believe this could be a plausible explanation for the lack of effect of the vegetation metrics we examine and the low DSR for indigo buntings during our research.

From our results, a reduction in vegetation height following grazing led to reduced DSR for field sparrow (PBG only) and red-winged blackbird, but they continued to select for the tallest vegetation within pastures. For both species, although DSR was lower in PBG pastures, DSR values were similar to those reported from other studies and, for field sparrow, there was no difference between pre-treatment and ROT pastures. Some grassland birds select nesting sites that are infrequently disturbed (1 - 2 yrs post-disturbance) with greater vegetation structure that could provide for increased concealment and reduce nest predation (Sandercock et al., 2014). Providing a staggered habitat disturbance and low – medium stocking rate across multiple

pastures or paddocks could provide grassland nesting birds with an increase in potential nest sites or nesting habitat during the breeding season in the Mid-South USA.

A potential cause of nest mortality during grazing could be failure or abandonment directly caused by livestock (cattle) through trampling or even depredation. Our project did not determine the direct impact of cattle on nest survival (i.e., remote cameras to determine the ultimate cause of nest failure). However, in native tallgrass prairie in southcentral Canada, nest failures directly attributed to cattle were low (~0–3%) for various grassland obligate species (Bleho et al., 2014). In fact, for every nest lost to cattle ~31 nests were lost to predators (Bleho et al., 2014). Previous research in Iowa on pastures that had one-third burned annually and low to moderate stocking (1.24 – 2.97 animal units per month ha^{-1}) exhibited high nest survival for eastern meadowlarks during the first year of a 2-year study (Hovick and Miller, 2016). Additionally, paddocks lightly grazed by cattle (i.e., 15 cattle/5day in a 2-ha paddock) or paddocks with deferred grazing until after grassland birds developed breeding territories, reduced nest abandonment or failure caused by cattle (Campomizzi et al., 2019). We are confident that our stocking rates were light enough (2.5 – 5.0-ha^{-1}) to minimize nest failure or abandonment caused by cattle.

Our research provides the first experimental use of ROT and PBG on NWSG pastures and the effects on grassland bird DSR and nest-site selection in the Mid-South USA. Previous research on ROT and PBG management effects on grassland bird breeding dynamics has been conducted in the Mid-West USA where tracts of managed lands are much larger (i.e., ~5,000–18,000-ha pastures) and under arid climatic (i.e., ~31-cm of precipitation) conditions. Researchers have cautioned about extrapolating habitat or landscape effects for a wide-ranging species (i.e., field sparrows) and across ecosystems (Winter et al., 2006). Current grazing

379 practices on pastures in the eastern USA involve year-round stocking, mowing, or hay
380 production due to the higher precipitation and longer growing season than the western
381 ecoregions (Askins et al., 2007; Monroe et al., 2019; Warren and Anderson, 2005). Restoring
382 Mid-South pastures currently dominated by exotic cool-season grasses to NWSG may be
383 accelerated by adoption of grazing methods such as PBG from the semi-arid Great Plains
384 (Keyser et al., 2019). Additionally, if large tracks of pasturelands across the Mid-South return to
385 NWSG grassland birds could benefit from an increase in potential nesting habitat (West et al.,
386 2016). Yet, until significant pasturelands of the Mid-South are restored to NWSG, we have
387 provided baseline information by comparing ROT and PBG management to NWSG in the Mid-
388 South for grassland bird reproductive efforts and nest-site selection that could guide conservation
389 strategies and future research.

390 **Conclusions**

391 Due to the extreme decline in grassland bird populations, it is imperative to fully explore
392 alternative livestock production strategies and their impacts on grassland bird populations across
393 ecoregions outside of the Great Plains. Our research shows that ROT and PBG management of
394 NWSG can have variable impacts on nesting success but little direct impact on nest-site selection
395 for grassland-associated bird species. Geller et al. (2004), Powell (2006), and Weir et al. (2013)
396 state that ~2.5 - 4 years following patch-burns can allow vegetation biomass and litter to
397 accumulate which can provide adequate nesting cover for birds that utilize ground and standing
398 vegetation to create nests. Our short-term data for the 2-year post-treatment period provide some
399 support for nest site selection for field sparrows. Based on this information it is important to
400 consider trade-offs between habitat disturbances and potential short-term impacts on grassland
401 breeding birds. Additionally, our research highlights the importance of continued monitoring,

because we do not know how our pastures will continue to change and species respond over longer time intervals. It is also important to note that our PBG treatment cycle (i.e., all 3 sections burned) had not been completed by the end of the study yet previous research has shown PBG can be useful in creating habitat disturbance for grassland birds (Churchwell et al., 2007; Coppedge et al., 2008; Fuhlendorf et al., 2006). With a lack of disturbance, grassland ecosystems in the Mid-South USA will quickly progress to later seral stages, thereby reducing available breeding habitat for grassland obligate bird species which can further exacerbate population declines.

Grazed native grasses appear to offer the opportunity to maintain livestock production while simultaneously achieving grassland bird conservation goals (Allred et al., 2014; Fuhlendorf et al., 2006). Managers can utilize ROT, PBG, and unburned/ungrazed areas in a rotation mosaic of vegetation that differs by age and size. Creating such a mosaic can create a heterogeneous vegetation structure that enhances grassland bird nesting habitat and nesting species diversity (Delany and Linda, 1998; Fuhlendorf and Engle, 2004; Hovick et al., 2015; Monroe et al., 2016). Our research along with Campomizzi et al. (2019) indicate that some combination of PBG, ROT, and unburned-ungrazed areas (i.e., our pre-treatment year, 2014) can provide adequate nesting habitat on small pasture lands (~1.8–7.8 ha) for a variety of grassland birds. We encourage future research to monitor nesting survival with cameras to determine the ultimate cause of mortality.

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Appendix A. Supplementary data

Supplementary material for this article can be found in the online version, at

References

Allred, B.W., Fuhlendorf, S.D., Engle, D.M., Elmore, R.D., 2011. Ungulate preference for burned patches reveals strength: of fire-grazing interaction. *Ecology and Evolution* 1, 132–144. https://doi.org/10.1002/ece3.12

Anderson, D., 2008. *Model based inference in the life sciences: a primer on evidence*. Springer, New York, NY USA.

