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ARTICLE

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Breeding bird response to adaptive multi-paddock and continuous grazing practices in Southeastern United States

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Abstract

Grassland bird populations are declining steeply, reflecting the degradation and loss of native grassland habitats. To assess how grazing management affects declining grassland bird populations, we compared breeding avifaunal communities in adaptive multi-paddock (AMP) grazed and continuously grazed (CG) pastures in the Southeastern United States. AMP grazing involves alternating very short grazing periods at high animal densities with prolonged recovery periods across many small paddocks. Both the AMP and CG paddocks attracted obligate grassland birds during the breeding season; however, AMP-grazed paddocks supported significantly higher detection of four obligate grassland breeding bird species. We used distance sampling techniques to account for differences in detectability for each species. The resulting densities for the grassland guild and Eastern Meadowlark as a species both revealed significantly higher densities within the AMP versus CG paddocks. Despite significantly more unadjusted detections of confirmed breeding ecotonal species, such as Blue Grosbeak, Eastern Bluebird, Brown Thrasher, Yellow-breasted Chat, Eastern Towhee, Loggerhead Shrike, and Field Sparrow in AMP versus CG paddocks, no significant difference was found in the ecotonal guild after adjusting densities using effective detection radii. The CG paddocks supported fewer obligate grassland and ecotonal birds, with some exceptions (e.g., higher adjusted density of Eastern Bluebirds in CG) but supported comparable overall bird species richness. AMP grazing practices offer a viable strategy for increasing the diversity and abundance of obligate grassland and ecotonal breeding birds within existing cattle-grazed landscapes in the Southeastern United States.

KEYWORDS

AMP grazing, biodiversity, bird conservation, breeding bird density, grassland, grazing practice

INTRODUCTION

Grazing occurs on ~3.5 billion ha of the earth's surface. Healthy grasslands support human food supplies and ability of soils to fix and store carbon (modulating climate change) and improve overall soil health by affecting their ability to absorb and store clean water, cycle nutrients, and sustain biodiversity, wildlife habitats, and overall biosphere integrity (Daily, 1997; Kimble et al., 2007; Savory & Butterfield, 2016; Teague et al., 2016). Grazing allows effective management of healthy grasslands (Ahlering et al., 2020; Russell & Bisinger, 2015; Wei et al., 2022). Nevertheless, overgrazing (defined as grazing pressure that reduces ecosystem services) continues to occur across many landscapes, threatening these values (Teague et al., 2011).

Adaptive multi-paddock (AMP) grazing involves intense grazing for short periods followed by up to 160-day rest periods before the next intensive grazing event. Limiting livestock to feed only for short periods (0.5–2 days) followed by a minimum 45–60-day recovery period allows plants to regrow, increasing standing crop biomass and landscape spatial heterogeneity relative to those in continuously grazed (CG) pastures in the Southeastern United States (southeast, henceforth) (Wang et al., 2021). Similar responses have been documented in the northern and southern Great Plains (Hillenbrand et al., 2019; Kempema et al., 2023; Teague et al., 2011). The general term "rotational grazing" fails to adequately capture the specific nature and effects of AMP grazing management because it refers to various levels of stocking, grazing duration, and recovery periods while ignoring the number of paddocks, paddock size, and grazing intensity (Teague et al., 2011). Therefore, AMP grazing represents a narrow and specific type of rotational grazing that differs from other grazing types involving small sub-paddocks and short grazing periods.

Populations of grassland birds have declined significantly across the United States (Brennan & Kuvlesky, 2005; Chesser et al., 2019; Hoekstra et al., 2004; Rosenberg et al., 2019; Wilsey et al., 2019). Decline in livestock grazing in western North America is well documented, but the specific details of grazing practices have rarely been well defined (Bock, 2002; Ranellucci et al., 2012; Wuerthner & Matteson, 2002). Researchers have studied the effects of grazing on grassland birds (Ahlering & Merkord, 2016; Golding & Drietz, 2017; Kempema et al., 2023; Skagen et al., 2018; Wuerthner & Matteson, 2002); however, only a few have studied grassland bird associations in the southeast. Native grasslands cover less than 1% of the land they did historically (40.5 M ha; Southeast Grassland Initiative, 2019). This remnant cover continued to decline owing to fire suppression, landscape clearing, drainage by ditching and tiling followed by crop production, and planting of pine plantations into former grasslands. If these remnant covers are fallowed, they are quickly invaded by non-native plant species or succeed to brush and then forests (Apfelbaum & Haney, 2010; Saab et al., 1995; Samson et al., 2004). The remaining native grasslands in the southeast are small and fragmented (Recher, 2004; Zellweger-Fischer et al., 2018), although efforts to restore these habitats have begun to address these losses (Apfelbaum & Haney, 2012; Southeast Grassland Initiative, 2019). Therefore, non-native grasslands, such as grazing paddocks, are the dominant grasslands in the southeast.

In this study, we compared grassland bird communities in paired AMP and CG grasslands in the southeast using methods that control local conditions and allow direct comparison of breeding birds in both management practices. We hypothesized that shifts in grassland conditions under AMP grazing would increase grassland habitat quality because of structural diversity, which would be reflected in changes in the abundance (higher densities) and richness (more species) of birds relying on these cattle-grazed grasslands. Such effects would support the value of increasing AMP grazing to improve bird habitat conditions across large areas of grazing land.

METHODS

Farm selection

We surveyed birds and analyzed soil chemistry, genomes, vegetation composition, greenhouse gas fluxes, insect fauna, and water infiltration across five pairs of AMP and CG farms in the southeast (Table 1). Each pair was compared for outcomes from different grazing methods on sites otherwise similar in biophysical features and patterns of historic land management, using criteria from the study by Teague et al. (2011). Their proximity ensured that the paired farms had comparable soil, vegetation, and (previous) land management (Table 1). Physical characteristics were first determined via ArcGIS using free and available datasets, such as slope, aspect, topography, soil, geology, hydrology, and land cover. Three of the five paired farms were adjacent (shared a property line) and the other two were within <2 km of each other. We relied on visits, farmer interviews, and records of grazing management history at each farm to confirm grazing practices and land use history and to find in-the-field biophysical matches for landform, slope, aspect, and current and historical vegetation. Socioeconomic perspectives, beef production records, and recent land

TABLE 1 Farm management details for each farm and the area cattle had access to in 2018 by farm pair for adaptive multi-paddock (AMP) and continuous grazing (CG) farm pairs.

Farm pair	Farm location	Grazing practice	Livestock in study area	No. sub-paddocks	Avg. sub-paddock size (ha)	Grassland total paddock area (ha)	Stocking mass (kg/ha × 1000)	Graze period goal (days)	Recovery goal (days)	Years of current management	Land use history
1	Adolphus, Kentucky	AMP	Beef cattle, sheep	45	1.2	15	280	2	45	13	Tobacco, grain then grazing >30 years
		CG	Beef cattle	3	14	13	56	Not moved	No rest	6	Tobacco and grain crops
2	Sequatchie, Tennessee	AMP	Beef cattle	45	1	28	280	2	90	12	Row crops, hay, and grazing
		CG	Beef cattle	4	11	30	<56	135	82.5	>25	Row crops, hay, and grazing
3	Fort Payne, Alabama	AMP	Beef cattle	60	1.2	30	>280	1	50	29	Small grains
		CG	Beef cattle	2	16+	28	68	15	82.5	17	Small grains
4	Piedmont, Alabama	AMP	Beef cattle	60	0.4	40	>448	1	80	24	Cotton
		CG	Beef cattle	2	8	30	< 56	Not moved	No rest	>25	Cotton
5	Woodville, Mississippi	AMP	Beef cattle	70	1	20	>600	0.5	52.5	>10	Tobacco, grain then grazing >50 years
		CG	Beef cattle	7	12	16	<56	75	90	40	Tobacco, cotton, market garden, grains

management practices (e.g., fertilizer, overseeding, haying, and last time in annual production) information was available only if willingly shared by farmers. These collective efforts helped obtain paired AMP/CG sites that controlled for variables such as soil catena, type, texture, soil carbon, and other measurements between pairs (Mosier et al., 2021). The landscape surrounding these farms was also evaluated in terms of forest and grassland vegetation (e.g., Wang et al., 2021). On AMP farms, the land was divided into small sub-paddocks grazed until ~50% of the original standing grass cover remained before moving the cattle to the next paddock (requiring movement once or more daily or every couple of days). Each paddock was allowed rest for 45–60 days before being regrazed. On the CG farms, grazing continued year-round on fewer larger paddocks (Table 1).

