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RESEARCH ARTICLE

Influence of Disturbance on Avian Communities in Agricultural Conservation Buffers in Mississippi, USA

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Abstract:

Introduction:

Periodic disturbance of agricultural conservation buffers is required to maintain early successional plant communities for grassland birds. However, a disturbance may temporarily reduce the availability of vegetation cover, food, and nesting sites in a buffer.

Objective:

Our objective was to determine how the type of disturbance (*i.e.*, prescribed burning, light disking) and time since the last disturbance event in agricultural conservation buffers influence the grassland bird community.

Methods:

Data collected during line-transect surveys conducted in 46 agricultural conservation buffers in northeast Mississippi during the 2007-2009 breeding seasons (May-early August) demonstrate periodic disturbance through prescribed burning and light disking does not influence breeding bird diversity or density in the buffers.

Results:

Density of Dickcissels (*Spiza americana*), Red-winged Blackbirds (*Agelaius phoeniceus*), and Indigo Buntings (*Passerina cyanea*) did not differ in the buffers regardless of the type of or time since disturbance.

Conclusion:

Large effect sizes, however, indicate a potential type two error resulting from this conclusion. Thus, based on relative effect sizes, avian density in undisturbed buffers may be greater than in buffers during their first growing season post-disturbance. Relative effect sizes among estimates also indicate disturbance, namely prescribed burning, may lead to greater densities of breeding birds in agricultural conservation buffers. Though disturbance may initially reduce avian density, it is necessary to maintain long-term early-successional herbaceous habitat in agricultural conservation buffers.

Keywords: *Agelaius phoeniceus*, Avian density, Avian diversity, Conservation buffers, Disturbance, *Passerina cyanea*, *Spiza americana*.

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1. INTRODUCTION

Global agricultural crop production has changed greatly in the last 100 years. With technological advances, such as mechanization, inorganic fertilizers, and chemical use, there has been a disassociation between agriculture and natural resources [1 - 3]. After World War II, for instance, European cereal production increased in an effort to be more self-sufficient [4]. This increase led to the overproduction of crops and a reduction in landscape biodiversity [4]. In the United States, agricultural cropland covers nearly 318 million ha, constituting 14% of the country's total land use [5]. These agricultural systems are often characterized by large, monocultural fields that have fragmented or replaced natural ecosystems important to native flora and fauna [6, 7].

Habitat loss associated with agricultural conversion and intensification is the greatest threat to declining bird populations, particularly grassland birds [8]. In some regions of North

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America, there has been a loss of up to 99.9% of natural grassland ecosystems since the birth of industrialized agriculture [9]. In turn, grassland birds have shown steeper and more consistent declines than any other breeding bird guild [10, 11]. Examples of species that experienced population declines in the United States in recent decades include Dickcissel (*Spiza americana*), Eastern (*Sturnella magna*) and Western Meadowlark (*Sturnella neglecta*), Bobolink (*Dolichonyx oryzivorus*), and Northern Bobwhite (*Colinus virginianus*) [11]. Similar trends have also been found in Europe. From 1970 to 1990, for instance, there was a negative relationship between European avian population sizes and agricultural intensification, especially in Western Europe [12]. As of 2012, 25% of land cover in 39 European countries, totaling 1,471,684 km^2, was classified as arable land and permanent crops [12].

A reversion to less intensive agriculture is often not feasible, thus conservation practices that incorporate natural areas for birds and other wildlife into existing agricultural systems may be the best alternative. This is especially true in field margins adjacent to more competitive vegetation, such as trees and woody shrubs [13]. Agricultural conservation buffers may be integrated easily into production systems and produce many conservation benefits with minimal changes in primary land use. When buffers were established around crop fields in Sweden, for instance, there was a 30% increase in Eurasian Skylark (*Alauda avensis*) density relative to fields without buffers [14]. In the United States, breeding grassland bird densities in buffered crop fields were greater compared to those crop fields without buffers [15]. Species-specific density differences included Northern Bobwhite (85-109% greater), Dickcissel (85-120% greater), and Field Sparrow (*Spizella pusilla*; 58-106% greater) [15]. Buffers can provide many other benefits, as well. Examples include serving as corridors to facilitate wildlife movement across the landscape, promoting populations of beneficial insects (*e.g*., pollinators), reducing soil erosion and agrochemical runoff, and increasing farm-level biodiversity [2, 16, 17].

While buffers may provide many ecological benefits, they are often established with a specific, predetermined management goal [18]. Buffers established with the specific objective of promoting grassland bird populations must be periodically disturbed to maintain them as early-successional habitat [7, 19]. Disturbance, such as prescribed burning and light disking, will not only prevent woody plant encroachment, but also enhance herbaceous structural diversity, reduce vegetation density, decrease litter cover, increase the abundance of bare ground, and promote plant diversity [20 - 23]. In turn, the ability of buffers to support breeding grassland birds is enhanced. When patches of Scottish buffers were cut, for instance, Yellowhammer (*Emberiza citrinella*) summer foraging activity was greater than in uncut patches [24]. In North Dakota, prescribed fire in mixed-grass prairies prevented woody plant encroachment without negatively influencing nest survival of the Clay-colored (*Spizella pallida*) and Savannah sparrow (*Passerculus sandwichensis*) [25]. The use of fire as a management tool, however, has declined in recent decades. In areas heavily influenced by humans, issues regarding smoke and fire management are of great concern. Agricultural systems fragmented by roads, developed areas, crop fields, and pastures may require fire-free buffers and smoke management [26]. Additionally, there may be public concerns about potential negative effects fire may have on air quality in and around a burn area [27].

Time since disturbance may also influence grassland bird diversity and density in buffers. For instance, immediately following disturbance, a buffer may have short and sparse grass cover, few forbs, and minimal litter cover, thus providing little in regards to nesting and foraging habitat for breeding grassland birds [22]. In an east-central North Dakota mixed-grass prairie, densities of Bobolink, Western Meadowlark, and Grasshopper Sparrow (*Ammodramus savannarum*) decreased immediately following a burn [28]. Between 2 and 8 years later, however, this same area had an increasing abundance of grasses, forbs, shrubs, and litter cover [28]. Thus, fire influences short and long-term habitat suitability for birds. Specific response to time after burn will vary among species and regions in relation to precipitation regimes and soil fertility.

For these reasons, the use of alternative types of disturbance, such as light disking, must be explored to determine which management methods are most effective for supporting grassland bird populations in buffers. Thus, our objective was to determine the effect of periodic disturbance (*e.g*., prescribed burning and light disking) on the breeding grassland bird diversity and density in agricultural conservation buffers during the avian breeding seasons of 2007-2009. We hypothesized prescribed burning would result in greater diversity and density of breeding grassland birds relative to light disking. The results of our study will aid private land owners and land managers in selecting the most appropriate disturbance tool for areas selected to be early-successional buffer habitat in agricultural systems to support grassland bird populations.