Arnold, T.W., 2010. Uninformative parameters and model selection using Akaike's information criterion. *Journal of Wildlife Management* 74, 1175–1178. https://doi.org/10.2193/2009-367

Askins, R.A., Chávez-ramírez, F., Dale, B.C., Haas, C.A., Herkert, J.R., Knopf, F.L., Vickery, P.D., 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. *The Auk* 64, 1–46.

444 Augustine, D.J., Derner, J.D., 2015. Patch-burn grazing management, vegetation heterogeneity,
445 and avian responses in a semi-arid grassland. *Journal of Wildlife Management* 79, 927–936.
446 https://doi.org/10.1002/jwmg.909

447 Augustine, D.J., Derner, J.D., 2012. Disturbance regimes and mountain plover habitat in
448 shortgrass steppe: large herbivore grazing does not substitute for prairie dog grazing or fire.
449 *Journal of Wildlife Management* 76, 721–728. https://doi.org/10.1002/jwmg.334

450 Auken, O.W. Van, 2000. Shrub invasions of North American semiarid grasslands. *Annual*
451 *Review of Ecology and Systematics* 31, 197–215.

452 Barrioz, S., Keyser, P., Buckley, D., Buehler, D., Harper, C., 2013. Vegetation and avian
453 response to oak savanna restoration in the Mid-South USA. *American Midland Naturalist*
454 169, 194–213. https://doi.org/10.1674/0003-0031-169.1.194

455 Bates, D., Mächler, M., Bolker, B.M., Walker, S.C., 2015. Fitting linear mixed-effects models
456 using lme4. *Journal of Statistical Software* 67. https://doi.org/10.18637/jss.v067.i01

457 Best, L.B., 1978. Field sparrow reproductive success and nesting ecology. *The Auk* 95, 9–22.

458 Bleho, B.I., Koper, N., Machtans, C.S., 2014. Direct effects of cattle on grassland birds in
459 Canada. *Conservation Biology* 28, 724–734. https://doi.org/10.1111/cobi.12259

460 Bowman, D.T., 2001. Common use of the CV: A statistical aberration in crop performance trials.
461 *Journal of Cotton Science* 5, 137–141.

462 Boyce, M.S., Vernier, P.R., Nielsen, S.E., Schmiegelow, F.K.A., 2002. Evaluating resource
463 selection functions. *Ecological Modelling* 157, 281–300.

464 Briske, D.D., Sayre, N.F., Huntsinger, L., Fernandez-Gimenez, M., Budd, B., Derner, J.D., 2011.
465 Origin, persistence, and resolution of the rotational grazing debate: integrating human
466 dimensions into rangeland research. *Rangeland Ecology and Manag*ement 64, 325–334.
467 https://doi.org/10.2111/REM-D-10-00084.1

468 Burhans, D.E., Dearborn, D., Thompson, F.R.I., Faaborg, J., 2002. Factors affecting predation at
469 songbird nests in old fields. *Journal of Wildlife Management* 66, 240–249.

470 Burhans, D.E., Iii, F.R.T., 1998. Effects of time and nest-site characteristics on concealment of
471 songbird nests'. *The Condor* 663–672.

472 Burnham, K.P., Anderson, D.R., 2002. *Model selection and multimodel inferences--a practical*
473 *information-theoretic approach*, 2nd edition. Springer-Verlag., New York, NY.

474 Campomizzi, A.J., Lebrun-Southcott, Z.M., Van Vliet, L.D., Morris, G.A., 2019. Rotational
475 grazing of beef cattle to support bobolink breeding success. *Avian Conservation and*
476 *Ecology* 14. https://doi.org/10.5751/ACE-01420-140213

477 Chanda, S., Kanke, Y., Dalen, M., Hoy, J., Tubana, B., 2018. Coefficient of variation from
478 vegetation index for sugarcane population and stalk evaluation. *Agrosystems, Geosciences*
479 *& Environment* 1, 1–9. https://doi.org/10.2134/age2018.07.0016

480 Churchwell, R.T., Davis, C.A., Fuhlendorf, S.D., Engle, D.M., 2007. Effects of patch-burn
481 management on dickcissel nest success in a tallgrass prairie. *Journal of Wildlife*
482 *Management* 72, 1596–1604. https://doi.org/10.2193/2007-365

483 Conover, R.R., Dinsmore, S.J., Burger, L.W., 2011. Effects of conservation practices on bird
484 nest density and survival in intensive agriculture. *Agriculture, Ecosystems and Environment*
485 141, 126–132. https://doi.org/10.1016/j.agee.2011.02.022

486 Coppedge, B.R., Fuhlendorf, S.D., Harrell, W.C., Engle, D.M., 2008. Avian community response
487 to vegetation and structural features in grasslands managed with fire and grazing. *Biological*
488 *Conservation* 141, 1196–1203. https://doi.org/10.1016/j.biocon.2008.02.015

489 Cornell Lab of Ornithology. 2019. All about birds. Cornell Lab of Ornithology, Ithica, New
490 York. *Available at https://www.allaboutbirds.org* (accessed on 20 December 2021).

491 Davis, C.A., Churchwell, R.T., Fuhlendorf, S.D., Engle, D.M., Hovick, T.J., 2016. Effect of
492 pyric herbivory on source–sink dynamics in grassland birds. *Journal of Applied Ecology* 53,
493 1004–1012. https://doi.org/10.1111/1365-2664.12641

494 Davis, S.K., 2005. Nest-site selection patterns and the influence of vegetation on nest survival of
495 mixed-grass prairie passerines. *The Condor* 107, 605–616.

496 Delany, M.F., Linda, S.B., 1998. Nesting habitat of Florida grasshopper sparrows at Avon Park
497 Air Force Range. *The Florida Ornithological Society* 26, 33–39.

498 Derner, J.D., Lauenroth, W.K., Stapp, P., Augustine, D.J., 2009. Livestock as ecosystem
499 engineers for grassland bird habitat in the western great plains of North America.
500 *Rangeland Ecology and Management* 62, 111–118.

501 di Virgilio, A., Lambertucci, S.A., Morales, J.M., 2019. Sustainable grazing management in
502 rangelands: Over a century searching for a silver bullet. *Agriculture, Ecosystems and*
503 *Environment* 283, 106561. https://doi.org/10.1016/j.agee.2019.05.020

504 Dinsmore, S.J.., White, G.C.., Knopf, F.L., 2002. Advanced techniques for modeling avian nest
505 survival. *Ecology* 83, 3476–3488.