Before data collection, the prerequisite for AMP treatment was at least 7 years of AMP grazing practice in the study fields. We recorded key operational details for all comparisons, including paddock and sub-paddock size and numbers, grazing duration, herd movement timing, post-grazing vegetation recovery period, and total livestock animal mass (a more precise estimator of foraging pressure than livestock density) (Table 1). This mass correlates well with the total forage consumption (Teague et al., 2011).

Study farms

North to south, the selected farms (Table 1) were located approximately 60 km south of Louisville, KY, 30 km east of Nashville, TN, near Ft Payne, AL, 5 km north of Jacksonville, AL, and 13 km south of Woodville, MS, at a north to south latitudinal distance of ~1078 km (670 mi). Regional grazing researchers and staff from USDA-NRCS, Nature Conservancy, and grazing associations helped us locate the AMP-grazed operations. CG farms were then selected based on the location of the AMP operations to ensure comparability and representativeness. We queried each farm using a detailed written survey to obtain information on grazing history and land management. The grazing history and practices were confirmed by R. Teague and A. Williams during farm visits.

The farms ranged from 100 to 200 ha with ~13–40 ha of grazed grassland in a forested landscape. A challenge in all farms was identifying grasslands uninterrupted by forest blocks, forested fence/hedge rows, or other habitat types (wetlands, ponds, livestock staging pens, etc.). We selected grassland paddocks that were regionally representative of the grasslands in the forested landscapes. Stratified random sampling was applied based on the landscape above biophysical conditions to ensure that the study sites represented the entire landscape. The study paddocks within each pair were selected to provide acreages comparable with those in the grazed grassland habitats. Although some farms were larger in acreage, our random selection of the predominant conditions between paired farms ensured scaled and comparable biophysical conditions.

Study layout

We used replicated, randomized, and nested sampling to estimate breeding bird use and vegetation in the soil catena shared between the AMP-CG farm pairs. At each farm, breeding birds were surveyed in two grazed grassland paddocks on the same soil catena. We also described the surrounding vegetation as (1) grassland: areas dominated entirely by graminoids and other herbaceous vegetation; (2) ecotonal habitat: supporting colonizing shrubs and tree saplings, often in the same grassland herbaceous plant species matrix; or (3) forested habitat: dominated by mature trees. Paired sites had comparable total farm acreage and total grazed paddock acreage, whereas the sub-paddocks varied in size as a function of grazing practices (Table 1).

Breeding bird surveys

Avian surveys followed the protocol reported by Reynolds et al. (1980), using unlimited distances and single observer point counts. Point counts continued for 10 min, binned at intervals of 0–3, 3–5, and 5–10 min. The two randomized sample points were separated by at least 300 m and plotted at least 150 m from the non-pastureland edges. The data used for the analysis were truncated by adding a distance limit during analysis so that only observations within 300 m of the observation point were included.

Two independent observers collectively surveyed each point four times annually (separated by at least 7 days) in May and June 2018 and 2019 to account for the breeding phenology of the target taxa, resulting in eight survey events spanning 20 points. All surveys were completed within approximately 30 min before sunrise to 4 h after sunrise under suitable meteorological conditions for collecting breeding bird observations as defined in section 6 of USGS (2024). We recorded temperature (in degrees Fahrenheit), wind speed (Beaufort wind scale), wind direction (cardinal direction), cloud cover (binned %), and precipitation (in millimeters) at the start of each survey. Surveys were not performed during inclement weather such as high winds or active precipitation. The bird nomenclature and taxonomic order followed the guidelines of American Ornithological Society (Chesser et al., 2019).

Each observation included species, behavior, horizontal distance, direction from the observer, and abundance. Behavioral categories included perching, flying, foraging, territorial singing, chip notes/calls, aggression, distraction display, fecal sac carrying, and nesting material carrying state-specific breeding bird codes (Breeding Bird Atlas Explorer, 2023; Haggerty, 2009; Schneider et al., 2010; Twedt & Pardiek, 2017). For birds in flight, we estimated the magnetic direction of flight and the height above the ground. These practices allowed us to infer the use of the study area by the birds (confirmed breeding, probable breeding, possible breeding, and visitors). Repeated songsters (singing territorially) were removed from the data collection (Buckland et al., 1993) after their first observation (one data line per bird). Confirmed territoriality was determined through repeated surveys to detect the same songster.

Effective detection radii and adjusted abundances

All statistical analyses were performed using R (R Core Team, 2023). The effective detection radii (EDR) was derived using Rdistance (McDonald et al., 2023) for the 0–300-m subset to determine (1) the distance at which the likelihood of detection dropped by approximately half by species and (2) any difference in detectability between AMP and CG fields. The EDR for each species was then used with unadjusted detection data to estimate the density by species per treatment, following the methods described by Farnsworth et al. (2005).

Statistical analyses of bird species and guilds

Data were entered into Microsoft Excel for QA/QC and then imported into R Version 4.3.1 for review and statistical analyses. We analyzed the effects of grazing on bird species richness, unadjusted detections per point, EDR, and adjusted bird abundance. Bird species richness was calculated as the total count of unique bird species per breeding habitat guild within each point averaged over time. Guilds were established based on breeding habitat preferences per species (e.g., grassland, forest, ecotonal, and generalist) as determined in Billerman et al. (2022). Unadjusted detections per point are given as the total count of birds in each guild within each point averaged over time. The EDR and adjusted abundances for each species were determined for each site and averaged across all sites.

We modeled the effect of AMP and CG grazing on unadjusted bird species detection per point in each guild using generalized mixed-effects models, assuming negative binomial distributions and including farm pairs as random effects (glmer.nb in R). Adjusted abundances were analyzed similarly but assumed a gamma distribution due to continuous (non-integer) data. Individual species were analyzed using the same tests. The Wilcoxon signed-rank test (wilcox.test in R) was used to assess whether the bird species richness of the AMP and CG from the matched (paired) samples was significantly different for each guild (Tate & Clelland, 1957; Wilcoxon, 1945). EDR met the assumptions of ANOVA; therefore, one-way ANOVA (aov in R) was used to compare the detectability of each species and guild overall.

Rank abundances were calculated based on unadjusted counts for all species within the study area, separated by grazing type. The resulting rank abundance was plotted against the relative proportion of the total dataset for each species. A subset of nine obligate grassland species and eight ecotonal species were selected for population density comparisons by grazing method.

RESULTS

Relative detection abundance and species richness across sites

In total, we recorded 3573 individual birds, representing 110 bird species, across the 10 farms in the southeast in 2018 and 2019 (Table 2). We observed 2055 individuals of 97 species at AMP sites and 1518 individuals of 93 species at CG sites. Species were binned to habitat guilds (obligate grassland, ecotonal, forest, wetland/waterbird, and generalist), revealing 11 obligate grassland species, 31 ecotonal species, 46 forest species, 12 generalist species, and 10 wetland/waterbird species across all sites. Surveys from AMP fields revealed 11 obligate grassland species, 29 ecotonal species, 38 forest species, 11 generalist species, and 9 wetland/waterbird species. Surveys from CG fields revealed 8 obligate grassland species, 25 ecotonal species, 42 forest species, 11 generalist species, and 8 wetland/waterbird species.

Paddock-specific detection and species richness across sites

After removing all observations beyond 300 m, we recorded 3301 individual birds, representing 110 bird species across the 10 farms (Table 2). We observed 1859 individuals of 93 species at AMP sites and 1442 individuals of 93 species at CG sites. Of these, we observed 24 and 9 confirmed breeding bird species in AMP and CG paddocks, respectively. Breeding birds comprised 6 grassland obligates, 15 ecotonal, 0 forest, 2 generalists, and 1 wetland/waterbird species.

Density and species richness by guild per grazing type

Across all farms, 3–7 obligate grassland bird species occurred in each AMP pasture (Figure 1). A significantly higher richness of obligate grassland species was observed in AMP pastures (mean $= 5.3$, SD $= 2.03$) than in CG pastures (mean $= 3.1$, SD $= 1.5$) ($z = 0.65$, $p = 0.041$). At four pairs of sites, AMP pastures showed higher (1.4–6 times) grassland bird richness than their CG counterparts. The ecotonal bird species richness did not differ significantly between AMP and CG pastures ($z = 0.33$, $p = 0.14$). However, in all AMP pastures, ecotonal species richness was equal to (in two pairs) or higher (1.3–2.1 times) than that in CG pastures. Within the forest, generalist, and wetland/waterbird guilds, species richness differed between grazing types at each pairing but not significantly and did not favor either AMP or CG.

