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Research Article

Effects of Haying on Breeding Birds in CRP Grasslands

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ABSTRACT The Conservation Reserve Program (CRP) is a voluntary program that is available to agricultural producers to help protect environmentally sensitive or highly erodible land. Management disturbances of CRP grasslands generally are not allowed unless authorized to provide relief to livestock producers during severe drought or a similar natural disaster (i.e., emergency haying and grazing) or to improve the quality and performance of the CRP cover (i.e., managed haying and grazing). Although CRP grasslands may not be hayed or grazed during the primary bird-nesting season, these disturbances may have short-term (1 yr after disturbance) and long-term ($\geq$2 yr after disturbance) effects on grassland bird populations. We assessed the effects of haying on 20 grassland bird species in 483 CRP grasslands in 9 counties of 4 states in the northern Great Plains, USA between 1993 and 2008. We compared breeding bird densities (as determined by total-area counts) in idle and hayed fields to evaluate changes 1, 2, 3, and 4 years after haying. Haying of CRP grasslands had either positive or negative effects on grassland birds, depending on the species, the county, and the number of years after the initial disturbance. Some species (e.g., horned lark [*Eremophila alpestris*], bobolink [*Dolichonyx oryzivorus*]) responded positively after haying, and others (e.g., song sparrow [*Melospiza melodia*]) responded negatively. The responses of some species changed direction as the fields recovered from haying. For example, densities for common yellowthroat (*Geothlypis trichas*), sedge wren (*Cistothorus platensis*), and clay-colored sparrow (*Spizella pallida*) declined the first year after haying but increased in the subsequent 3 years. Ten species showed treatment $\times$ county interactions, indicating that the effects of haying varied geographically. This long-term evaluation on the effects of haying on breeding birds provides important information on the strength and direction of changes in bird populations following a disturbance. Results from this study can help guide management of CRP and other grasslands and inform future agricultural programs that address biomass energy production. © 2016 This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS agricultural programs, breeding birds, Conservation Reserve Program, CRP, grassland, haying, mowing, northern Great Plains.

Although disturbances are fundamental elements in the ecology and maintenance of native and seeded grasslands (Kirsch et al. 1978, Duebbert et al. 1981, Kantrud 1981, Fuhlendorf and Engle 2001), management of Conservation Reserve Program (CRP) grasslands has been inadequate since the program's inception (Rodgers 2005). The 1985 Food Security Act excluded most commercial uses of CRP lands but permitted haying and grazing on eligible fields during droughts or excessive precipitation to provide relief to livestock producers (U.S. Department of Agriculture [USDA] 2003). Declarations for emergency assistance are made by the United States Secretary of Agriculture and vary by county and year. Emergency management of CRP is voluntary at the discretion of the landowner. Under an emergency declaration, typically only a fraction of the eligible CRP grasslands are hayed or grazed in any year or county (Renner et al. 1995, Allen and Vandever 2003), but repeated approval for emergency haying and grazing of CRP grasslands in some regions (e.g., northern and central Great Plains; Fig. 1) has been a contentious issue among the USDA, CRP participants, and those focused on the wildlife potential and long-term environmental benefits of CRP grasslands (Allen 1994, Renner et al. 1995, Allen et al. 2001, Rodgers 2005).

Despite the skepticism concerning emergency haying and grazing, researchers (Hays and Farmer 1990, Renner et al. 1995, Millenbah et al. 1996, Rodgers 2005) and CRP participants (Allen and Vandever 2003) have expressed similar interests in policies that incorporate periodic but controlled (i.e., managed) perturbations into the long-term management of CRP grasslands. The 2002 Farm Security