506 Doxon, E.D., 2009. Nesting and feeding ecology of grassland birds in mixed-grass prairie
507 managed with patch-burn techniques. Thesis. Oklahoma State University, Stillwater, OK,
508 USA.

509 Elzinga, C.L., Salzer, D.W., Willoughby, J.W., 1999. Measuring and monitoring plant
510 populations. *Journal of Range Management* 52, 544. https://doi.org/10.2307/4003786

511 Erickson, A.N., 2009. Response of grassland birds to patch-burn grazing in the Flint Hills of
512 Kansas. Thesis. Kansas State University, Manhattan, KS, USA.

513 Fletcher, R.J., Koford, R.R., 2002. Habitat and landscape associations of breeding birds in native
514 and restored grasslands. *Journal of Wildlife Management* 66, 1011–1022.

515 Fox, J., Weisberg, S., 2018. *Functions to accompany, in: An R Companion to Applied*
516 *Regressions*. Sage Publications, Inc., Washington D.C., p. 608.

517 Fuhlendorf, S.D., Engle, D.M., 2004. Application of the fire-grazing interaction to restore a
518 shifting mosaic on tallgrass prairie. *Journal of Applied Ecology* 41, 604–614.
519 https://doi.org/10.1111/j.0021-8901.2004.00937.x

520 Fuhlendorf, S.D., Engle, D.M., Kerby, J., Hamilton, R., 2009. Pyric herbivory: rewilding
521 landscapes through the recoupling of fire and grazing. Conservation Biology 23, 588–598.
522 https://doi.org/10.1111/j.1523-1739.2008.01139.x

523 Geller, G., Sample, D., Henderson, R., 2004. Response of grassland birds to fire on a Wisconsin
524 Sand Prairie over an 18-year period, in: *Proceedings of the 19th North American Prairie*
525 *Conference*. pp. 86–94.

526 Green, R.E., Cornell, S.J., Scharlemann, J.P.W., Balmford, A., 2005. Farming and the fate of
527 wild nature. *Science*. 307, 550–555.

528 Griffith, G., 2010. Level III North American terrestrial ecoregions: United States descriptions.
529 *Prepared for the North American Commission for Environmental Cooperation* 1–64.

530 Harper, C.A., Birckhead, J.L., Keyser, P.D., Waller, J.C., Matt, M., Bates, G.E., Holcomb, E.D.,
531 Brooke, J.M., 2015. Avian habitat following grazing native warm-season forages in the
532 mid-south United States. *Rangeland Ecology & Management* 68, 166–172.

533 Hayes, G.F., Holl, K.D., 2003. Cattle grazing impacts on annual forbs and vegetation
534 composition of mesic grasslands in California. *Conservation Biology* 17, 1694–1702.
535 https://doi.org/10.1111/j.1523-1739.2003.00281.x

536 Herkert, J.R., 1994. The effects of habitat fragmentation on midwestern grassland bird
537 communities. *Ecological Applications* 4, 461–471.

538 Holcomb, E.D., Davis, C.A., Fuhlendorf, S.D., 2014. Patch-burn management: implications for
539 conservation of avian communities in fire-dependent sagebrush ecosystems. *Journal of*
540 *Wildlife Management* 78, 848–856. https://doi.org/10.1002/jwmg.723

541 Holling, C.S., 1978. *Adaptive environmental assessment and management*. John Wiley & Sons,
542 Ltd, London, UK.

543 Hovick, T.J., Elmore, R.D., Fuhlendorf, S.D., Engle, D.M., Hamilton, R.G., 2015. Spatial
544 heterogeneity increases diversity and stability in grassland bird communities. *Ecological*
545 *Applications* 25, 662–672. https://doi.org/10.1890/14-1067.1

546 Hovick, T.J., Miller, J.R., 2016. Patch-burn grazing moderates Eastern Meadowlark nest survival
547 in Midwestern Grasslands. *American Midland Naturalist* 176, 72–80.
548 https://doi.org/10.1674/0003-0031-176.1.72

549 James, G., Witten, D., Hastie, T., Tibshirani, R., 2014. *An introduction to statistical learning:*
550 *with applications* in R. Springer, New York, NY USA.

551 Kerns, C.K., Ryan, M.R., Murphy, R.K., Thompson, F.R., Rubin, C.S., 2010. Factors affecting
552 songbird nest survival in Northern Mixed-Grass Prairie. *Journal of Wildlife Management*
553 74, 257–264. https://doi.org/10.2193/2008-249

554 Keyser, P.D., Bates, G.E., Waller, J.C., Harper, C.A., Holcomb, E.D., 2015a. Grazing native
555 warm-season grasses in the Mid-South. University of Tennessee, UT Extension SP 731-c.

556 Keyser, P.D., Buehler, D.A., Hedges, K., Hodges, J., Lituma, C.M., Loncarich, F., Martin, J.A.,
557 2019. Eastern grasslands: conservation challenges and opportunities on private lands.
558 *Wildlife Society Bulletin* 43, 382–390. https://doi.org/10.1002/wsb.1000

559 Keyser, P.D., Hancock, D.W., Marks, L., Dillard, L., 2015b. Establishing native grass forages in
560 the southeast. University of Tennessee Extension PB 1873, 1–28.

561 King, J.W., Savidge, J.A., King, J.W., Savidge, J.A., 2006. Effects of the conservation reserve
562 program on wildlife in southeast Nebraska. *Wildlife Society Bulletin* 23, 377–385.

563 Kremen, C., Merenlender, A.M., 2018. Landscapes that work for biodiversity and people.
564 *Science*. 362, eaau6020. https://doi.org/10.1126/science.aau6020

565 Laake, J.L., 2013. *RMark: an R interface for analysis of capture-recapture data with MARK*.
566 Seattle, WA.

567 Manly, B., McDonald, L., Thomas, D., McDonald, T., Erickson, W., 2002. *Resource selection by*
568 *animals*, 2cd ed. Kluwer Academic Publishers.

569 Martin, T.E., Geupel, G.R., 2016. Nest-monitoring plots : methods for locating nests and
570 monitoring success. *Journal of Field Ornithology* 64, 507–519.