Selected bird guild comparisons

Grassland obligate and ecotonal guilds were selected for evaluation, as these were the primary and secondary in-field habitats, respectively, within both treatment types and comprised >98% of all confirmed breeding bird observations.

Grassland obligate guild

A subset of breeding obligate grassland (Figure 1a) and ecotonal bird species (Figure 1b) was compared using grazing practices based on the frequency of observations.

TABLE 2 List of all birds detected from survey points (unlimited distance).

Common name	Taxonomic binomial	AMP	CG	Nesting habitat guild
Canada Goose	*Branta canadensis*	0.923	0.077	Wetland/waterbird
Wood Duck	*Aix sponsa*	0.000	1.000	Wetland/waterbird
Northern Bobwhite	*Colinus virginianus*	1.000[a]	0.000	Ecotonal species
Wild Turkey	*Meleagris gallopavo*	0.529	0.471	Forest
Eurasian Collared-Dove	*Streptopelia decaocto*	1.000	0.000	Generalist
Mourning Dove	*Zenaida macroura*	0.583[a]	0.417	Generalist
Yellow-billed Cuckoo	*Coccyzus americanus*	0.500	0.500	Forest
Black-billed Cuckoo	*Coccyzus erythropthalmus*	0.667	0.333	Forest
Common Nighthawk	*Chordeiles minor*	0.000	1.000	Ecotonal species
Chuck-will's-widow	*Antrostomus carolinensis*	1.000	0.000	Ecotonal species
Eastern Whip-poor-will	*Antrostomus vociferus*	1.000	0.000	Ecotonal species
Chimney Swift	*Chaetura pelagica*	0.091	0.909	Forest
Ruby-throated Hummingbird	*Archilochus colubris*	0.200	0.800	Forest
Killdeer	*Charadrius vociferus*	0.666[a]	0.333[a]	Grassland obligate
Double-crested Cormorant	*Phalacrocorax auritus*	0.000	1.000	Wetland/waterbird
Great Blue Heron	*Ardea herodias*	0.750	0.250	Wetland/waterbird
Great Egret	*Ardea alba*	1.000	0.000	Wetland/waterbird
Snowy Egret	*Egretta thula*	0.333	0.667	Wetland/waterbird
Little Blue Heron	*Egretta caerulea*	1.000	0.000	Wetland/waterbird
Cattle Egret	*Bubulcus ibis*	0.100	0.900	Wetland/waterbird
Green Heron	*Butorides virescens*	0.750	0.250	Wetland/waterbird
Black Vulture	*Coragyps atratus*	0.462	0.538	Generalist
Turkey Vulture	*Cathartes aura*	0.333	0.667	Forest
Cooper's Hawk	*Accipiter cooperii*	0.250	0.750	Forest
Mississippi Kite	*Ictinia mississippiensis*	0.154	0.846	Forest
Red-shouldered Hawk	*Buteo lineatus*	0.520	0.480	Forest
Red-tailed Hawk	*Buteo jamaicensis*	0.636	0.364	Forest
Great Horned Owl	*Bubo virginianus*	0.000	1.000	Forest
Barred Owl	*Strix varia*	1.000	0.000	Forest
Red-headed Woodpecker	*Melanerpes erythrocephalus*	0.636[a]	0.364	Ecotonal species
Red-bellied Woodpecker	*Melanerpes carolinus*	0.456	0.544	Forest
Downy Woodpecker	*Dryobates pubescens*	0.280	0.720	Forest
Hairy Woodpecker	*Dryobates villosus*	0.500	0.500	Forest
Northern Flicker	*Colaptes auratus*	0.467	0.533	Forest
Pileated Woodpecker	*Dryocopus pileatus*	0.364	0.636	Forest
American Kestrel	*Falco sparverius*	0.200[a]	0.800	Grassland obligate
Great Crested Flycatcher	*Myiarchus crinitus*	0.538	0.462	Ecotonal species
Eastern Kingbird	*Tyrannus tyrannus*	0.456[a]	0.543[a]	Ecotonal species
Eastern Wood-Pewee	*Contopus virens*	0.375	0.625	Forest
Least Flycatcher	*Empidonax minimus*	1.000	0.000	Forest
Eastern Phoebe	*Sayornis phoebe*	0.467	0.533	Ecotonal species
Loggerhead Shrike	*Lanius ludovicianus*	1.000[a]	0.000	Ecotonal species
White-eyed Vireo	*Vireo griseus*	0.659	0.341	Ecotonal species

TABLE 2 (Continued)

Common name	Taxonomic binomial	AMP	CG	Nesting habitat guild
Yellow-throated Vireo	*Vireo flavifrons*	0.571	0.429	Forest
Blue-headed Vireo	*Vireo solitarius*	0.000	1.000	Forest
Warbling Vireo	*Vireo gilvus*	0.500	0.500	Forest
Red-eyed Vireo	*Vireo olivaceus*	0.531	0.469	Forest
Blue Jay	*Cyanocitta cristata*	0.500	0.500	Forest
American Crow	*Corvus brachyrhynchos*	0.463	0.537	Generalist
Horned Lark	*Eremophila alpestris*	1.000	0.000	Grassland obligate
Bank Swallow	*Riparia riparia*	1.000	0.000	Ecotonal species
Tree Swallow	*Tachycineta bicolor*	0.754	0.246	Ecotonal species
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	0.500	0.500	Ecotonal species
Purple Martin	*Progne subis*	0.671[a]	0.328[a]	Ecotonal species
Barn Swallow	*Hirundo rustica*	0.632	0.368	Ecotonal species
Carolina Chickadee	*Poecile carolinensis*	0.158	0.842	Forest
Tufted Titmouse	*Baeolophus bicolor*	0.402	0.598	Forest
White-breasted Nuthatch	*Sitta carolinensis*	0.444	0.556	Forest
House Wren	*Troglodytes aedon*	0.000	1.000	Generalist
Sedge Wren	*Cistothorus platensis*	1.000	0.000	Grassland obligate
Carolina Wren	*Thryothorus ludovicianus*	0.476	0.524	Generalist
Blue-gray Gnatcatcher	*Polioptila caerulea*	0.421	0.579	Forest
Eastern Bluebird	*Sialia sialis*	0.669[a]	0.331[a]	Ecotonal species
Wood Thrush	*Hylocichla mustelina*	0.000	1.000	Forest
American Robin	*Turdus migratorius*	0.357	0.643	Generalist
Gray Catbird	*Dumetella carolinensis*	0.667	0.333	Forest
Brown Thrasher	*Toxostoma rufum*	0.676[a]	0.324	Ecotonal species
Northern Mockingbird	*Mimus polyglottos*	0.490	0.510	Forest
European Starling	*Sturnus vulgaris*	0.481	0.519	Generalist
Cedar Waxwing	*Bombycilla cedrorum*	1.000	0.000	Forest
House Sparrow	*Passer domesticus*	0.059	0.941	Generalist
House Finch	*Haemorhous mexicanus*	0.429	0.571	Generalist
American Goldfinch	*Spinus tristis*	0.691	0.309	Ecotonal species
Grasshopper Sparrow	*Ammodramus savannarum*	0.750[a]	0.250	Grassland obligate
Chipping Sparrow	*Spizella passerina*	0.353	0.647	Ecotonal species
Field Sparrow	*Spizella pusilla*	0.652[a]	0.347	Ecotonal species
Vesper Sparrow	*Pooecetes gramineus*	1.000	0.000	Grassland obligate
Henslow's Sparrow	*Centronyx henslowii*	1.000	0.000	Grassland obligate
Savannah Sparrow	*Passerculus sandwichensis*	0.827[a]	0.173	Grassland obligate
Song Sparrow	*Melospiza melodia*	0.393	0.607	Ecotonal species
Eastern Towhee	*Pipilo erythrophthalmus*	0.593[a]	0.407[a]	Ecotonal species
Yellow-breasted Chat	*Icteria virens*	0.683[a]	0.317[a]	Ecotonal species
Bobolink	*Dolichonyx oryzivorus*	0.286	0.714	Grassland obligate
Eastern Meadowlark	*Sturnella magna*	0.757[a]	0.243[a]	Grassland obligate
Orchard Oriole	*Icterus spurius*	0.641[a]	0.359	Ecotonal species