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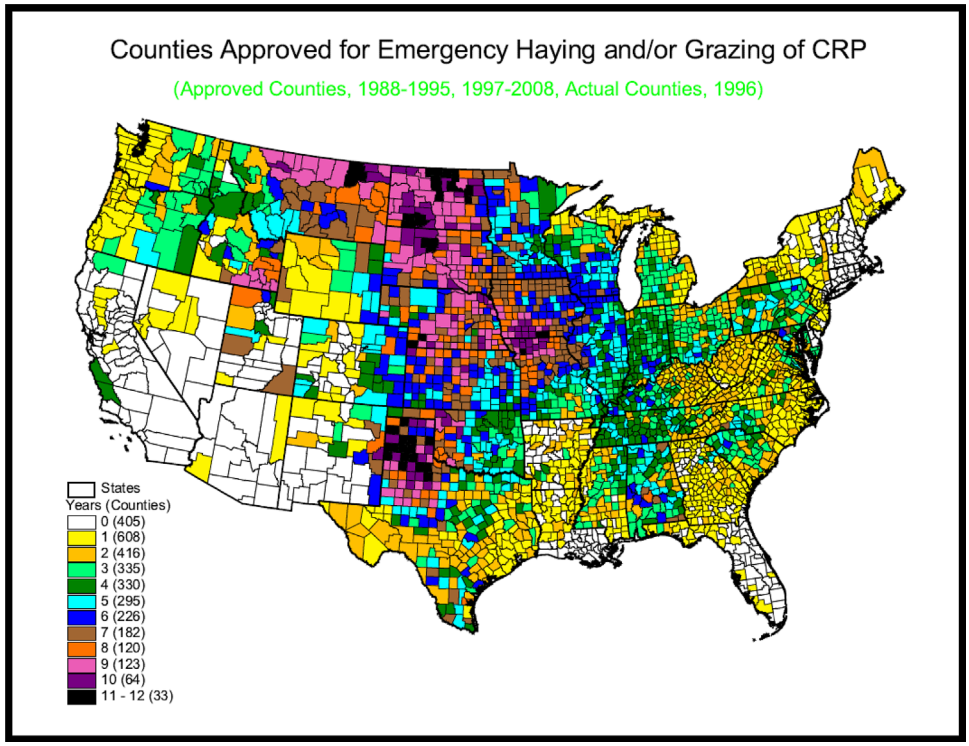

Figure 1. Frequency of approval for emergency haying and grazing in Conservation Reserve Program (CRP) grassland fields by county in the United States, 1988–2008. Map used with permission from the United States Department of Agriculture (J. Michaels, U.S. Department of Agriculture, Washington, D.C., USA).

and Rural Investment Act amended the CRP provisions of the 1985 Food Security Act by adding an exception for managed haying and grazing in CRP fields provided that these management practices are "consistent with the conservation of soil, water quality, and wildlife habitat (including habitat during nesting seasons for birds in the area)" (USDA 2003:24845). Managed provisions interact with emergency authorizations by incorporating CRP fields that had been hayed or grazed under an emergency authority into the managed haying and grazing disturbance cycle (USDA 2003). As with emergency haying and grazing, managed haying and grazing activities are voluntary. Moreover, given that there was no mechanism in place to evaluate the effects of managed haying and grazing on wildlife, it was only assumed that management was providing benefits (Campiche et al. 2011).

Of the 2 management alternatives (i.e., haying or grazing), haying appears to be the preferred option used by landowners under disaster or emergency declarations (Johnson 2000, Allen et al. 2001). Moreover, a majority of CRP participants have identified haying as the most acceptable management option for periodic non-emergency management (i.e., managed haying or grazing; Allen and Vandever 2003). The effects of haying of CRP grasslands on wildlife can be divided into 3 categories: immediate, short-term, and long-term (Jones-Farrand et al. 2007).

Immediate effects of haying on wildlife include effects that occur within the year of the disturbance. Immediate effects of haying have been well-studied and include the destruction or abandonment of active nests (Frawley and Best 1991, Dale et al. 1997, Giuliano and Daves 2002, McMaster et al. 2005, Luscier and Thompson 2009), mortality of adults or young (Rodenhouse et al. 1992, Calverley and Sankowski 1995), increased predation pressure on surviving adults and young (Bollinger et al. 1990), dispersal of breeding adults to other areas (Frawley and Best 1991, Igl 1991, Ingold et al. 2010), alteration of social and genetic mating patterns (Perlut et al. 2008), and alteration of the structure and composition of vegetative cover (Frawley and Best 1991, Luttschwager et al. 1994). To mitigate the immediate effects of haying, the USDA prohibits management activities in CRP during the primary nesting and brood-rearing seasons of grassland bird species (USDA 2003, Jones-Farrand et al. 2007).

Although CRP grasslands are hayed after the peak nesting and brood-rearing season, changes in vegetation may influence breeding bird populations in $\geq$1 year after the disturbance. Haying removes CRP vegetation that would become residual cover or litter in subsequent breeding seasons (Luttschwager et al. 1994, Renner et al. 1995, Horn and Koford 2000, Johnson 2000, Roth et al. 2005). Haying also may alter plant species composition in future years (Allen et al. 2001).