571 Milligan, M.C., Berkeley, L.I., McNew, L.B., 2020. Effects of rangeland management on the
572 nesting ecology of sharp-tailed grouse. *Rangeland Ecology and Management* 73, 128–137.
573 https://doi.org/10.1016/j.rama.2019.08.009

574 Moineddin, R., Matheson, F.I., Glazier, R., 2007. A simulation study of sample size for
575 multilevel logistic regression models research article models. *BMC Medical Research*
576 *Methodology* 7:34. https://doi.org/10.1186/1471-2288-7-34

577 Monroe, A.P., Burger, L.W., Martin, J.A., 2019. Pasture-scale vegetation predicts Dickcissel
578 nest-site selection and success in native and exotic grass pastures. *The Condor* 121, 1–14.
579 https://doi.org/10.1093/condor/duz027

580 Monroe, A.P., Chandler, R.B., Burger, L.W., Martin, J.A., 2016. Converting exotic forages to
581 native warm-season grass can increase avian productivity in beef production systems.
582 *Agriculture, Ecosystems and Environment* 233, 85–93.
583 https://doi.org/10.1016/j.agee.2016.08.024

584 Mundry, R., Nunn, C.L., 2009. Stepwise model fitting and statistical inference: turning noise into
585 signal pollution. *American Naturalist* 173, 119–123. https://doi.org/10.1086/593303

586 Payne, R.B., 2006. *Indigo bunting (Passerina cyanea)*, in: Rodewald, P. (Ed.), The Birds of
587 North American. Cornell Lab of Ornithology, Ithaca, NY, USA.

588 Pearson, K., 1895. Contributions to the mathematical theory of evolution: II. skew variation in
589 homogeneous material. *Philosophical Transactions of the Royal Society of London*
590 186:343-414. URL http://rsta.royalsocietypublishing.org/content/roypta/186/343.full.pdf

591 Perlut, N.G., Strong, A.M., 2011. Grassland birds and rotational-gazing in the northeast:
592 breeding ecology, survival, and management opportunities. *Journal of Wildlife Management*
593 75, 715–720. https://doi.org/10.1002/jwmg.81

594 Powell, A.F.L.A., 2006. Effects of prescribed burns and bison (*Bos bison*) grazing on breeding
595 bird abundances in tallgrass prairie. *The Auk* 123, 183–197. https://doi.org/10.1642/0004-
596 8038(2006)123[0183:EOPBAB]2.0.CO;2

597 Robel, R.J., Briggs, J.M., Dayton, A.D., Hulbert, L.C., 1970. Relationships between viusal
598 obstruction meansurements and wieght of grassland vegetation. *Journal of Range*
599 *Management* 23, 295–297.

600 Rosenberg, K. V, Dokter, A.M., Blancher, P.J., Sauer, J.R., Smith, A.C., Smith, P.A., Stanton,
601 J.C., Panjabi, A., Helft, L., Parr, M., Marra, P.P., 2019. Decline of the North American
602 avifauna. *Science*. 366, 120–124.

603 Rotella, J., 2012. *Nest survival models*, in: Cooch, E.G., White, G.C. (Eds.), *Program MARK* -
604 *"A Gentle Introduction*." Fort Collins, CO, USA.

605 Sample, D.W., 1989. Grassland birds in southern Wisconsin: habitat preference, population
606 trends, and response to land use changes. University of Wisconsin, Madison, Wisconsin.

607 Sandercock, B.K., Alfaro-Barrios, M., Casey, A.E., Johnson, T.N., Mong, T.W., Odom, K.J.,
608 Strum, K.M., Winder, V.L., 2014. Effects of grazing and prescribed fire on resource
609 selection and nest survival of upland sandpipers in an experimental landscape. *Landscape*
610 *Ecology* 30, 325–337. https://doi.org/10.1007/s10980-014-0133-9

611 Scasta, J.D., Thacker, E.T., Hovick, T.J., Engle, D.M., Allred, B.. W., Fuhlendorf, S.D., 2016.
612 Patch-burn grazing (PBG) as a livestock management alternative for fire-prone ecosystems
613 of North America. *Renewable Agriculture and Food Systems* 31, 550–567.
614 https://doi.org/10.1017/S1742170515000411

615 Skagen, S.K., Augustine, D.J., Derner, J.D., 2018. Semi-arid grassland bird responses to patch-
616 burn grazing and drought. *Journal of Wildlife Management* 82, 445–456.
617 https://doi.org/10.1002/jwmg.21379

618 Sliwinski, M., Powell, L., Schacht, W., 2019. Grazing systems do not affect bird habitat on a
619 sandhills landscape. *Rangeland Ecology & Management* 72, 136-144.e4.
620 https://doi.org/10.1016/j.rama.2018.07.006

621 Smith, W.P., Twedt, D.J., Cooper, R.J., Wiedenfeld, D.A., Hamel, P.B., Ford, R.P., 1997.
622 *Sample size and allocation of effort in point count sampling of birds in bottomland*
623 *hardwood forests*, in: Ralph, C.J., Sauer, J.R., Droege, S. (Eds.), *Monitoring Bird*
624 *Population by Point Counts*. Pacific Southwest Research Station, Forest Service, USDA,
625 Berkeley, CA, p. 63.

626 Soderstrom, B., Part, T., Linnarsson, E., 2001. Grazing effects on between-year variation of
627 farmland bird communities. *Ecological Applications* 11, 1141–1150.

628 Sousa, P.J., 1983. Habitat suitability index models: field sparrow. FWS/OBS-82/10.62.

629 Temple, S.A., Fevold, B.M., Paine, L.K., Undersander, D.J., Sample, D.W., 1999. Nesting birds
630 and grazing cattle: accommodating both on Midwestern pastures. *Studies in Avian Biology*
631 196–202.

632 The Nature Conservancy, 2005. *The interior low plateau ecoregion: a conservation plan*.
633 Arlington, Virginia, USA.

634 The Nature Conservancy, 2003. *Cumberlands and southern ridge & valley ecoregion: a plan for*
635 *biodiversity conservation*. Arlington, Virginia, USA.

636 Tilman, D., 1999. Global environmental impacts of agricultural expansion: the need for
637 sustainable and efficient practices. *Proceedings of the National Academy of Sciences of the*
638 *United States of America* 96, 5995–6000.