2. METHODS

2.1. Data Collection

We collected data at a privately-owned farm in northeast Mississippi, USA, which consisted of 2,104 ha, 486 ha of which were used for row crop production and 587 ha that were used for a cattle operation (Fig. **1**). In spring 2005, 79 ha of this property were enrolled in the Conservation Reserve Program's Conservation Practice 33 (CP33: Habitat Buffers for Upland Birds). Based on the enrollment criteria for this practice, agricultural conservation buffers 9.1-36.5 m wide are established around the perimeter of crop production fields with native warm-season grasses and forbs. Producers implementing CP33 on their land receive a cost-share to offset establishment costs, as well as monetary incentives and annual rental payments to compensate for lost opportunity costs [29]. Buffers enrolled in CP33 are required to be disturbed to maintain them as early-successional habitat specifically for Northern Bobwhite and potentially other grassland birds [29].

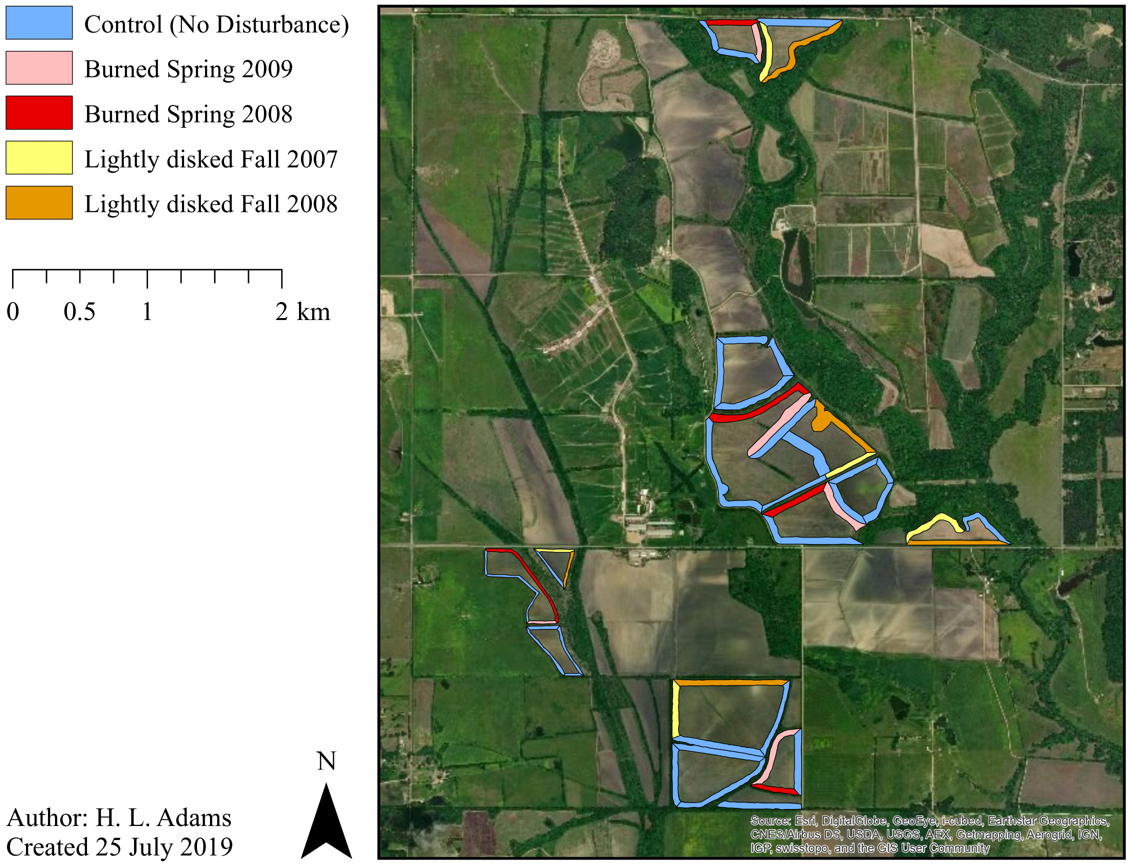

Fig. (1). Aerial photograph of agricultural land enrolled in Conservation Reserve Program practice CP33: Habitat Buffers for Upland Birds at a privately-owned farm in northeast Mississippi, USA. Disturbance schedule of buffers indicated by red (prescribed burn), blue (control), and yellow (light disking) polygons, 2007-2009.

After CP33 enrollment, buffers measuring 18.2 or 36.5 m wide were then established, surrounding the perimeter of 14 crop production fields at the farm. These buffers included a mix of native warm-season grasses [*e.g.*, big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*)] and forbs [*e.g.*, partridge pea (*Chamaecrista fasciculata*), black-eyed susan (*Rudbeckia hirta*), maximilian sunflower (*Helianthus maximiliani*)].

We investigated 3 different disturbance treatments in agricultural conservation buffers at the study site: **(1)** Light disking in the fall (September-October), **(2)** Prescribed burning in the spring (March-April), and **(3)** No disturbance (control). Because data collection occurred during the avian breeding season (May-early August), confounding between disturbance type and breeding season did not influence the data. We randomly assigned 1 of the 3 disturbance treatments to each group of buffers surrounding the same field, with only 1 buffer/field group disturbed each year (14 buffer-bordered fields, 51 total buffers). Planted crops in the fields included a corn-soybean rotation or Bermuda grass (*Cynodon dactylon*) established for cattle forage. Data we collected during 2007 provided pre-disturbance information. We documented vegetation and bird responses to disturbance during the first (2008 and 2009) and second (2009) growing seasons post-disturbance. Because this study concluded prior to 2010, we considered buffers disturbed after the 2009 breeding season in-field controls.

We used distance sampling techniques to estimate breeding bird density as it incorporates a decreasing detection probability with increasing distance from an observer [30]. We established 200-m long line transects that ran parallel to a buffer's long axis in 46 of the agricultural conservation buffers at the study site [5 buffers were too short to accommodate a 200-m line transect; (Fig. **2**)]. Strip transect surveys were conducted by a single observer (HLA) 0530-1000 (central standard time) on mornings with no precipitation and wind speeds less than 24 km/hour [31]. Fixed-width transect surveys were conducted at a travel rate of 10 m/min, during which the observer recorded bird detections in 1 of 4 distance bands that together covered the width of the buffers: 0-5 m, 5-10 m, 10-15 m, and 15-20 m. Temperature, percent cloud coverage, and wind speed were recorded at the start of each transect survey. The observer visited each transect 6 times during each breeding season (twice monthly, May-early August), 2007-2009.