(Continues)

TABLE 2 (Continued)

Common name	Taxonomic binomial	AMP	CG	Nesting habitat guild
Baltimore Oriole	*Icterus galbula*	0.700	0.300	Forest
Red-winged Blackbird	*Agelaius phoeniceus*	0.748[a]	0.252	Wetland/waterbird
Brown-headed Cowbird	*Molothrus ater*	0.810[a]	0.190[a]	Generalist
Common Grackle	*Quiscalus quiscula*	0.563	0.438	Generalist
Ovenbird	*Seiurus aurocapilla*	0.000	1.000	Forest
Northern Waterthrush	*Parkesia noveboracensis*	1.000	0.000	Forest
Blue-winged Warbler	*Vermivora cyanoptera*	1.000	0.000	Ecotonal species
Kentucky Warbler	*Geothlypis formosa*	0.000	1.000	Ecotonal species
Common Yellowthroat	*Geothlypis trichas*	0.667[a]	0.333	Ecotonal species
Hooded Warbler	*Setophaga citrina*	0.167	0.833	Forest
American Redstart	*Setophaga ruticilla*	0.571	0.429	Forest
Cerulean Warbler	*Setophaga cerulea*	0.000	1.000	Forest
Northern Parula	*Setophaga americana*	0.000	1.000	Forest
Magnolia Warbler	*Setophaga magnolia*	0.600	0.400	Forest
Yellow Warbler	*Setophaga petechia*	0.000	1.000	Forest
Chestnut-sided Warbler	*Setophaga pensylvanica*	0.000	1.000	Forest
Prairie Warbler	*Setophaga discolor*	0.167	0.833	Ecotonal species
Canada Warbler	*Cardellina canadensis*	0.500	0.500	Forest
Scarlet Tanager	*Piranga olivacea*	0.600	0.400	Forest
Summer Tanager	*Piranga rubra*	0.381[a]	0.619	Ecotonal species
Northern Cardinal	*Cardinalis cardinalis*	0.460	0.540	Forest
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0.333	0.667	Forest
Blue Grosbeak	*Passerina caerulea*	0.873[a]	0.127	Ecotonal species
Indigo Bunting	*Passerina cyanea*	0.545[a]	0.454[a]	Ecotonal species
Dickcissel	*Spiza americana*	0.905[a]	0.095	Grassland obligate

Note: Columns denote percentage of observations by species per grazing practice. Breeding bird observation codes are the highest breeding status within each grazing practice as determined by behavioral observations. Asterisk denotes all confirmed breeding bird species by treatment type. Species are listed in taxonomic order.

Abbreviations: AMP, adaptive multi-paddock; CG, continuous grazing.

[a]Confirmed breeding.

Nonbreeders of the region and species with fewer than 20 detections were excluded from the analysis. Four of the five selected obligate grassland birds were significantly more abundant in AMP paddocks than in CG paddocks based on unadjusted counts. More than three-quarters (76.7%) of all obligate grassland bird observations in this study were within AMP-grazed paddocks.

After adjusting for detectability, Eastern Meadowlarks were significantly more abundant in AMP paddocks (Figure 1c). All five species had higher mean adjusted abundances in AMP paddocks; however, due to overdispersion (variances were greater than means), the statistical power was lower in these tests. This effect was most evident in the Grasshopper Sparrows and Savannah Sparrows because of their relatively low detectability. Thus, there was an apparent difference in the adjusted abundance of these species, despite statistical non-significance. We could not calculate the variance for EDR and adjust the abundance for Dickcissels in CG pastures because of inadequate observations (two CG farms with one observation each); therefore, no significance test was performed.

Ecotonal guild

The six most frequently observed ecotonal species during the study were selected for the analysis. Three of the six ecotonal bird species showed significantly higher detection in AMP than in CG (Figure 1a). Over half (63.1%) of

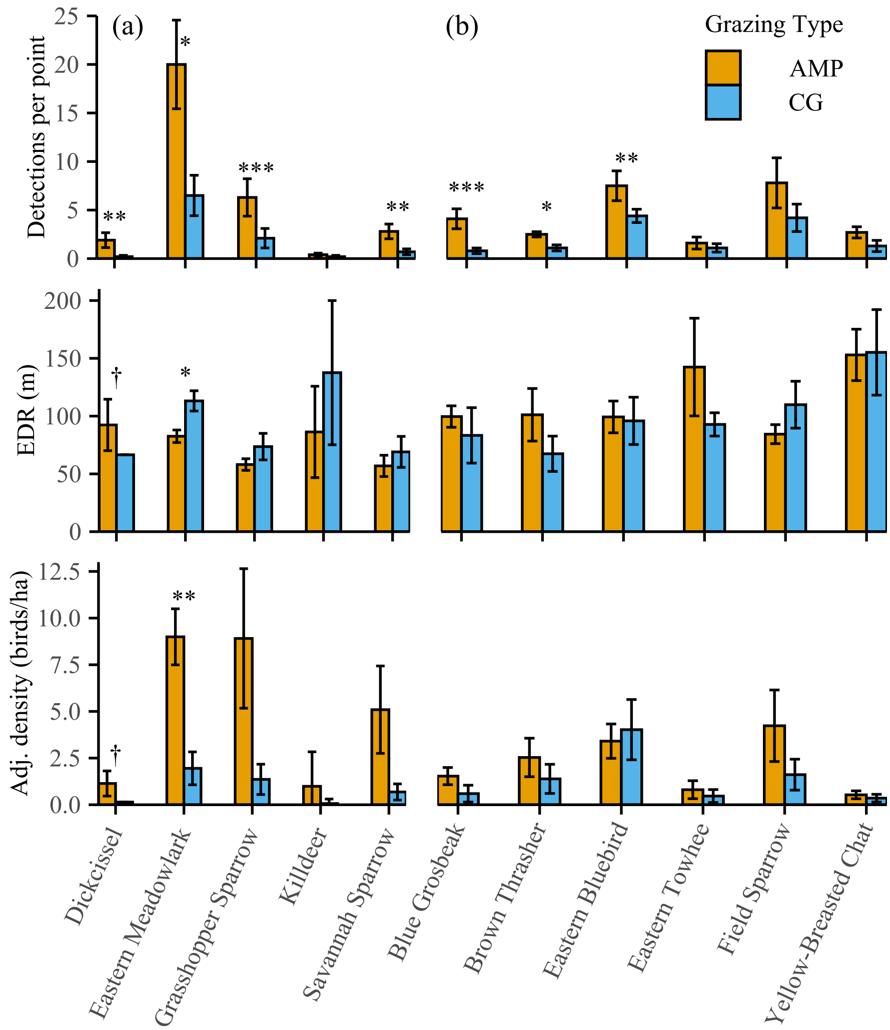

FIGURE 1 Comparisons of five grassland obligate (a) and six ecotonal (b) bird species within adaptive multi-paddock (AMP) and continuous grazing (CG) farms (mean ± SE). (Top) Mean number of detected birds per observation point ($n = 20$). (Middle) Effective detection radius (EDR) estimates for each species. (Bottom) Estimated density of each species (estimated using Rdistance in R). Significant differences are denoted by asterisks (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). †There were inadequate observations within CG to calculate the SE on EDR for Dickcissel, so no significance test was performed.

all the ecotonal birds were observed within AMP paddocks. After adjusting for abundances using EDRs, the differences between AMP and CG were nonsignificant for all selected ecotonal species, and the difference in means was much smaller or even reversed (for the Eastern Bluebird).

Rank abundance for grassland and ecotonal guilds

The rank abundances of eight obligate grassland bird species were higher in AMP than in CG pastures (Figure 2a). The sole exception was Bobolink, an uncommon breeder in this region. This comparison included three species removed from other analyses as nonbreeding/visiting species (Sedge Wren, Henslow's Sparrow, and Vesper Sparrow) in AMP. These visitors were not observed in any CG paddocks. The two remaining obligate grassland species (American Kestrel and Horned Lark) were removed from all comparisons because of a paucity of observations for treatment type.

All eight selected ecotonal species had higher rank abundances in AMP pastures than in CG pastures (Figure 2b). Loggerhead Shrikes and Northern Bobwhites were confirmed to be breeding in multiple AMP paddocks but were not observed in any CG paddock.