639 U. S. Fish and Wildlife Service, 2008. *Birds of conservation concern 2008*. Arlington, Virginia,
640 USA.

641 Warren, K.A., Anderson, J.T., 2005. Grassland songbird nest-site selection and response to
642 mowing in West Virginia. *Wildlife Society Bulletin* 33, 285–292.
643 https://doi.org/10.2193/0091-7648(2005)33[285:gsnsar]2.0.co;2

644 Weir, J.R., Fuhlendorf, S.D., Engle, D.M., Bidwell, T.G., Cummings, D.C., Elmore, D., Limb,
645 R.F., Allred, B.W., Scasta, J.D., Winter, S.L., 2013. Patch burning: integrating fire and

646 grazing. *US Fish and Wildlife Publications*, 440.
647 hhtp://digitalcommons.unl.edu/usfwspubs/440.

648 Weldon, A.J., 2006. How corridors reduce indigo bunting nest success. *Conservation Biology* 20,
649 1300–1305. https://doi.org/10.1111/j.1523-1739.2006.00403.x

650 West, A.S., Keyser, P.D., Lituma, C.M., Buehler, D.A., Applegate, R.D., Morgan, J.J., 2016.
651 Grasslands bird occupancy of native warm-season grass. *Journal of Wildlife Management*
652 80, 1081–1090. https://doi.org/10.1002/jwmg.21103

653 White, G.C., Burnham, K.P., 1999. Program MARK: survival estimation form populations of
654 marked animals. *Bird Study* 46, 120–139.

655 White, R., Murray, S., Rohweder, M., 2000. *Pilot analysis of global ecosystems: grassland*
656 *ecosystems*. World Resources Institute, Washington D.C.

657 Whittingham, M.J., Stephens, P.A., Bradbury, R.B., Freckleton, R.P., 2006. Why do we still use
658 stepwise modelling in ecology and behaviour? *Journal of Animal Ecology* 75, 1182–1189.
659 https://doi.org/10.1111/j.1365-2656.2006.01141.x

660 Willcox, E. V., Tanner, G.W., Giuliano, W.M., McSorley, R., 2010. Avian community response
661 to grazing intensity on monoculture and mixed Florida pastures. *Rangeland Ecology and*
662 *Management* 63, 203–222. https://doi.org/10.2111/REM-D-09-00092.1

663 Winter, M., 1999. Nesting biology of dickcissels and Henslow's sparrows in southwestern
664 Missouri prairie fragments. *The Wilson Bulletin* 111, 515–526.

665 Winter, M., Hawks, S.E., Shaffer, J.A., Johnson, D.H., 2003. Guidelines for finding nests of
666 passerine birds in tallgrass prairie. *Prairie Naturalist* 35, 197–211.

667 Winter, M., Johnson, D.H., Shaffer, J.A., Donovan, T.M., Svedarsky, W.D., 2006. Patch size and
668 landscape effects on density and nesting success of grassland birds. *Journal of Wildlife*
669 *Management 70*, 158–172. https://doi.org/10.2193/0022-541x(2006)70[158:psaleo]2.0.co;2

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Table 1(on next page)

Top-ranked nest survival models and *post-hoc* sets for top ranked models for selected grassland-associated bird species with support for within-field variables influence on daily survival rates (DSR).

Nests were monitored at three Mid-South sites comparing ungrazed (2014 only) and rotationally and patch-burn grazed pastures, 2015 - 2016. Model selection was based on Akaike's information criteria for small sample sizes (AIC*c*), the difference between ranked models (Δ AIC*c*), and model weight or likelihood (ΔAIC*cw*$_i$).

Table 1

Top-ranked nest survival models ($\Delta AICc < 2.0$) and *post-hoc* sets for top ranked models for selected grassland-associated bird species with support for within-field variables influence on daily survival rates (DSR). Nests were monitored at three Mid-South sites comparing ungrazed (2014 only) and rotationally and patch-burn grazed pastures, 2015 - 2016. Model selection was based on Akaike's information criteria for small sample sizes (AIC*c*), the difference between ranked models (Δ AIC*c*), and model weight or likelihood ($\Delta AICcw_i$).

Models	*K*	AIC*c*	Δ AIC*c*	Δ AIC*c* w_i	β (95%CI)	
Field sparrow						
(Combined Model)						
S(~PBG)	2	491.34	0.00	0.28	-0.44 (-0.86 – -0.01)	
S(~VegHgt)	2	491.38	0.03	0.27	0.00 (-2.44 – 0.00)	
S(~VOR)	2	491.78	0.43	0.22	0.00 (-0.00 – 0.01)	
S(~PRE)	2	292.98	1.63	0.12	0.40 (-0.11 – 0.92)	
S(~1)*	1	493.51	2.17	0.09		
Field sparrow						
(*Post Hoc*)						
S(~VegHgt+PBG)	3	491.39	0.00	0.24	VegHgt: 0.00 (-0.00 – 0.00)	PBG: -0.32 (-0.77 – 0.12)
S(~VOR+PBG)	3	491.81	0.42	0.19	VOR: 0.00 (-0.00 – 0.01)	PBG: -0.32 (-0.78 – 0.13)
S(~NHgt+PBG)	3	492.33	0.94	0.15	NHgt: -0.00 (-0.01 – 0.00)	PBG: -0.46 (-0.89 – -0.38)
S(~Grass+PBG)	3	492.67	1.27	0.12	Grass: 0.00 (-0.00 – 0.00)	PBG: -0.37 (-0.82 – 0.07)
S(~Forb+PBG)	3	493.16	1.76	0.10	Forb: -0.00 (-0.01 – 0.00)	PBG: -0.46 (-0.90 – -0.02)
S(~Lit+PBG)	3	493.35	1.95	0.09	Lit: -0.00 (-0.00 – 0.00)	PBG: -0.43 (-0.87 – -0.00)