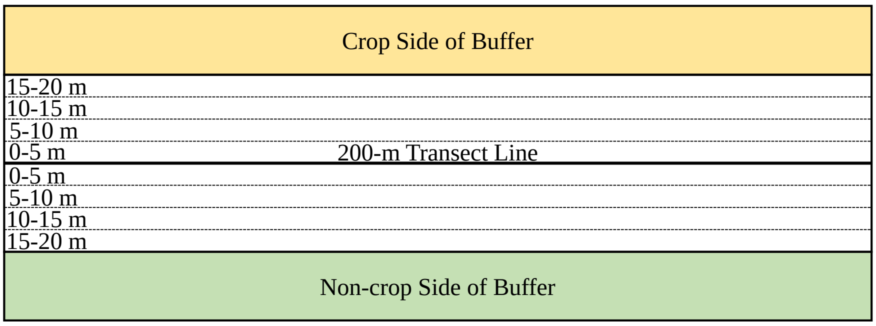

Fig. (2). Diagram of a 200-m transect used to estimate diversity and density of breeding birds in agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007-2009.

2.2. Data Analyses

We estimated avian diversity in the agricultural conservation buffers using Shannon's Diversity Index [32], which is calculated as:

$$H' = \sum_{i=1}^{n} -(P_i * \ln P_i) \quad (1)$$

where H' is the Shannon's Diversity Index value, n is the number of detected species, and P_i is the fraction of the observed sample composed of the i^{th} species. We calculated diversity indices for the type of and time since disturbance using mean detections/ha for all birds detected during line-transect surveys.

To determine if disturbance influenced avian diversity at the buffer level, we compared mean avian diversity in buffers based upon variables reflecting year (2007, 2008, 2009) by treatment (burn, disk, control) using general linear models in SAS PROC MIXED [33]. Because individual buffers of the same field were physically connected and adjacent to the same crop field, we included field as a random variable. To determine if disturbance influenced avian density at the field level, we compared the mean avian diversity of fields based on year by treatment variables using general linear models in SAS PROC MIXED, including year as a repeated measure [33]. At both the buffer and field level, we further evaluated significant results using a Welch t-test. For all these statistical analyses, we used a significance level of $\alpha = 0.05$.

We used conventional distance sampling techniques in Program Distance to estimate the detection function of all birds of any species in the agricultural conservation buffers based on the type of and time since disturbance [34]. Additionally, we estimated detection functions for species with more than 100 detections in the buffers (*i.e.*, Dickcissel, Red-winged Blackbird, Indigo Bunting). Species with less than 100 detections provided insufficient data to generate a robust estimate of a detection function [30].

It is recommended that approximately 5-10% of distance data be right-truncated to increase model precision [30]. Because we recorded detections in 5-m distance bands rather than exact distances, truncation required censoring all or none of the detections in a given band. The 15-20 m band terminated at the buffer-crop ecotone at a transect's crop side (*i.e.*, field interior) and the buffer-field margin ecotone at a transect's non-crop side (*i.e.*, field exterior). Vegetation discontinuities associated with edges attracted birds, resulting in more detections in the outer distance bands (15-20 m) and a non-monotonically declining detection function with distance (Fig. **3**). This violated an assumption of distance sampling, which states the probability of detecting an object; in this case, a bird, decreases with increasing distance from an observer [30]. Thus, we truncated detections in this band and estimated detection functions using detections in the first 3 distance bands (0-15 m). We used Akaike's Information Criterion (AIC) to determine the best fit detection function from appropriate key functions (half-normal or uniform) with possible cosine or simple polynomial adjustment terms. Model selection was based on the least AIC value, goodness-of-fit, and detection probability.

Given that model selection results most frequently supported uniform detection probabilities at or near 1.0 and a relatively narrow detection width, we estimated buffer-and year-specific avian density in the agricultural conservation buffers with respect to type of and time since disturbance by calculating mean number of avian detections/ha for each buffer during 2008 and 2009. We made these estimations using all avian detection data and not just the truncated data used in Program Distance analyses. We evaluated potential differences in avian density between control and disturbed buffers at the buffer and field level using general linear models in SAS PROC MIXED [33]. Procedures for these analyses were similar to diversity analyses, again with $\alpha = 0.05$.

3. RESULTS

We detected 26 avian species in the agricultural conservation buffers at the study site during the 2007-2009 breeding seasons (Table **1**). Of these 26 species, 5 were grassland species, 6 were facultative grassland, 9 were edge species that use the field-forest ecotone, 3 were woodland species, and 3 were more commonly associated with urban or developed areas. Dickcissels (grassland, 427 detections), Red-winged Blackbirds (facultative grassland, 336 detections), and Indigo Buntings (edge, 252 detections) were the most frequently detected species in the agricultural conservation buffers.

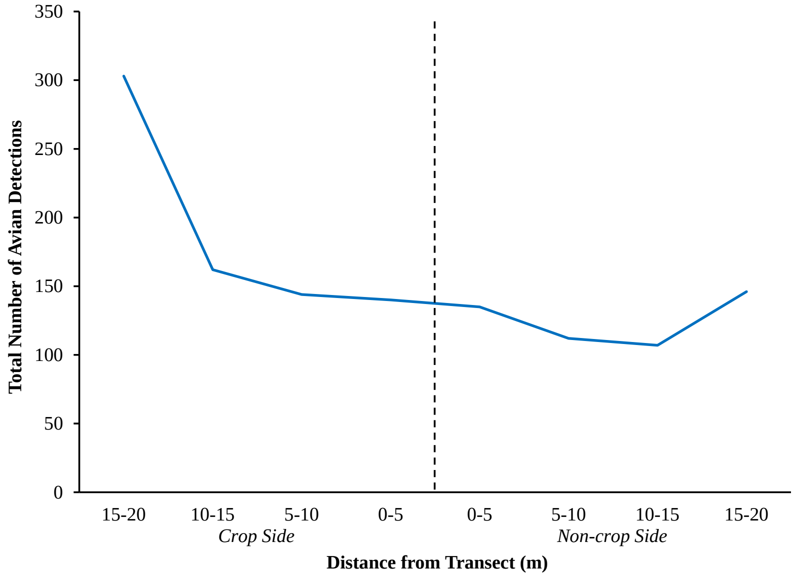

Fig. (3). The total number of birds detected during strip transect surveys in agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007-2009.

Table 1. Avian species detected during transect surveys in agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007-2009.