Avifaunal response to grazing method

Grassland bird species richness was significantly higher in AMP pastures than in CG pastures but did not differ for other guilds (Figure 3a). The overall number of

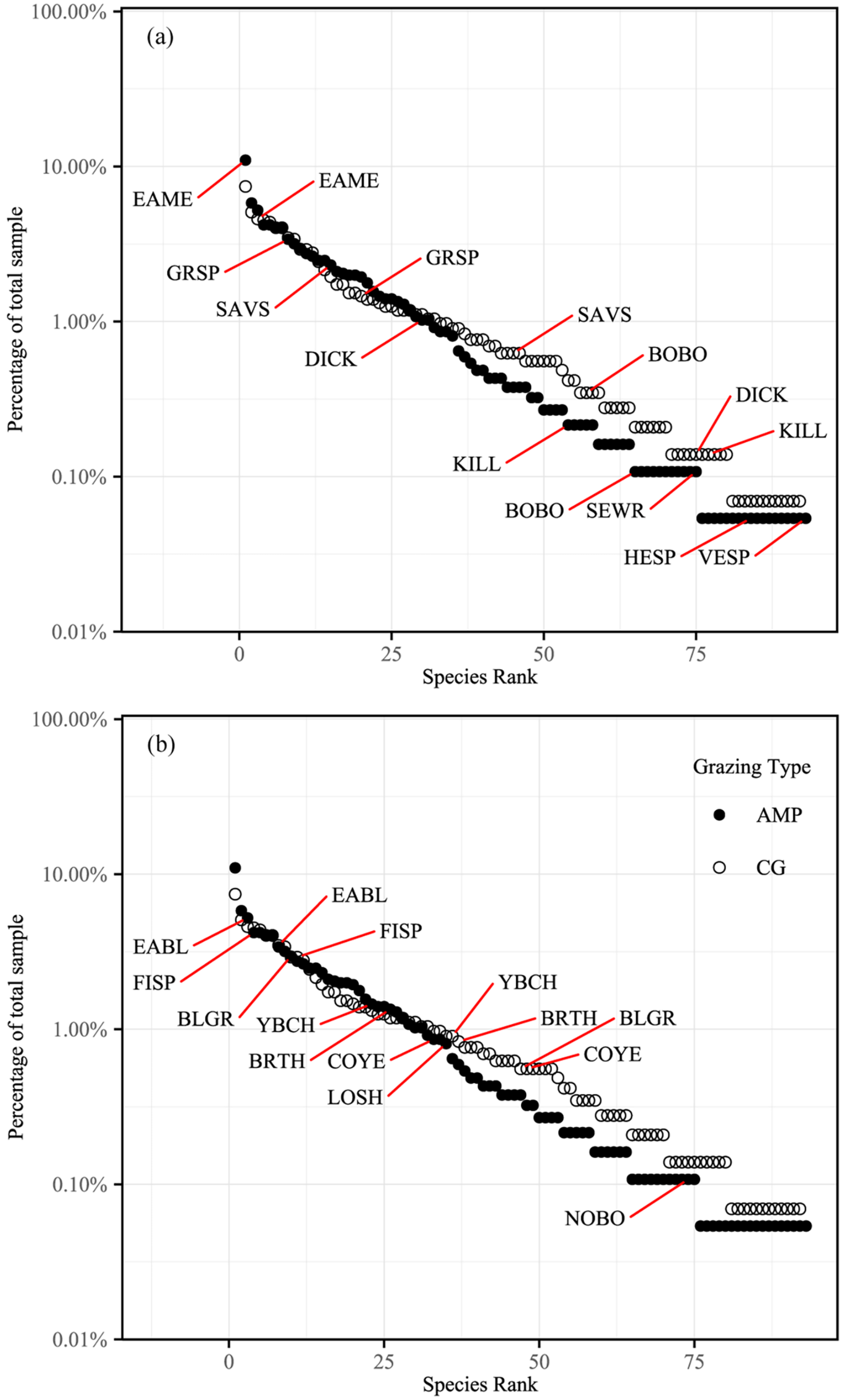

FIGURE 2 Rank abundance of bird species within five adaptive multi-paddock (AMP) and five continuous grazing (CG) farms. Species are indicated as points according to their abundance rank (x axis) and the proportion of all observations that species represents (y axis). All species are represented in both graphs with a subset of grassland obligates indicated in (a) and a subset of ecotonal birds indicated in (b). Species above and to the right of the data points indicate the rank abundance within CG units and species below and to the left of the data points reflect AMP units. Species not listed for CG were not detected in any CG units. BLGR, Blue Grosbeak; BOBO, Bobolink; BRTH, Brown Thrasher; COYE, Common Yellowthroat; DICK, Dickcissel; EABL, Eastern Bluebird; EAME, Eastern Meadowlark; FISP, Field Sparrow; GRSP, Grasshopper Sparrow; HESP, Henslow's Sparrow; KILL, Killdeer; LOSH, Loggerhead Shrike; NOBO, Northern Bobwhite; SAVS, Savannah Sparrow; SEWR, Sedge Wren; VESP, Vesper Sparrow; YBCH, Yellow-breasted Chat.

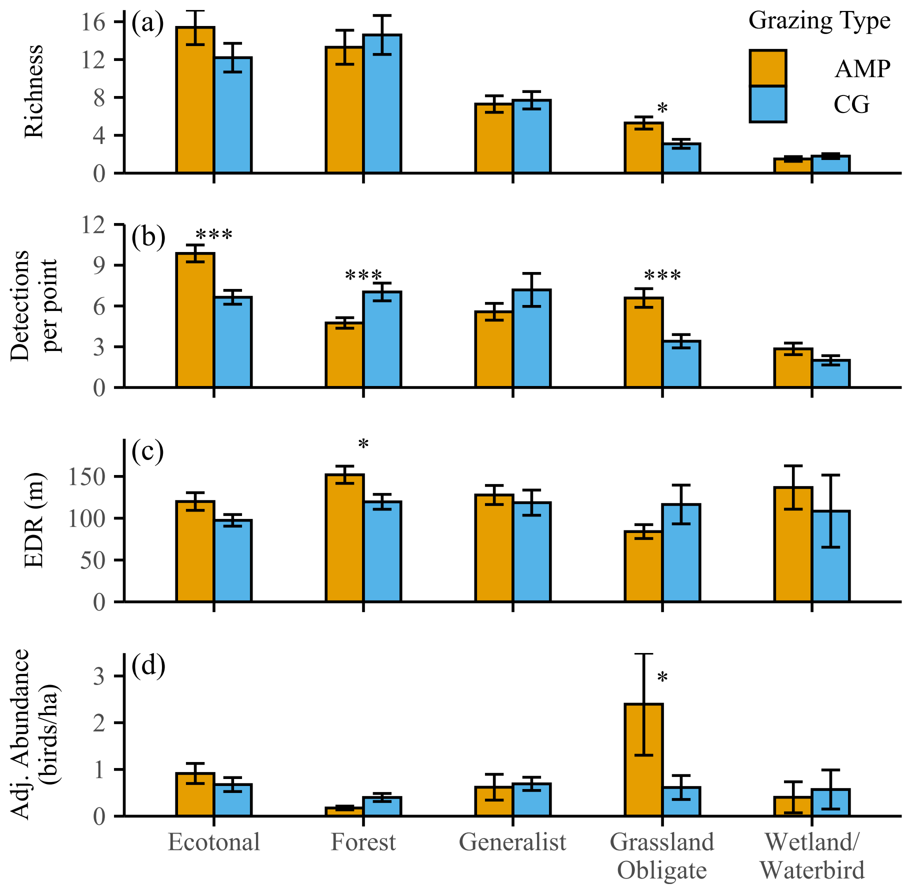

FIGURE 3 Summary values for two points at each of five adaptive multi-paddock (AMP) and five continuous grazing (CG) farms ($n = 20$) (mean ± SE). (a) Species richness of each guild, averaged for each sampling point; (b) unadjusted count of birds, averaged over time for each sampling point; (c) mean effective detection radius (EDR) for all species within the given guild; and (d) adjusted abundances of each guild. Unadjusted counts were analyzed using a Poisson generalized mixed-effects model; adjusted abundances were analyzed using a gamma generalized linear model; EDR values were analyzed using ANOVA; and differences between grazing types in species richness were tested using a Wilcoxon signed-ranks test. Significant differences are denoted by asterisk (*$p < 0.05$, ***$p < 0.001$).

unadjusted observations of grassland and ecotonal species was significantly higher in AMP paddocks than in CG paddocks. In contrast, the opposite was true for forest bird species (Figure 3b). Notably, the EDR of forest bird species differed significantly between the two grazing types (Figure 3c). After calculating the adjusted abundances, only grassland obligate guild density differed significantly between the two grazing types (Figure 3d).