	S(~1)*	1	493.51	2.12	0.08		
	Indigo bunting						
	(Combined Model)						
	S(~1)*	1	140.51	0.00	0.16		
	S(~NHgt)	2	140.85	0.34	0.14		0.00 (-0.00 – 0.02)
	S(~VegHgt)	2	140.96	0.45	0.13		0.00 (-0.00 – 0.01)
	S(~BGAD)	2	141.11	0.60	0.12		-0.46 (-1.22 – 0.29)
	S(~Forb)	2	141.61	1.10	0.09		-0.00 (-0.01 – 0.00)
	S(~Grass)	2	142.24	1.73	0.07		0.00 (-0.01 – 0.02)
	Red-winged blackbird						
	(Combined Model)						
	S(~ROT)	2	87.99	0.00	0.28		-1.09 (-2.20 – 0.01)
	S(~DREC)	2	89.47	1.47	0.13		0.91 (-0.38 – 2.22)
	S(~1)*	1	89.62	1.63	0.12		
	S(~Grass)	2	90.60	2.61	0.07		0.00 (-0.00 – 0.02)
	Red-winged blackbird						
	(*Post Hoc*)						
	S(~VegHgt+ROT)	3	88.71	0.00	0.22	VegHgt: 0.00(-0.02 – 0.00)	ROT: -1.14 (-2.25 – -0.02)
	S(~1)*	1	89.62	0.91	0.14		
	S(~NHgt+ROT)	3	89.67	0.96	0.13	NHgt: 0.00 (-0.01 – 0.01)	ROT: -1.16 (-2.29 – -0.03)
	S(~Forb+ROT)	3	89.78	1.07	0.13	Forb: -0.00 (-0.02 – 0.01)	ROT: -1.13 (-2.25 – -0.00)
	S(~Lit+ROT)	3	89.86	1.15	0.12	Lit: 0.01 (-0.07 – 0.11)	ROT: -1.19 (-2.39 – 0.01)
	S(~Grass+ROT)	3	89.99	1.28	0.11	Grass: 0.00 (-0.01 – 0.02)	ROT: -1.03 (-2.29 – 0.22)
	S(~VOR+ROT)	3	89.99	1.28	0.11	VOR: -0.00 (-0.01 – 0.01)	ROT: -1.10 (-2.23 – 0.01)

K is the number of parameters for each model; VegHgt: vegetation height (cm); INBU: indigo bunting; RWBL: red-winged blackbird; BGAD and DREC (research sites); PBG: patch-burn grazing treatment, PRE: Pre-treatment, ROT: rotational grazed treatment; VegHgt: vegetation height (cm), Forb: % forb, Lit: litter depth (cm), Grass: % grass, VOR: visual obstruction reading, NHgt: nest height (cm), and * indicate null model

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Table 2 (on next page)

Resource selection function results from the top competing model analysis (ΔAIC*c* < 2.0) and the closest competing model for nest site selection for 3 selected grassland-associated bird species.

Nests were monitored at three Mid-South sites comparing ungrazed (2014 only) and rotationally and patch-burn grazed pastures, 2015 - 2016. Model selection was based on Akaike's information criteria for small sample sizes (AIC*c*), the difference between ranked models (ΔAIC*c*), and model weight or likelihood (Δ$AICcw_i$).

Table 2

Resource selection function results from the top competing model analysis (ΔAIC*c* < 2.0) and the closest competing model for nest site selection for 3 selected grassland-associated bird species. Nests were monitored at three Mid-South sites comparing ungrazed (2014 only) and rotationally and patch-burn grazed pastures, 2015 - 2016. Model selection was based on Akaike's information criteria for small sample sizes (AIC*c*), the difference between ranked models (ΔAIC*c*), and model weight or likelihood (ΔAICcw_i).

Models	K	AICc	Δ AICc	Δ AICcw_i	Variable: β (95%CI)
Field sparrow					
Use ~ VegHgt+Grass+BG+(1|Site)	5	737.38	0.00	0.96	VegHgt :0.05 (0.00-0.05) Grass: -0.02 (-0.03- -0.00) BG: -0.02 (-0.04- -0.00)
Use ~ VegHgt+Grass+Forb+(1|Site)	5	743.82	6.44	0.04	Forb:
Indigo bunting					
Use ~ VegHgt+Grass+Forb+BG+(1|Site)	6	135.88	0.00	1.00	VegHgt: 0.03 (0.02-0.04) Grass: -0.03 (-0.05- -0.01) Forb: 0.02 (0.00-0.04) BG: -0.08 (-0.16- -0.00)
Use ~ (1|Site)*	3	258.52	122.64	0.00	
Red-winged blackbird					
Use ~ VegHgt+Lit+(1|Site)	4	69.25	0.00	1.00	VegHgt: 3.55(2.27-4.82) Lit: -2.50 (-4.36- -0.64)
Use ~ PRE+(1|Site)	4	116.98	47.73	0.00	PRE: 23.68 (-4512.75-4560.12)

K is the number of parameters for each model; site was treated as a random effect for each model, (1|site); PRE: pre-treatment (2014); VegHgt: vegetation height (cm); Forb: % forb; Lit: litter depth (cm); Grass: % grass; BG: % bare ground; and * indicate null model.

Table 3(on next page)

Totals samples collected (*N*) and means (Standard Error) results for within-field vegetation variables for 3 research sites (BGAD, DREC, and QUICK) across Tennessee and Kentucky.

This data was used to ascertain the impacts of patch-burn grazing and rotational grazing management effects on grassland-associated bird nest-site selection and nest success from 2014 – 2016.

Table 3

Totals samples collected (*N*) and means (Standard Error) results for within-field vegetation variables for 3 research sites (BGAD, DREC, and QUICK) across Tennessee and Kentucky to ascertain the impacts of patch-burn grazing and rotational grazing management effects on grassland-associated bird nest-site selection and nest success from 2014 – 2016

Site	Year	*N*	Veg Height (cm)	(SE)	Litter Depth (cm)	(SE)	Grass (%)	(SE)	Forb (%)	(SE)	Litter (%)	(SE)	Bare Ground (%)	(SE)
BGAD	2014	576	76.30	(1.19)	0.91	(0.07)	83.36	(0.94)	14.27	(0.87)	0.61	(0.18)	0.55	(0.19)
BGAD	2015	576	29.12	(0.81)	2.20	(0.20)	46.43	(1.15)	14.32	(0.84)	31.97	(1.16)	6.85	(0.73)
BGAD	2016	576	45.28	(0.74)	0.19	(0.02)	63.81	(1.04)	8.18	(0.65)	19.46	(0.83)	8.19	(0.68)
DREC	2014	378	70.63	(1.99)	3.33	(0.21)	58.21	(1.76)	3.90	(0.56)	28.20	(1.48)	9.46	(1.01)
DREC	2015	288	41.94	(1.28)	3.46	(0.18)	47.22	(1.64)	1.58	(0.36)	41.23	(1.89)	9.98	(1.22)
DREC	2016	306	53.38	(0.87)	2.49	(0.09)	77.04	(0.01)	1.07	(0.00)	19.72	(0.01)	1.58	(0.00)
QUICK	2014	324	46.01	(1.07)	2.85	(0.22)	56.51	(1.61)	17.55	(1.04)	6.94	(0.58)	18.92	(1.46)
QUICK	2015	324	25.94	(1.05)	5.28	(0.31)	53.07	(1.56)	5.83	(0.68)	26.34	(1.36)	13.92	(1.34)
QUICK	2016	342	21.15	(0.77)	0.89	(0.07)	20.07	(0.87)	6.49	(0.58)	50.18	(1.61)	23.41	(1.49)