Species	Habitat Association [53, 67]	Number of Detections
Northern Bobwhite (*Colinus virginianus*)	Grassland	8
Mourning Dove (*Zenaida macroura*)	Facultative grassland	18
Ruby-throated Hummingbird (*Archilochus colubris*)	Woodland	8
Eastern Kingbird (*Tyrannus tyrannus*)	Facultative grassland	10
Loggerhead Shrike (*Lanius ludovicianus*)	Facultative grassland	1
Purple Martin (*Progne subis*)	Urban	1
Tree Swallow (*Tachycineta thalassina*)	Edge	1
Barn Swallow (*Hirundo rustica*)	Urban	3
Carolina Chickadee (*Poecile carolinensis*)	Woodland	3
Blue-gray Gnatcatcher (*Polioptila cerulea*)	Woodland	1
Sedge Wren (*Cistothorus platensis*)	Grassland	3
Northern Mockingbird (*Mimus polyglottos*)	Urban	8
Common Yellowthroat (*Geothlypis trichas*)	Facultative grassland	8
Yellow-breasted Chat (*Icteria virens*)	Edge	5
Eastern Towhee (*Pipilo erythrophthalmus*)	Edge	5
Field Sparrow (*Spizella pusilla*)	Edge	17
Grasshopper Sparrow (*Ammodramus savannarum*)	Grassland	1
Song Sparrow (*Melospiza melodia*)	Edge	1
Northern Cardinal (*Cardinalis cardinalis*)	Edge	28
Blue Grosbeak (*Guiraca caerulea*)	Edge	35
Indigo Bunting (*Passerina cyanea*)	Edge	252
Dickcissel (*Spiza americana*)	Grassland	427
Red-winged Blackbird (*Agelaius phoeniceus*)	Facultative grassland	338
Eastern Meadowlark (*Sturnella magna*)	Grassland	8
Brown-headed Cowbird (*Molothrus ater*)	Facultative grassland	3
Orchard Oriole (*Icterus spurius*)	Edge	7

3.1. Avian Diversity

There were no pre-treatment differences in mean avian diversity in 2007 among the agricultural conservation buffers ($F_{4,34.9}$ = 0.65, P = 0.630). There was still no difference in diversity at the buffer level regardless of type of or time since disturbance in 2008 ($F_{2,36}$ = 1.34, P = 0.274) and 2009 ($F_{4,37.4}$ = 0.32, P = 0.864). In 2008, although relative effect sizes were large, -29% for burned buffers and -92% for disked buffers compared to control buffers suggesting a short-term reduction in avian diversity the first growing season post-disturbance, confidence intervals included zero (Fig. **4**). In 2009, effect sizes on diversity were 70% in burned buffers in their second growing season and 42% for disked buffers in their first growing season relative to controls, suggesting a positive response to disturbance, although confidence intervals again included 0.

At the field level in 2007, there were no pre-treatment differences in avian diversity ($F_{2,11}$ = 0.69, P = 0.523). Implementation of disturbance treatments did not affect avian diversity in 2008 ($F_{2,11}$ = 0.62, P = 0.557) and 2009 ($F_{2,11}$ = 1.37, P = 0.294). Estimates of effect sizes (relative to control fields) were relatively large and in opposite directions for prescribed burning (2008, 69% increase in diversity; 2009, 124%) and light strip-disking (2008, 25% decrease in diversity; 2009, 5%).

3.2. Avian Density

All model selection results generated in Program Distance supported the uniform key function with a cosine adjustment to estimate detection functions regardless of the type of or time since disturbance (Table **2**). Detection probabilities were also all 1.00 ± 0.00 for Dickcissels (Table **3**) and Indigo Buntings (Table **4**); Red-winged Blackbird detection probabilities were all 1.00 ± 0.00 except for buffers during the second growing season post-disking (0.50 ± 0.12; Table **5**).

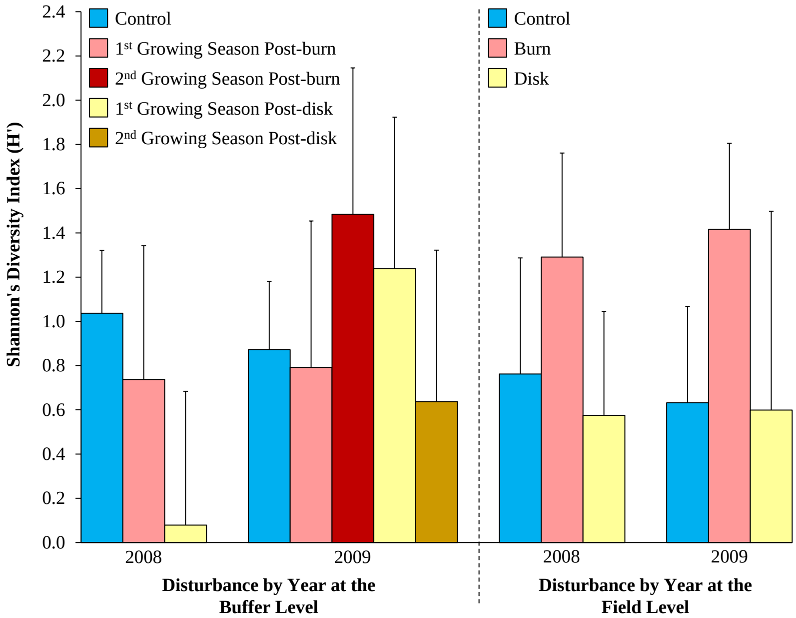

Fig. (4). Shannon's Diversity Indices (mean ±1 standard error) at the buffer (left) and field (right) levels for all bird species detected in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2008-2009.

Table 2. Results of Akaike's information criterion (AIC), detection function [f(0)], probability of detection (*p*), and percent coefficient of variation (%CV) for all birds detected in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007-2009.

Disturbance	Key Function	Adjustment	AIC	f(0)	*p*	%CV
Control	Uniform	Cosine	1379.86	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	1381.86	6.67E-02	1.00 ± 0.05	4.80
	Half-normal	Simple polynomial	1381.86	6.67E-02	1.00 ± 0.05	4.80
First growing season post-burn	Uniform	Cosine	153.81	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	154.60	7.76E-02	0.86 ± 0.11	13.25
	Half-normal	Simple polynomial	154.60	7.76E-02	0.86 ± 0.11	13.25

(Table 2) contd.....

Disturbance	Key Function	Adjustment	AIC	f(0)	*p*	%CV
Second growing season post-burn	Uniform	Cosine	65.92	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	67.90	6.88E-02	0.97 ± 0.21	21.59
	Half-normal	Simple polynomial	97.90	6.88E-02	0.97 ± 0.21	21.59
First growing season post-disk	Uniform	Cosine	114.26	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	116.26	6.67E-02	1.00 ± 0.17	16.68
	Half-normal	Simple polynomial	116.26	6.67E-02	1.00 ± 0.17	16.68
Second growing season post-disk	Uniform	Cosine	43.94	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	44.79	1.24E-01	0.54 ± 0.18	33.13
	Half-normal	Simple polynomial	44.87	8.67E-02	0.80 ± 0.18	23.38

Table 3. Results of Akaike's information criterion (AIC), detection function [f(0)], probability of detection (*p*), and percent coefficient of variation (%CV) for Dickcissels (*Spiza americana*) detected in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007-2009.