DISCUSSION

Target breeding bird populations

Five confirmed breeding obligate grassland species had sufficient data from the 0–300-m subset to determine the adjusted densities by treatment using EDR. Except for Eastern Meadowlark ($p < 0.01$), adjusted densities did not differ between AMP and CG. Despite lack of significance in the other four, the effect of adjusting for density favored AMP over CG for all obligate grassland birds. The same analysis revealed six ecotonal species with sufficient data. None of the six ecotonal species differed in densities between treatments. These findings are further supported by an abundance of confirmed breeding bird observations (e.g., carrying food, carrying fecal sacs, begging young, occupied nests, and fledged young) within all (five of five) AMP fields, no confirmed breeding bird behaviors documented in most (three of five) CG fields, and very few confirmed breeding observations in the remaining (two of five) CG fields for grassland birds. We did not conduct systematic nest searches or fledging success studies. Therefore, we do not know the role of AMP or CG grazing in bird populations as a source or sink; however, these behavioral observations strongly suggest that AMP is important for breeding grassland birds in this region.

Detections (unadjusted) of grassland bird species within the 0–300-m dataset were significantly higher in

AMP for four of the five grassland species (Savannah Sparrow, Grasshopper Sparrow, Dickcissel, and Eastern Meadowlark) and three of the six ecotonal species (Blue Grosbeak, Brown Thrasher, and Eastern Bluebird). However, when applying EDR to Eastern Bluebirds, the adjusted density was higher in the CG because bluebird observations in the AMP were more distant from the observation points when compared with the CG. We also recorded late spring migratory grassland birds, such as Sedge Wren, Bobolink, Henslow's Sparrow, and Vesper Sparrow in AMP fields in low numbers. Of these four grassland migrants, one species (Bobolink) was observed in a CG field set aside for haying and therefore had rest and tall grass in the spring months before the hay bale harvest (anomalous in CG practices). The EDR for forest bird species differed significantly between the two grazing types. We suspect this is a landscape effect, where more parcels adjacent to CG farms were forested than at AMP sites (thus increasing the likelihood of encountering forest birds from CG points). No other EDR value was significantly different according to grazing type.

This study strongly suggests that AMP grazing practices can be part of a conservation solution for the breeding grassland bird population decline in the southeast. Despite these farms being in the same landscape (sometimes adjacent parcels) and over identical soil catenas, AMP-grazed paddocks attracted and sustained a more abundant and diverse obligate grassland breeding bird community. As the most imperiled habitat guild in North America (Rosenberg et al., 2019), this has significant and immediate implications for conservation management of grasslands.

Vegetation differences by grazing practice

Zellweger-Fischer et al. (2018) reported lower bird species richness and abundance in larger CG paddocks and hayed fields and, inversely, higher diversity in intensely grazed, smaller paddocks, and fields with greater retained plant species richness and vegetation structural diversity. Apfelbaum et al. (2022) revealed that AMP-grazed paddocks in this particular study had significantly higher standing crop of vegetation biomass compared with CG paddocks. Concurrently, we found richness and abundance of obligate grassland breeding birds were significantly higher in AMP-grazed paddocks than in the CG paddocks. This is consistent with previous studies showing that vegetation structural diversity is positively correlated with increasing bird species richness (Ahlering & Merkord, 2016; Fisher & Davis, 2010; Johnson, 2007; Zellweger-Fischer et al., 2018) and declining grassland bird populations where grassland habitat and structure have been modified by haying or overgrazing (Ahlering & Merkord, 2016; Askins et al., 2007; Willson, 1974).

While we did not study nest success or fecundity, Frey et al. (2008) documented that the nest success of Dickcissels and Eastern Meadowlarks depends on vertical plant structure and that Grasshopper Sparrow nest success increases with increased litter and grass cover. These are documented structural characteristics of AMP-grazed pastures in this study (Apfelbaum et al., 2022). The effects of CG grazing on vegetation, as measured by Apfelbaum et al. (2022), confirmed an increase in homogeneous, low-growing, and often mowed lawn-like vegetation growth and habitats. Grasshopper and Savannah Sparrow abundances were greater in AMP pastures with higher average percentage of fine litter, lower levels of percentage of bare soil, and significantly higher standing crop biomass compared with those in CG pastures (Apfelbaum et al., 2022).

Overgrazing, a common symptom of CG management, can prevent plant flowering and seed maturity, reduce plant cover and biomass, and result in the loss of soil characteristics critical for supporting vegetation. Bird species requiring herbaceous plant cover for nesting were either less abundant or absent in the CG fields. Furthermore, grassland birds require insect-based proteins to meet the energetic demands of breeding and brood rearing. The negative effects on vegetation under overgrazing conditions may also attract fewer insects (Schmid et al., 2021). Greater insect species richness has been documented in habitats experiencing intermediate disturbances (Szentkiralyi & Kozar, 1991), which we believe adequately defines the disturbance patterns resulting from AMP compared with CG grazing.

Additional benefits of working lands as conservation lands using AMP grazing

This study found that AMP grazing, defined by higher total animal mass and brief but intensive grazing followed by at least 45 days of recovery, improves breeding habitats on working lands for grassland birds because of significantly higher richness and abundance of grassland obligate species in AMP-grazed paddocks than in CG paddocks in the Southeastern United States. Our interviews with livestock producers using AMP grazing suggested that they can reliably grow more available grass, improve livestock health, reduce veterinary costs, reduce inputs, and realize other benefits, as found in previous studies (LaCanne & Lundgren, 2018; Norton, 2003; Teague et al., 2011, 2013; Teague & Kreuter, 2020; Waters, 2019; Wilsey et al., 2019), strongly suggesting both ecological and economic benefits under AMP grazing. Teague and others also documented improvements in soil carbon (Fuhlendorf et al., 2002; Teague et al., 2016), forage stocks (Teague, 2018), and surface water relationships (Teague et al., 2004) under AMP management, which is consistent with our findings (Apfelbaum et al., 2022; Mosier et al., 2021; Wang et al., 2021). Given the wide range of ecosystem services recognized, AMP grazing is identified as a possible strategy to combat climate change as well (Delgado et al., 2011; Gosnell, Charnley, et al., 2020; Gosnell, Grimm, et al., 2020).

Concurrent with the breeding bird surveys, soil carbon (Mosier et al., 2021, 2022), soil microorganisms (White et al., 2023), vegetation (Apfelbaum et al., 2022; Wang et al., 2021), greenhouse gases (Gomez-Casanovas et al., 2021; Teague et al., 2016), animal welfare/health, and insect populations (Schmid et al., 2015, 2021, 2024) were measured as well as a suite of metrics related to economic inputs (e.g., fertilizer, seed, antibiotics, and hay) and outcomes (e.g., pounds per acre of cattle sold) through livestock producer interviews. Future studies should examine the potential correlations between these biological and economic elements.

In summary, this study suggests that converting CG pastures to AMP grazing practices may help address the decline in species richness and populations of imperiled grassland bird communities in the southeast. The native grasslands of the southeast are greatly reduced in the current landscape. Herds of wild grazers, wildfire regimes, and prescribed fire by Indigenous humans maintained these disturbance-dependent systems. The remaining small and isolated grassland remnants not actively managed with prescribed fire or grazed with livestock are converted to brushlands and/or forests or plowed and converted to annual croplands (Southeast Grassland Initiative, 2019). Most remaining perennial grass systems in the southeast are active pasturelands on working farms. This study revealed that AMP grazing in active pasturelands could be critical for grassland bird conservation in the Southeastern United States.