Jones-Farrand et al. (2007) considered short-term effects of haying on wildlife to include those that manifest themselves within a year after haying (e.g., decrease or increase in densities of breeding pairs or nests). A few studies have focused on the short-term effects of haying on grassland birds (e.g., Luttschwager et al. 1994, Renner et al. 1995,

Horn and Koford 2000, McCoy et al. 2001, Roth et al. 2005). Jones-Farrand et al. (2007) defined long-term effects as those that persist or become apparent ≥2 years after haying. The long-term effects of haying on breeding bird populations in CRP or other grasslands are unknown or poorly understood for most grassland birds.

Attaining the long-term conservation benefits associated with CRP will require information on the short- and long-term effects of repeated disturbance events. Between 1993 and 2008, we conducted annual surveys of breeding birds in several hundred CRP grassland fields in 9 counties in North Dakota, South Dakota, Minnesota, and Montana (Johnson and Schwartz 1993*a*, *b*; Johnson and Igl 1995, 2001). In nearly every year since 1993, droughts, excessive precipitation, or political and economic pressures led to the release of CRP grasslands for emergency haying or grazing in ≥1 county in those 4 states. Beginning in 2003, periodic managed disturbances also were allowed on eligible CRP fields to increase the diversity and quality of vegetative cover and to improve wildlife habitat benefits. Data from these bird surveys provide an opportunity to evaluate short- and long-term impacts of emergency and managed haying on grassland birds, many of which are declining throughout North America (Sauer et al. 2009). The objective of this study is to assess the influence of haying—the most preferred management option in this region—on changes in breeding bird populations in selected CRP grasslands in 1993–2008 by comparing breeding abundance within undisturbed (idle) fields and fields that had been hayed 1, 2, 3, or 4 years earlier.

STUDY AREA

We selected 9 counties in the northern Great Plains and the Interior Lowlands in the north-central United States for sampling to include 1 county representing each of the 4 major physiographic regions within the grassland areas of North Dakota, South Dakota, Minnesota, and Montana (Fig. 2; Johnson and Schwartz 1993*a*, *b*). We selected the counties to provide a wide spatial distribution, a representation of regional landforms, and a reasonably large number of fields of many sizes enrolled in the CRP. The 9 counties included Fallon County in Montana, Hettinger County in North Dakota, and Butte County in South Dakota, all in the Great Plains Roughlands; Sheridan County in Montana, Kidder County in North Dakota, and McPherson County in South Dakota, all in the Missouri Coteau; Eddy County in North Dakota and Day County in South Dakota, both in the Drift Prairie; and Grant County, Minnesota, in the Black Prairie. The topography of the area ranges from rugged unglaciated badlands in the Great Plains Roughlands, to gently or moderately rolling uplands in the Drift Prairie and Missouri Coteau, to flat ancient lake beds in the Black Prairie.

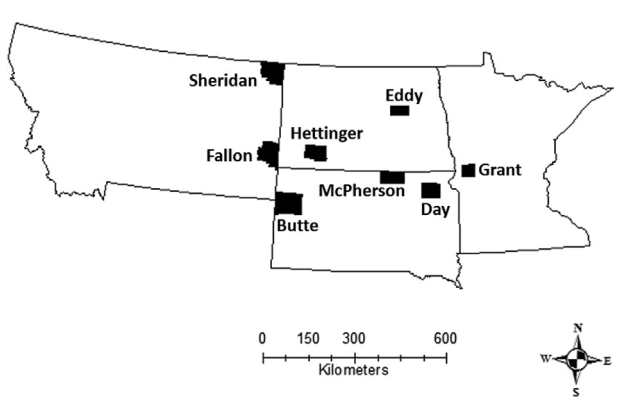

Figure 2. Counties in which we surveyed Conservation Reserve Program grassland fields for breeding birds in North Dakota, South Dakota, Minnesota, and Montana, 1990–2008.

METHODS

CRP Field Selection

We selected CRP fields based on several considerations. In each county, we selected fields with a broad range of field sizes to ensure representation of a variety of birds that use grasslands in this region. We selected fields with well-established vegetation (>2 yr after planting) because they afforded more mature cover and thus a better perspective on long-term, rather than transient, effects. We limited our CRP study fields to those enrolled in the following CRP conservation practices (CP): CP1 (new introduced grasses and legumes), CP2 (new native grasses), CP4D (permanent wildlife habitat), and CP10 (existing grasses and legumes; Johnson and Schwartz 1993*b*). All of the fields were dominated by grasses or other herbaceous vegetation in the year that they were selected, and all 4 conservation practices were eligible for emergency or managed haying or grazing.