Disturbance	Key Function	Adjustment	AIC	f(0)	*p*	%CV
Control	Uniform	Cosine	520.74	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	522.61	6.86E-02	0.97 ± 0.07	7.70
	Half-normal	Simple polynomial	522.61	6.86E-02	0.97 ± 0.07	7.70
First growing season post-burn	Uniform	Cosine	37.35	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	37.57	9.55E-02	0.70 ± 0.17	24.10
	Half-normal	Simple polynomial	37.57	9.55E-02	0.70 ± 0.17	24.10
Second growing season post-burn	Uniform	Cosine	39.55	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	41.55	6.67E-02	1.00 ± 0.28	28.34
	Half-normal	Simple polynomial	41.55	6.67E-02	1.00 ± 0.28	28.34
First growing season post-disk	Uniform	Cosine	21.97	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	23.22	9.06E-02	0.74 ± 0.24	32.29
	Half-normal	Simple polynomial	23.22	9.06E-02	0.74 ± 0.24	32.29
Second growing season post-disk*	Uniform	Cosine	13.18	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	15.18	6.67E-02	1.00 ± 0.49	40.09
	Half-normal	Simple polynomial	15.18	6.67E-02	1.00 ± 0.49	40.09

*Number of observations was too small to expect accurate results.

Table 4. Results of Akaike's information criterion (AIC), detection function [f(0)], probability of detection (*p*), and percent coefficient of variation (%CV) for Indigo Buntings (*Passerina cyanea*) detected in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007-2009.

Disturbance	Key Function	Adjustment	AIC	f(0)	*p*	%CV
Control	Uniform	Cosine	215.33	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	217.33	6.67E-02	1.00 ± 0.12	12.15
	Half-normal	Simple polynomial	217.33	6.67E-02	1.00 ± 0.12	12.15
First growing season post-burn	Uniform	Cosine	41.75	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	43.09	8.25E-02	0.81 ± 0.20	24.63
	Half-normal	Simple polynomial	43.09	8.25E-02	0.81 ± 0.20	24.63
Second growing season post-burn	Uniform	Cosine	4.39	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	6.39	6.67E-02	1.00 ± 0.85	85.03
	Half-normal	Simple polynomial	6.39	6.67E-02	1.00 ± 0.85	85.03
First growing season post-disk	Uniform	Cosine	32.96	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	34.96	6.67E-02	1.00 ± 0.31	31.05
	Half-normal	Simple polynomial	34.96	6.67E-02	1.00 ± 0.31	31.05
Second growing season post-disk*	Uniform	Cosine	13.18	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	15.07	7.80E-02	0.86 ± 0.39	45.17
	Half-normal	Simple polynomial	15.07	7.80E-02	0.86 ± 0.39	45.17

*Number of observations was too small to expect accurate results.

Table 5. Results of Akaike's information criterion (AIC), detection function [f(0)], probability of detection (*p*), and percent coefficient of variation (%CV) for Red-winged Blackbirds (*Agelaius phoeniceus*) detected in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2007–2009.

Disturbance	Key Function	Adjustment	AIC	f(0)	*p*	%CV
Control	Uniform	Cosine	402.09	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	404.09	6.67E-02	1.00 ± 0.09	8.89
	Half-normal	Simple polynomial	404.09	6.67E-02	1.00 ± 0.09	8.89
First growing season post-burn	Uniform	Cosine	46.14	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	48.14	6.67E-02	1.00 ± 0.26	26.24
	Half-normal	Simple polynomial	48.14	6.67E-02	1.00 ± 0.26	26.24
Second growing season post-burn	Uniform	Cosine	13.18	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	13.24	1.22E-02	0.55 ± 0.20	35.97
	Half-normal	Simple polynomial	13.24	1.22E-02	0.55 ± 0.20	35.97
First growing season post-disk	Uniform	Cosine	24.17	6.67E-02	1.00 ± 0.00	0.00
	Half-normal	Cosine	26.17	6.67E-02	1.00 ± 0.36	36.26
	Half-normal	Simple polynomial	26.17	6.67E-02	1.00 ± 0.36	36.26
Second growing season post-disk*	Uniform	Cosine	4.98	1.33E-01	0.50 ± 0.12	24.03
	Half-normal	Cosine	2.00	5.33	0.01 ± 1.25	9999.99
	Half-normal	Simple polynomial	2.00	5.33	0.01 ± 1.25	9999.99

*Number of observations was too small to expect accurate results.

At the buffer level in 2007, there was no difference in avian density among buffers prior to disturbance ($F_{4,35.1}$ = 1.76, P = 0.160). Avian density in control and disturbed buffers did not differ in 2008 ($F_{2,35.4}$ = 0.99, P = 0.383) and 2009 ($F_{4,37.4}$ = 0.58, P = 0.680). In 2008, relative effect sizes on avian density were -26% for burned buffers in the first growing season and -68% for disked buffers in the first growing season (Fig. **5**), reflecting a short-term decline in density. However, confidence intervals included 0. In 2009, relative effect sizes on total avian density were -10% for buffer the first growing season post-burn and -2% the second season post-burn. Again, confidence intervals on effect sizes included 0.

At the field level, prior to disturbance, there was no difference in avian density among fields bordered by agricultural conservation buffers ($F_{2,11}$ = 0.59, P = 0.572). After disturbance regimes had been implemented, total avian density did not differ among treatments in 2008 ($F_{2,11}$ = 0.80, P = 0.475) and 2009 ($F_{2,11}$ = 0.28, P = 0.752). Relative effect sizes for avian density were positive for prescribed burning (2008, 112%; 2009, 15%), whereas effect sizes on avian density were mixed for disked fields (2008, 10%; 2009, -29%). However, field level confidence intervals on effect sizes included 0 for years and treatments.