More detailed studies, such as morphometric and physiological assessments of breeding and nestling birds or food availability/energy budgets for food acquisition within grazing treatments, may further contribute to understanding, evaluating, and refining the potential use of AMP grazing as a conservation tool for grassland birds in the southeast. Grazing strategies that forge a strong alignment between bird conservation and farming are needed (Askins et al., 2007; Waters, 2019). Working relationships between conservationists and privately held lands have been critical to the recovery of Kirtland's Warblers in Michigan (Kashian et al., 2017). Given the precipitous decline in North American grassland birds, similar landowner relationships and AMP grazing may be important considerations for conserving grassland breeding bird communities in the southeast. Given the importance and reliability of avifauna as indicators of ecosystem conditions, grassland bird community stewardship implies a functional ecosystem within AMP grazing, supported by other studies (insects, soils, and vegetation). These findings suggest that converting grazing practices from CG to AMP within the pasture acreage in the southeast may support increased populations of rare and declining obligate grassland bird species. The observations of four obligate grassland species that breed farther north within the AMP-grazed paddocks in this study also suggested values for grassland obligate birds during migration.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data and code (Byck & McGraw, 2024) are available from the Arizona State University Research Data Repository: https://doi.org/10.48349/ASU/7DCWIK.

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REFERENCES

Ahlering, M., D. Carlson, S. Vacek, S. Jacobi, V. Hunt, J. C. Stanton, M. G. Knutson, and E. Lonsdorf. 2020. "Cooperatively Improving Tallgrass Prairie with Adaptive Management." *Ecosphere* 11: e03095.

Ahlering, M., and C. L. Merkord. 2016. "Cattle Grazing and Grassland Birds in the Northern Tallgrass Prairie." *The Journal of Wildlife Management* 80: 643–654.

Apfelbaum, S., and A. Haney. 2010. *Restoring Ecological Health to Your Land*. Washington, DC: Island Press. xvii + 240 p.

Apfelbaum, S., and A. Haney. 2012. *The Restoring Ecological Health to Your Land Workbook*. Washington, DC: Island Press. xvii + 138 p + appendices.

Apfelbaum, S., R. Thompson, F. Wang, S. Mosier, R. Teague, and P. Byck. 2022. "Vegetation, Water Infiltration and Soil Carbon Response to Multipaddock and Conventional Grazed Southeastern USA Ranches." *Journal of Environmental Management* 308: 114576.

Askins, R. A., F. Chávez-Ramírez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. "Conservation of Grassland Birds in North America: Understanding Ecological Processes in Different Regions: 'Report of the AOU Committee on Conservation'." *Ornithological Monographs* 64: iii–viii, 1–46.

Billerman, S. M., B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, eds. 2022. *Birds of the World*. Ithaca, NY: Cornell Lab of Ornithology.

Bock, C. E. 2002. "Birds and Bovines: Effects of Livestock Grazing on Birds in the West." In *Welfare Ranching: The Subsidized Destruction of the American West*, edited by G. Wuerthner and M. Matteson. Covelo, CA: Island Press.

Breeding Bird Atlas Explorer (Online Resource). 2023. "U.S. Geological Survey Patuxent Wildlife Research Center." http://www.pwrc.usgs.gov/bba. Data extracted from: Palmer-Ball, B. L. Jr. 1996. *The Kentucky Breeding Bird Atlas Patuxent Wildlife Research Center*. Lexington, KY: The University Press of Kentucky. 372 p.

Brennan, L. A., and W. P. Kuvlesky. 2005. "North American Grassland Birds: An Unfolding Conservation Crisis?" *Journal of Wildlife Management* 69: 1–13.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. *Distance Sampling: Estimating Abundance of Biological Populations*. London: Chapman and Hall. 446 p.

Byck, P., and M. J. McGraw. 2024. "Replication Data for: Breeding Bird Response to Adaptive Multi-Paddock and Continuous Grazing Practices in Southeastern United States." ASU Library Research Data Repository. https://doi.org/10.48349/ASU/7DCWIK.

Chesser, R. T., K. J. Burns, C. Cicero, J. L. Dunn, A. W. Kratter, I. J. Lovette, P. C. Rasmussen, J. V. Remsen, Jr., D. F. Stotz, and K. Winker. 2019. *Checklist of North American Birds*. Chicago, IL: American Ornithological Society. http://checklist.aou.org/taxa.

Daily, G. C. 1997. "Introduction: What Are Ecosystem Services?" In *Nature's Services: Societal Dependence on Natural Ecosystems*, edited by G. C. Daily, 1–10. Washington, DC: Island Press.

Delgado, J. A., P. M. Groffman, M. A. Nearing, T. Goddard, D. Reicosky, R. Lal, N. R. Kitchen, C. W. Rice, D. Towery, and P. Salon. 2011. "Conservation Practices to Mitigate and Adapt to Climate Change." *Journal of Soil and Water Conservation* 66: 118A–129A.

Farnsworth, G. L., J. D. Nichols, J. R. Sauer, S. G. Fancy, K. H. Polack, S. A. Shriner, and T. R. Simon. 2005. *Statistical Approaches to the Analysis of Point Count Data: A Little Extra Information Goes a Long Way*. Albany, CA:US Forest Service Pacific Southwest Research Station Gen. Tech. Rep. PSW-GTR-191, 736–743. https://pubs.usgs.gov/publication/5211328

Fisher, R. J., and S. K. Davis. 2010. "From Wiens to Robel: A Review of Grassland-Bird Habitat Selection." *Journal of Wildlife Management* 74: 265–273.

Frey, C. M., W. E. Jensen, and K. A. With. 2008. "Topographic Patterns of Nest Placement and Habitat Quality for Grassland Birds in Tallgrass Prairie." *The American Midland Naturalist* 160: 220–234.

Fuhlendorf, S. D., H. Zhang, T. R. Tunnell, D. M. Engle, and A. F. Cross. 2002. "Effects of Grazing on Restoration of Southern Mixed Prairie Soils." *Restoration Ecology* 10: 401–7.

Golding, J. D., and V. J. Drietz. 2017. "Songbird Response to Rest-Rotation and Season-Long Cattle Grazing in a Grassland Sagebrush Ecosystem." *Journal of Environmental Management* 204: 605–612.

Gomez-Casanovas, N., E. Blanc-Betes, C. E. Moore, C. J. Beracchi, I. Kantola, and E. H. DeLucia. 2021. "A Review of Transformative Strategies for Climate Mitigation by Grasslands." *Science of the Total Environment* 799: 149466.

Gosnell, H., S. Charnley, and P. Stanley. 2020. "Climate Change Mitigation as a Co-Benefit of Regenerative Ranching: Insights from Australia and the United States." *Interface Focus* 10: 20200027.

Gosnell, H., K. Grimm, and B. E. Goldstein. 2020. "A Half Century of Holistic Management: What Does the Evidence Reveal?" *Agriculture and Human Values* 37: 849–867.

Haggerty, T. M., ed. 2009. *Alabama Breeding Bird Atlas 2000–2006 Homepage*. Dauphin Island, AL: Alabama Ornithological Society.

Hillenbrand, M., R. Thompson, F. Wang, S. Apfelbaum, and R. Teague. 2019. "Impacts of Holistic Planned Grazing with Bison Compared to Continuous Grazing with Cattle in South Dakota Shortgrass Prairie." *Agriculture, Ecosystems and Environment* 279: 156–322.

Hoekstra, J. M., T. M. Boucher, T. H. Ricketts, and C. Roberts. 2004. "Confronting a Biome Crisis: Global Disparities of Habitat Loss and Protection." *Ecology Letters* 8: 23–29.

Johnson, M. D. 2007. "Measuring Habitat Quality: A Review." *The Condor* 109: 489–504.

Kashian, D. M., J. R. Sosin, P. W. Huber, M. M. Tucker, and J. Dombrowski. 2017. "A Neutral Modeling Approach for Designing Spatially Heterogeneous Jack Pine Plantations in Northern Lower Michigan, USA." *Landscape Ecology* 32: 1117–31.

Kempema, S. L. F., W. H. Schacht, and L. A. Powell. 2023. "The Influence of Grazing Systems on Bird Species Richness and Density in the Nebraska Sandhills." *Diversity* 15: 1160.

Kimble, J. M., C. W. Rice, D. Reed, S. Mooney, R. F. Follett, and R. Lal, eds. 2007. *Soil Carbon Management: Economic, Environmental and Societal Benefits*. Boca Raton, FL: CRC Press.

LaCanne, C. E., and J. G. Lundgren. 2018. "Regenerative Agriculture: Merging Farming and Natural Resource Conservation Profitably." *PeerJ* 6: e4428.

McDonald, T., J. Carlisle, and A. McDonald. 2023. "Rdistance: Distance-Sampling Analyses for Density and Abundance

Estimation." R Package Version 3.0.0. https://CRAN.R-project.org/package=Rdistance.