Table 4(on next page)

Means, standard deviation (SD), and coefficient of variation (CV) for vegetation height on rotational grazed, patch-burn grazed, and pre-treatment pastures at research sites (BGAD, DREC, and QUICK).

This data was used to assess the impacts of each method on grassland bird nest survival and nest-site selection in the Mid-South USA from 2014 – 2016.

Table 4

Means, standard deviation (SD), and coefficient of variation (CV) for vegetation height on rotational grazed, patch-burn grazed, and pre-treatment (2014*) pastures at 3 different research sites (BGAD, DREC, and QUICK) to assess the impacts of each method on grassland bird nest survival and nest-site selection in the Mid-South USA from 2014 – 2016.

Rotational Grazing (ROT)					Patch-Burn Grazing (PBG)				
Site	Year	Mean	SD	CV	Site	Year	Mean	SD	CV
BGAD	2014*	74.33	28.63	38.51	BGAD	2014*	77.70	28.62	36.83
	2015	29.08	19.33	66.47		2015	28.84	19.33	67.02
	2016	43.29	17.81	41.14		2016	44.53	17.87	40.13
DREC	2014*	64.85	38.92	60.01	DREC	2014*	67.76	38.74	57.17
	2015	38.92	21.72	55.80		2015	44.96	21.72	48.30
	2016	51.11	15.17	29.68		2016	55.80	15.17	27.18
QUICK	2014*	49.05	19.34	39.42	QUICK	2014*	42.32	19.34	45.69
	2015	27.74	18.91	68.16		2015	24.65	18.91	76.71
	2016	22.09	14.28	64.64		2016	20.65	14.28	69.15

Figure 1

Study site locations used to examine livestock impacts on grassland-associated birds

Study site location for patch-burn grazing and rotational grazing assessment of grassland-associated bird nest-site selection and nest success on native warm-season grasses pastures on 3 research sites in the Mid-South in Tennessee and Kentucky, USA from 2014 – 2016.

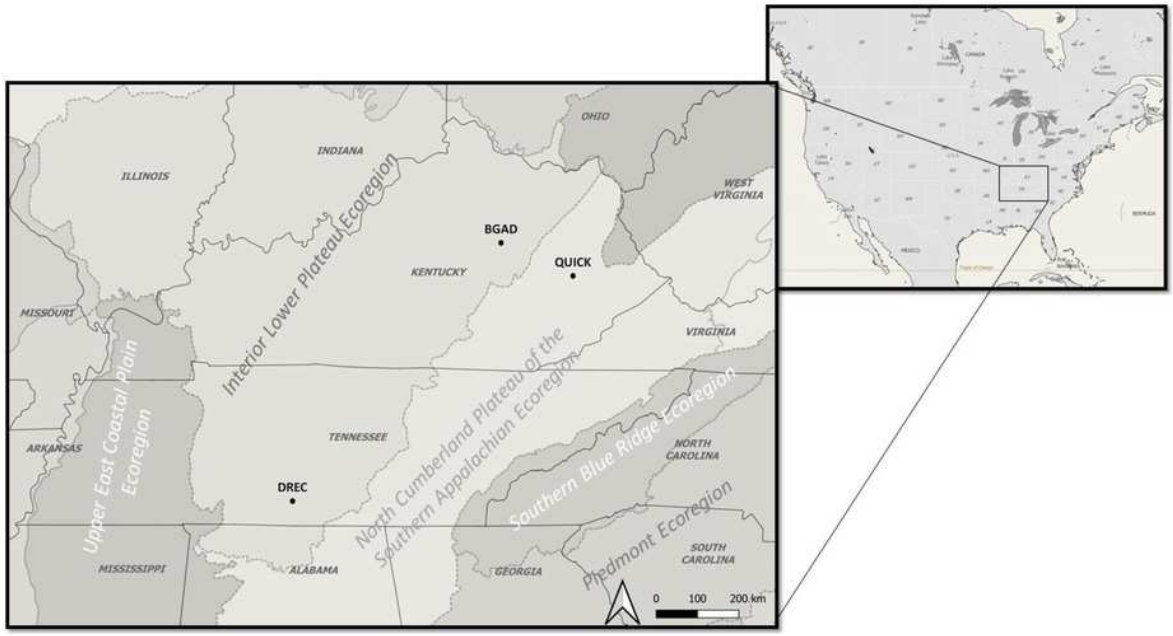


Figure 2

Daily survival rate (DSR) and nest success for field sparrow, red-winged blackbird, and indigo bunting comparing 2 grazing treatments and pre-treatment in the Mid-South, USA, 2014 – 2016.

Red-winged blackbird DSR for patch-burn grazed pastures were removed due to low sample size (N=2).