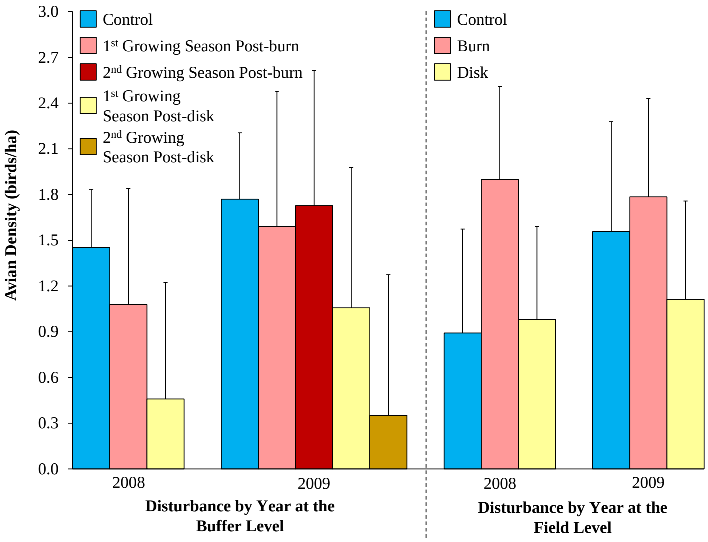

Fig. (5). Least squares mean density estimates (mean ±1 standard error) at the buffer (left) and field (right) levels for all bird species detected in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2008-2009.

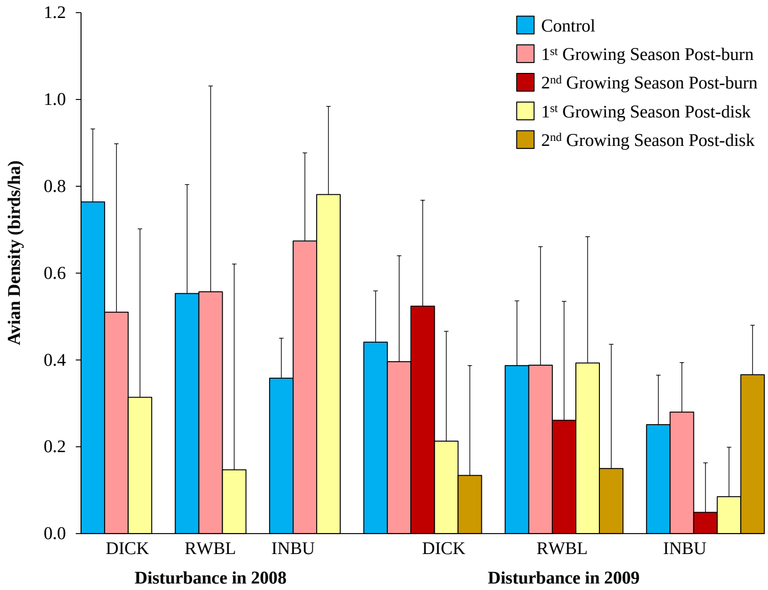

Fig. (6). Dickcissel (DICK), Red-winged Blackbird (RWBL), and Indigo Bunting (INBU) densities (mean ±1 standard error) at the buffer level in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2008-2009.

3.3. Dickcissels

In 2007, there was no difference in Dickcissel density prior to disturbance ($F_{4,38}$ = 0.98, P = 0.428). Furthermore, neither type of nor time since disturbance influenced Dickcissel density in buffers during 2008 ($F_{2,37.7}$ = 0.81, P = 0.454) and 2009 ($F_{4,38.9}$ = 0.50, P = 0.735). In 2008, Dickcissel density in buffers the first growing season post-burn was -33% relative to control buffers (Fig. **6**). In 2009, relative effect size in Dickcissel density between these same buffers their second growing season post-burn and controls was 19%. Confidence intervals on effect sizes, however, included 0 for years and treatments.

At the field level in 2007, there was no difference in Dickcissel density ($F_{2,11}$ = 0.01, P = 0.989). Post-disturbance Dickcissel density still did not differ among fields bordered by agricultural conservation buffers in 2008 ($F_{2,11}$ = 0.09, P = 0.911) and 2009 ($F_{2,11}$ = 0.54, P = 0.599). Effect sizes on mean Dickcissel density in fields with disking as the assigned treatment were -6% in 2008 and -3% in 2009 relative to control fields (Fig. **7**). Conversely, the relative effect size in Dickcissel density between burned and control fields was 19% in 2008 and 27% in 2009. Though these results suggest a positive response to prescribed burning, confidence intervals included 0.

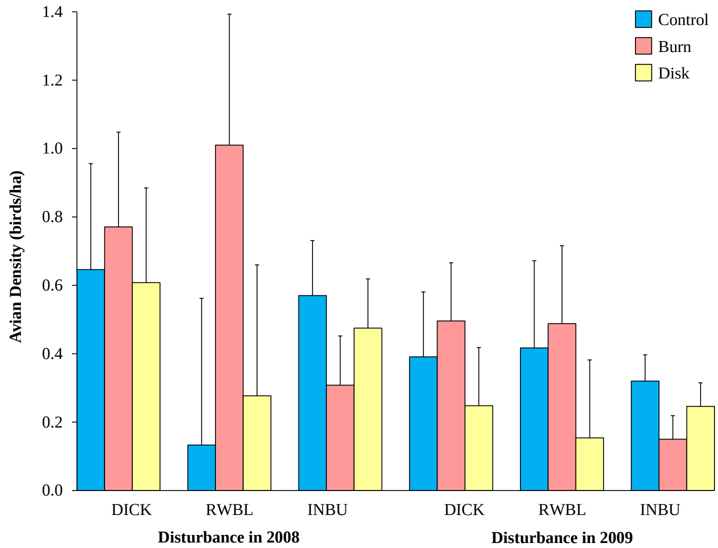

Fig. (7). Dickcissel (DICK), Red-winged Blackbird (RWBL), and Indigo Bunting (INBU) densities (mean ±1 standard error) at the field level in control and disturbed agricultural conservation buffers at a privately-owned farm in northeast Mississippi, USA, 2008-2009.

3.4. Red-winged Blackbirds

In 2007, there was no difference in Red-winged Blackbird density in agricultural conservation buffers prior to disturbance ($F_{4,34.7}$ = 1.43, P = 0.246). Blackbird density did not differ between disturbed and control buffers in 2008 ($F_{2,34.8}$ = 0.40, P = 0.675) and 2009 ($F_{4,36.5}$ = 0.21, P = 0.931). In 2008, there was a 73% difference in relative effect size between blackbird densities in buffers the first growing season post-disk and control buffers. Based on relative effect sizes in 2009, blackbird density in disked buffers compared to control buffers was -33% during the first growing season post-disk, and -61% the second growing season. Confidence intervals of these effect sizes, however, included 0.

At the field level, there was no difference in Red-winged Blackbird density in buffer-bordered fields prior to disturbance ($F_{2,11}$ = 1.50, P = 0.267). After disturbance had occurred, there was still no difference in blackbird density among the fields in 2008 ($F_{2,11}$ = 1.42, P = 0.283) and 2009 ($F_{2,11}$ = 0.58, P = 0.575). In 2008, relative effect sizes in blackbird density were 659% for burned fields and 108% for disked fields compared to control fields. In 2009, this difference was reduced to 17% for burned fields. At this time, the relative effect size between disked and control fields was -63%. Despite these large relative effect sizes, though, their respective confidence intervals included 0.