Mosier, S., S. Apfelbaum, P. Byck, F. Calderon, R. Teague, R. Thompson, and M. F. Cotrufo. 2021. "Adaptive Multi-Paddock Grazing Enhances Soil Carbon and Nitrogen Stocks and Stabilization through Mineral Association in Southeastern U.S. Grazing Lands." *Journal of Environmental Management* 288: 112409.

Mosier, S., S. Apfelbaum, P. Byck, J. Ippolito, and M. F. Cotrufo. 2022. "Improvements in Soil Properties under Adaptive Multipaddock Grazing Relative to Conventional Grazing." *Agronomy Journal* 2022: 1–14.

Norton, B. E. 2003. "Spatial Management of Grazing to Enhance both Livestock Production and Resource Condition: A Scientific Argument." In *Proceedings of the VII International Rangeland Congress, Durban, South Africa*, eds. N. Allsopp, A. R. Palmer, S. J. Milton, K. P. Kirkman, G. I. H. Kerley, C. R. Hurt, and C. J. Brown, 810–20.

R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing. https://www.R-project.org/.

Ranellucci, C., N. Koper, and D. C. Henderson. 2012. "Twice-Over Rotational Grazing and Its Impacts on Grassland Songbird Abundance and Habitat Structure." *Rangeland Ecology & Management* 65: 109–118.

Recher, H. F. 2004. "Specialist or Generalist: Avian Response to Spatial and Temporal Changes in Resources." In *Avian Foraging: Theory, Methodology, and Applications. Studies in Avian Biology*, Vol. 13, edited by M. L. Morrison, C. J. Ralph, J. Verner, and J. R. Jehl, Jr., 333–36. Chicago, IL: Cooper Ornithological Society.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. "A Variable Circular-Plot Method for Estimating Bird Numbers." *The Condor* 82: 309–313.

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, et al. 2019. "Decline of the North American Avifauna." *Science* 366: 120–24.

Russell, J. R., and J. J. Bisinger. 2015. "Forages and Pastures Symposium: Improving Soil Health and Productivity on Grasslands Using Managed Grazing of Livestock." *Journal of Animal Science* 93: 2626–40.

Saab, V. A., C. E. Bock, T. D. Rich, and D. S. Dobkin. 1995. "Livestock Grazing Effects on Migratory Land Birds in Western North America." In *Ecology and Management of Neotropical Migratory Birds: A Synthesis and Review of Critical Issues*, edited by T. E. Martin and D. M. Finch, 311–353. New York: Oxford University Press.

Samson, F. B., F. L. Knopf, and W. Ostlie. 2004. "Great Plains Ecosystems: Past, Present, and Future." *Wildlife Society Bulletin* 32: 6–15.

Savory, A., and J. Butterfield. 2016. *Holistic Management: A Commonsense Revolution to Restore Our Environment*, 3rd ed. Washington, DC: Island Press. 552 p.

Schmid, R. B., R. M. Lehman, V. S. Brözel, and J. G. Lundgren. 2015. "Gut Bacterial Symbiont Diversity in Beneficial Insects Linked to Reductions in Local Biodiversity." *Annals of the Entomological Society of America* 108: 993–99.

Schmid, R. B., K. D. Welch, and J. G. Lundgren. 2021. "An Inventory of Foliar, Soil and Dung Arthropod Communities in Pastures of the Southeast United States." *Ecology and Evolution* 11: 10761–68.

Schmid, R. B., K. D. Welch, R. Teague, and J. G. Lundgren. 2024. *Adaptive Multipaddock (AMP) Pasture Management Increases Arthropod Community Guild Diversity without Increasing Pests*. Wichita, KS: The Society for Range Management. https://doi.org/10.1016/j.rama.2024.03.001.

Schneider, T. M., G. Beaton, T. S. Keyes, and N. A. Klaus. 2010. *The Breeding Bird Atlas of Georgia*. Athens, GA: University of Georgia Press. 520 p.

Skagen, S. K., D. J. Augustine, and J. D. Dermer. 2018. "Semi-Arid Grassland Bird Responses to Patch-Burn Grazing and Drought." *The Journal of Wildlife Management* 82: 445–456.

Southeast Grassland Initiative. 2019. A web-based resource. https://www.segrassland.org.

Szentkiralyi, P., and F. Kozar. 1991. "How Many Species Are There in Apple Insect Communities?: Testing the Resource Diversity and Intermediate Disturbance Hypotheses." *Ecological Entomology* 16: 491–503.

Tate, M. W., and R. C. Clelland. 1957. *Nonparametric and Shortcut Statistics*. Danville, IL: The Interstate Printers and Publishers. 171 p.

Teague, W. R. 2018. "Forages and Pastures Symposium: Cover Crops in Livestock Production: Whole-System Approach: Managing Grazing to Restore Soil Health and Farm Livelihoods." *Journal of Animal Science* 96: 1519–30.

Teague, W. R., S. Apfelbaum, R. Lal, U. P. Kreuter, J. Rowntree, C. A. Davies, R. Conser, et al. 2016. "The Role of Ruminants in Reducing Agriculture's Carbon Footprint in North America." *Journal of Soil and Water Conservation* 71: 156–164.

Teague, W. R., S. L. Dowhower, S. A. Baker, N. Haile, P. B. DeLaune, and D. M. Conover. 2011. "Grazing Management Impacts on Vegetation, Soil Biota and Soil Chemical, Physical and Hydrological Properties in Tall Grass Prairie." *Agriculture Ecosystems and Environment* 141: 310–322.

Teague, W. R., S. L. Dowhower, and J. A. Waggoner. 2004. "Drought and Grazing Patch Dynamics under Different Grazing Management." *Journal of Arid Environments* 58: 97–117.

Teague, W. R., and U. P. Kreuter. 2020. "Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services." *Frontiers in Sustainable Food Systems* 4: 534187.

Teague, W. R., F. D. Provenza, U. P. Kreuter, T. Steffens, and M. K. Barnes. 2013. "Multipaddock Grazing on Rangelands: Why the Perceptual Dichotomy between Research Results and Rancher Experience?" *Journal of Environmental Management* 128: 699–717.

Twedt, D. J., and K. L. Pardiek. 2017. "North American Breeding Bird Survey in Mississippi." *The Mississippi Kite* 4: 14.

USGS. 2024. "Instructions for Conducting the North American Breeding Bird Survey." A Technical Document. https://www.pwrc.usgs.gov/bbs/participate/BBSInstructions.pdf.

Wang, F., S. I. Apfelbaum, R. L. Thompson, R. Teague, and P. Byck. 2021. "Effects of Adaptive Multipaddock and Continuous Grazing on Fine Scale Spatial Patterns of Vegetation Species and Biomass." *Landscape Ecology* 36: 2725–41.

Waters, H. 2019. *Grazing like Its 1799: How Ranchers Can Bring Back Grassland Birds*. New York, NY: National Audubon Magazine.

Wei, W., Q. Zhen, J. Deng, H. Yue, M. Qin, and M. K. Oosthuizen. 2022. "Grazing during the Grassland Greenup Period Promotes Plant Species Richness in Alpine Grassland in Winter Pastures." *Frontiers in Plant Science* 13: 973662.

White, L. J., K. M. Yeater, and R. M. Lehman. 2023. "Soil Microorganisms Respond Distinctively to Adaptive Multi-Paddock and Conventional Grazing in Southeastern United States." *Soil Science Society of America Journal* 2023: 1–13.

Wilcoxon, F. 1945. "Individual Comparisons by Ranking Methods." *Biometrics* 1: 80–83.

Willson, M. F. 1974. "Avian Community Organization and Habitat Structure." *Ecology* 55: 1017–29.

Wilsey, C. B., J. Grand, J. Wu, N. Michel, J. Grogan-Brown, and B. Trusty. 2019. *North American Grasslands and Birds Report, North American Grasslands*. New York: National Audubon Society. 57 p.

Wuerthner, G., and M. Matteson, eds. 2002. *Welfare Ranching: The Subsidized Destruction of the American West*. Covelo, CA: Island Press.

Zellweger-Fischer, J., J. Hoffmann, P. Korner-Nievergelt, L. Pfiffner, S. Stoeckli, and S. Birrer. 2018. "Identifying Factors that Influence Bird Richness and Abundance on Farms." *Bird Study* 65: 161–173.

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