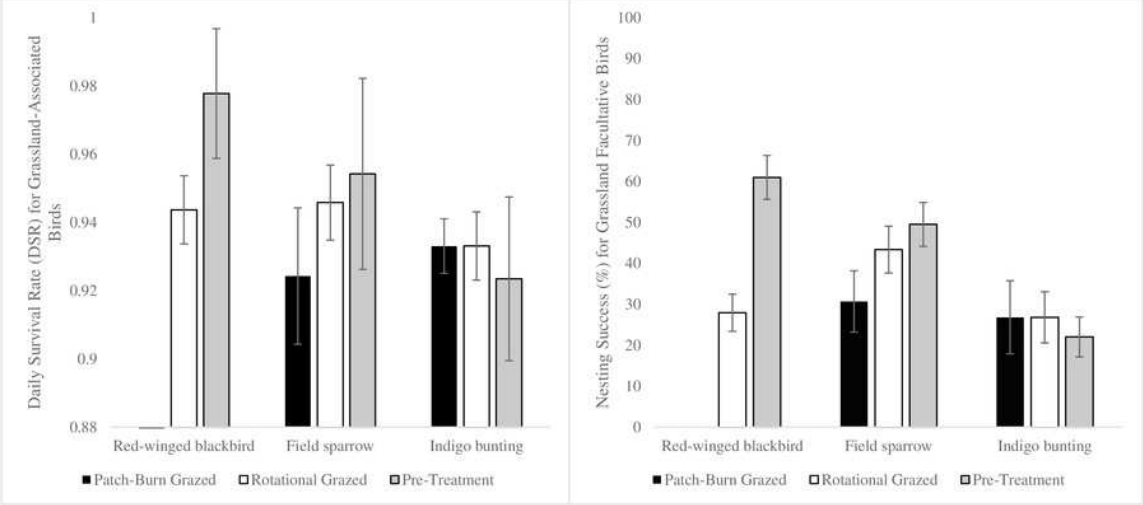
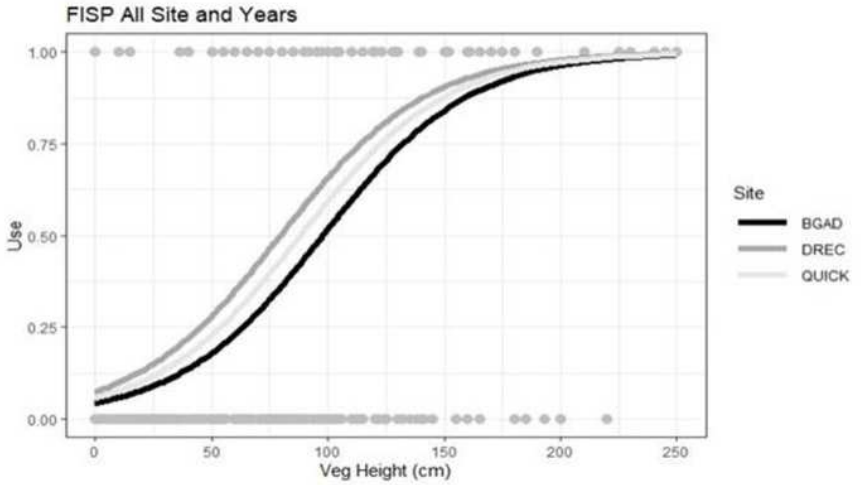
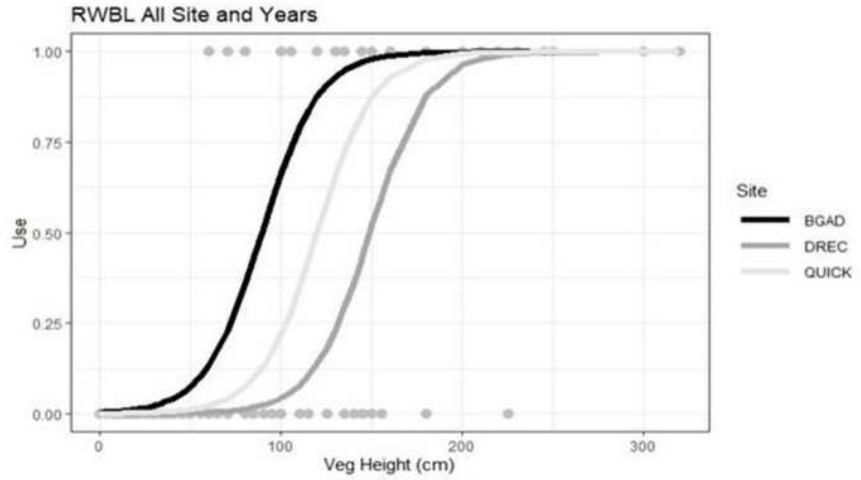


Figure 3

Resource selection function predicted model estimates for field sparrows (FISP), red-winged blackbird (RWBL), and indigo bunting (INBU) for the area used compared with vegetation height (cm)

From dataset for assess patch-burn grazing and rotational grazing between 3 research sites in Tennessee and Kentucky, USA from 2014 – 2016.


FISP All Site and Years
Use
1.00
0.75
0.50
0.25
0.00
0
50
100
150
200
250
Veg Height (cm)
Site
BGAD
DREC
QUICK


RWBL All Site and Years
Use
1.00
0.75
0.50
0.25
0.00
0
100
200
300
Veg Height (cm)
Site
BGAD
DREC
QUICK

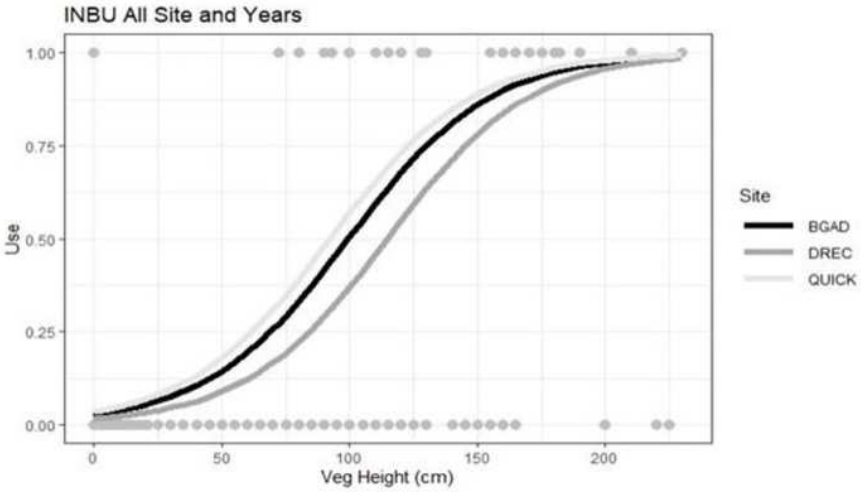

INBU All Site and Years
Use
1.00
0.75
0.50
0.25
0.00
0
50
100
150
200
Veg Height (cm)
Site
BGAD
DREC
QUICK

Figure 4

Mean vegetation height differences for rotational grazed (ROT) and patch-burn grazed (PBG) pastures during a 3 years (2014 – 2016).

Research was conducted at BGAD and QUICK in Kentucky, and DREC in Tennessee, USA.