3.5. Indigo Buntings

Indigo Bunting density did not differ among agricultural conservation buffers prior to disturbance in 2007 ($F_{4,38}$ = 1.12, P = 0.362). Based on relative effect sizes in 2008, bunting density in burned and disked buffers during their first growing season post-disturbance was greater than in control buffers (burned, 88%; disked, 118%). In 2009, bunting density in buffers during their first growing season post-burn was 12% greater relative to controls. Bunting density in disked buffers during their second growing season was 46% greater compared to controls. Despite these large effect sizes, however, there was no difference in bunting density regardless of type of or time since disturbance (2008, $F_{2,36}$ = 3.18, P = 0.053; 2009, $F_{4,41}$ = 1.49, P = 0.224).

Indigo Bunting density did not differ among buffer-bordered fields prior to disturbance in 2007 ($F_{2,11}$ = 1.22, P = 0.331). Indigo Bunting density still did not differ among buffer-bordered fields after disturbance had occurred (2008, $F_{2,11}$ = 0.77, P = 0.486; 2009, $F_{2,11}$ = 1.38, P = 0.292). In 2008, relative effect sizes for bunting density between disturbed and control fields were -46% for burned fields and -17% for disked fields. These differences increased to -53% for burned fields and -23% for disked fields in 2009. Confidence intervals for these effects sizes, however, did include 0.

4. DISCUSSION

4.1. Avian Diversity and Density

Our results most frequently supported uniform detection functions, thus it is likely all birds present in the agricultural conservation buffers during transect surveys were detected. Similarly, based on a review of 75 published papers from 1985 to 2001 that conducted transect surveys of grassland birds, the probability of detection of Henslow's (*Ammodramus henslowii*), Grasshopper, and Savannah Sparrows ranged from 0.93 to 1.0 when a bird was within 25 m of an observer [35]. Due to uniform detection in the 0-15 m distance range, followed by an increase in detections in the 15-20 m distance range, avian behavior was likely not negatively influenced by observer presence and birds were attracted to the buffer edge where there was alternative vegetative cover (*i.e*., crop or non-crop habitat). If birds had been negatively influenced by observer presence, detections would have increased with increasing distance from the observer. Therefore, vegetation differences among buffers (*e.g.,* vegetation height, vegetation density) and aversion behavior exhibited by birds in response to the observer did not influence the probability of detection during transect surveys.

Prescribed fire and light disking did not affect breeding bird diversity and density at either the buffer or field level during the first and second growing seasons post-disturbance. However, direction and magnitude of relative effect sizes on diversity and density for burned and disked buffers indicate the possibility of a type two error (*i.e*., failing to reject a false null hypothesis). If indeed our alternate hypothesis was true, this would be consistent with previous studies reporting differences in avian diversity and density between disturbed and undisturbed habitats. In northeast Nebraska, grassland bird abundance and diversity were greater in disked CRP fields than those that were unmanaged [36]. In northwestern North Dakota, avian species richness and abundance of Bobolink, Grasshopper Sparrow, and Western Meadowlark were greater in burned than in unburned mixed-grass prairie sites [21]. These studies, however, occurred in large blocks of grassland habitat. Many grassland bird species, including Dickcissels, are area-sensitive species that prefer large habitat patches [37]. Because agricultural conservation buffers only provide strip grassland habitat and cover a small area (0.17-3.49 ha in this study), disturbance methods used to maintain the early-successional state of buffers may not be an important factor in avian habitat selection at the field level. When applied in a rotational fashion, only ¼-⅓ of buffers is disturbed within any single year, leaving the remainder undisturbed, creating a mosaic of successional stages at the whole-field scale.

Although disturbance did not statistically affect diversity or density of breeding birds in our agricultural conservation buffers, disturbance does alter vegetation structure (*e.g*., vegetation height and density), which may influence a bird's choice of habitat [38]. Burned mixed-grass prairies in north-central North Dakota had minimal vegetation coverage with little standing dead vegetation 1-year post-burn, but this increased and stabilized following the second growing season [39]. In the agricultural conservation buffers at our study site, nest densities of Dickcissels and Red-winged Blackbirds were greater in burned buffers than in disked buffers [40]. Alternatively, disking encourages the germination of forbs by disrupting grass-root structures and setting succession back further than burning [41]. In buffers used during this study, forb species richness in disked buffers was greater than in control and burned buffers during summer 2008 (P =

0.009-0.039) [42]. In May 2009, these same buffers had a greater number of forb species than control and burned buffers (P = 0.009) [42]. A greater presence of forbs in disked buffers can create suitable habitat for pollinating insects [17], or other insect species that could serve as a food source for breeding grassland birds and their nestlings [43].

4.2. Dickcissels

Dickcissels are grassland specialists and a species of concern. From 1966 to 1979, Dickcissel populations in the Southeastern United States were declining at a rate of 6.1% every year [44]. In recent years, however, Dickcissel populations have begun to increase. For instance, in the Mississippi Alluvial Valley; the physiographic region where our study site is located; the 2005-2015 Dickcissel population increased at a rate of 2.42% per year [45]. Dickcissels likely do not require as large of early successional areas during the breeding season compared to other grassland birds (*e.g*., Eastern Meadowlark, Savannah Sparrow) [46]. Thus, Dickcissels may respond positively to conservation practices in fragmented areas, like those of the CRP in agricultural landscapes.

Dickcissels prefer grassland habitat with tall, dense vegetation structure [47, 48]. This may be one reason why Dickcissels were detected frequently in control buffers during this study. Because of the absence of disturbance, vegetation in these buffers provided many perching, singing, and foraging sites for birds. Disturbance temporarily alters this vegetation structure by reducing ground cover and vertical density. Time since disturbance can determine how quickly buffers can recover and once again accommodate Dickcissels during the breeding season. Dickcissels at our study site, for instance, had greater nest densities in burned buffers than those that were disked [40].

Prescribed burning in agricultural conservation buffers did not significantly reduce Dickcissel density relative to the control buffer regardless of time since disturbance. Frequently, though, Dickcissel densities in grassland habitats decline immediately following a prescribed burn because of a lack of vegetative cover [23]. Given time, vegetation in burned buffers can recover quickly from disturbance because of warmer soil temperatures and greater availability of soil nutrients [49]. This quick recovery may provide Dickcissels cover later in the breeding season. In central South Dakota, Dickcissel densities increased from early to late seral stages of a mixed-grass prairie [50]. Additionally, Dickcissel abundance in Oklahoma grasslands increased with time since burning [18].

Alternatively, vegetation in disked buffers did not recover from disturbance as quickly as vegetation in burned buffers [41]. Because of this, Dickcissel density was greater in control and burned buffers than in disked buffers with respect to relative effect sizes. Though a greater abundance of forbs in disked buffers can provide Dickcissels foraging sites, these plants may not be able to provide optimal breeding and nesting sites for this species. Thus, Dickcissels occur in reduced abundance due to the lack of perching, singing, and nesting sites.

4.3. Red-winged Blackbirds

Red-winged Blackbirds, though commonly known as a wetland species, will breed in several habitat types throughout Mississippi, such as lowlands, weedy fields, roadways, and ditch banks [51]. Blackbirds are also a facultative grassland species and will benefit from management practices used to promote grassland birds [52, 53]. Furthermore, this species is known commonly as a crop pest and their presence in agricultural conservation buffers may be viewed as a drawback to this conservation practice by land managers. For instance, the flocking and foraging behavior of Red-winged Blackbirds in the northern Great Plains causes extensive damage to sunflower (*Helianthus annuus*) [54]. However, in the southeastern United States, cultivated rice may make up a large portion of the birds' diet [54], which is a crop not typically grown in upland areas where buffers are more commonly established.

Red-winged Blackbird density in burned buffers did not differ from control buffers in 2008 and 2009. In a Kansas study, Red-winged Blackbird density was greater in unburned than burned sites, but this difference was not significant [55]. Red-winged Blackbird densities in an east-central North Dakota mixed-grass prairie increased 2 to 5 years post-burn [28]. Though there was no significant difference in blackbird densities between burned and unburned buffers in this study, we did not collect data past the second growing season post-disturbance. Thus, it is possible a difference in blackbird density between these 2 disturbance types may have been detected had the study continued during subsequent years [28].

Though there were no significant differences found in this study, Red-winged Blackbird density in 2008 was greater in control buffers than in disked buffers based on relative effect sizes. In 2009, this difference was still existent in these same buffers during their second growing season after disking. Like Dickcissels, Red-winged Blackbirds are associated positively with vertical vegetation density [52]. Thus, these birds may avoid disked buffers because of a lack of foraging and breeding habitat.

Red-winged blackbirds are known for causing excessive crop damage. In North Dakota, South Dakota, and Nebraska, for instance, the average annual impacts of Red-winged Blackbirds, along with Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) and Common Grackles (*Quiscalus quiscula*), on sunflower production from 2009 to 2013 were US $18.7 million, US $7.3 million, and US $2.6 million, respectively [56]. In regards to our study, planted crops included soybean, corn, and Bermudagrass. We did not observe any occurrences of crop damage by Red-winged Blackbirds to these crops while performing transect surveys. Furthermore, in a concurrent study, we determined Red-winged Blackbird nest success was only 12.9% at the peak of their breeding season (early August), thus buffers may serve only as sink habitat for this species [40]. However, land managers should be attentive to potential crop damage by Red-winged Blackbirds or similar species.

4.4. Indigo Buntings

Indigo Buntings are a common forest-field edge species that will utilize woodland and grassland habitat in close proximity [57]. These birds may also be found in shrubby areas and weedy fields [58]. Indigo Buntings may also prefer edge habitat more irregular in shape than linear habitat [57, 59], such as that commonly provided by agricultural conservation buffers.

As with Dickcissels and Red-winged Blackbirds, Indigo Bunting density did not vary significantly between disturbed and undisturbed buffers during this study. Several studies, however, have shown Indigo Buntings respond positively to disturbance. In North American oak (*Quercus* spp.) savannahs, for instance, bunting densities increased following prescribed burns [60]. Indigo Buntings have also been frequently observed in New Hampshire clear-cut forest sites [61]. However, Indigo Bunting density can be least immediately following disturbance due to lack of vegetative cover. Frequent burning, for instance, can reduce shrub density and, in turn, Indigo Bunting density [62]. Also, Indigo Buntings preferred areas with dense herbaceous ground cover when white-tailed deer (*Odocoileus virginianus*) were excluded from forested sites in Virginia-Indigo Bunting density increased with time since exclusion [63].

Unmanaged agricultural conservation buffers may be able to provide more cover for Indigo Buntings than those that have recently been disturbed. With time, however, disturbed buffers could be preferred Indigo Bunting habitat as vegetation density in unmanaged buffers increases.

CONCLUSION

We were unable to support our hypothesis that prescribed fire is the best form of periodic disturbance to manage agricultural conservation buffers for breeding grassland birds. Though disturbance did not significantly affect diversity or density of breeding birds in the buffers, relative effect sizes indicated a potential biological significance in avian diversity and density between burned and disked buffers, possibly promoting the use of burning over disking.

Fire effects on herbaceous vegetation in agricultural conservation buffers will differ with frequency and intensity of burns, amount and type of litter cover, soil and biomass moisture, temperature, and wind speed [47]. This can benefit other vertebrate species other than birds, such as amphibians, reptiles, and small mammals [62]. Given variation among these aforementioned factors with both time and space, using prescribed burning can also lead to a heterogeneous landscape [64]. In Australia, for instance, the use of a patch mosaic burn (PMB) may further encourage landscape heterogeneity and biodiversity [64]. This technique, however, was not feasible given our buffers occurred in small, linear strips ranging from 0.17 to 3.12 ha, greatly limiting the number of ignition points [65]. The buffers in our study area, however, existed in a heterogeneous landscape that included pastures, woodlands, wetlands, and ponds. Such varying types of land cover may contribute to increasing biodiversity of flora and fauna in and around the buffers.

Prescribed burning for this study was performed during the dormant season in mid- to late March. This time is beneficial because it briefly removes winter cover for wildlife and it reduces the likelihood of harming breeding birds and their young. There is a risk, though, of negatively influencing other populations inhabiting the buffers, specifically insects that serve as an important food source for breeding birds. For instance, the abundance of litter-dwelling insects decreased after a prescribed burn in small prairies of the Midwestern United States [66]. To maintain agricultural conservation buffers as early-successional habitat for Northern Bobwhite (as was required in the buffers of our study), a disturbance is necessary to prevent woody plant encroachment. However, the inclusion of forbs, such as black-eyed susan and partridge pea in our buffers, will encourage greater insect populations in the buffers, particularly pollinating insects.

Disking can be used as an alternative to fire when the landscape does not permit safe burns. Disking can encourage biomass decomposition, expose bare ground, and increase nutrient availability [49]. Additionally, disking can promote insect activity by setting further back than burning, allowing forbs to become the dominant vegetation group. In the same buffers as our study, butterfly abundance increased 1- to 2-years post-disking due to the increase in forb abundance in the buffers [17]. Thus, we strongly recommend landowners consider their objectives when establishing and managing agricultural conservation buffers around their crop production fields.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

Data supporting the findings of the article are available in the Mississippi State University Institutional Repository at https://hdl.handle.net/11668/16484.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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