Most fields (about 70%) had been planted to non-native grasses and legumes and the remaining were planted to native vegetation (Johnson and Schwartz 1993*b*). A few of the CRP fields contained tree plantings (CP3 or CP3A), wildlife food plots (CP12), or wetlands; for this evaluation, we excluded from consideration any data collected in tree plantings, food plots, and wetlands. With a single bird survey in a CRP field within a given year, we were able to incorporate several hundred independent samples over an extensive area. Different CRP fields replaced original CRP fields that were no longer enrolled in the program or for which permission to access the field was denied.

In the 4 counties, haying and other management activities occurred on or after 15 July (i.e., after the birds were surveyed). The vegetation in a few fields (<1%) were accidentally or intentionally burned after 15 July. Some fields were spot-mowed or spot-sprayed for weed control in some years. Most of these spot perturbations affected only small weed-infested areas within a field. Rarely, weed control involved whole-field manipulations (i.e., mowing), but those maintenance or management activities occurred after the primary breeding season.

Each year, we contacted landowners and operators by telephone or in person to request permission to survey breeding birds on their CRP field(s). Fields that were wholly or partially hayed or grazed were identified by landowners, county offices of the USDA's Farm Service Agency (FSA), or

field observers. We did not attempt to influence the landowner's decisions to graze, hay, or otherwise manage a CRP field, nor were we aware of the landowner's motivations behind these decisions.

We assigned fields or portions of the fields to treatments in each year depending upon whether the field had been idle, hayed, grazed, or burned the previous year. To account for any delayed effects of management, we further categorized treatment assignments based on the number of years after the disturbance, up to 5 years. If treatment assignments were interrupted by another disturbance before the fifth year post-treatment, treatment assignments began again from the first year post-disturbance. After 5 years from the initial disturbance, the field was treated as idle, regardless of the management technique that had been used. If portions of fields were treated differently within or among years, we used the following criteria to categorize treatments. We assigned the field to the predominant treatment if >80% of the field had been so treated. We excluded from analysis fields on which no treatment dominated (≤80% of the area).

Some individual fields were subject to multiple disturbances over the course of the study, and the frequency of disturbances in individual fields decreased the sample size of treatments in the later post-disturbance years. We did not evaluate the effects of 1 haying treatment (5-yr post-treatment) or any grazing and burning treatments on grassland bird densities because of small sample sizes.

Breeding Bird Surveys

Bird survey procedures conformed to recommendations of The Ornithological Council (Fair et al. 2010) for the study of wild birds and followed the protocols contained in Study Plan 00136.01, which was approved on 28 June 1991 by the Chairperson of the Animal Care and Use Committee at Northern Prairie Wildlife Research Center. We conducted total-area counts of breeding birds using a minor modification of the strip-transect procedures described by Stewart and Kantrud (1972) and Igl and Johnson (1997). This survey method originally was designed by Stewart and Kantrud (1972) to survey breeding birds on an entire legal quarter-section (800 × 800 m, 64.74 ha) using 2 observers, each simultaneously surveying the breeding birds on a rectangular half (800 × 400 m; 32.38 ha) of the quarter-section and each following a standardized survey route. In this study, field size and shape varied considerably; this required us to modify the survey methodology accordingly. We surveyed CRP fields once each year by 1 or 2 observers walking slowly (1.0–1.5 km/hr) on foot. This rate of progress allowed 1 or 2 observers to efficiently cover 1 large field or several smaller fields in a short period of time (1–2 hr), and was implicit in balancing the length of exposure to individual breeding pairs and reducing duplication of counts.

A single observer usually surveyed small fields (≤32.4 ha); 2 observers typically surveyed large fields (>32.4 ha), each covering about half of the field. The 2 observers usually surveyed the halves simultaneously. The number, placement, length, and orientation of transects varied among fields depending upon the field size and shape but were consistent among years. Strip width never exceeded 100 m on either side of the transect line. As recommended by Stewart and Kantrud (1972), deviations from the route were sometimes necessary to adequately survey all portions of the fields (e.g., in rolling topography) or to track down elusive individuals to confirm identification. We recorded large or wide-ranging birds (e.g., raptors) that flushed from the field upon the observer's arrival or during the survey as being within the field. In fields surveyed by 2 observers, observers compared field notes at the end of the survey to prevent duplication in the counts of large or wide-ranging birds or birds that occurred along the shared survey boundary.

Prior to entering the field, observers were trained in distance estimation, regional bird identification (i.e., aural, visual, and nest), and identification of management treatments. An experienced observer accompanied new observers for several surveys at the beginning of each field season to establish a consistent protocol before proceeding to collect data independently. Observers periodically recalibrated their distance estimation during the field season.

Observers identified all breeding birds based on visual or aural observations of adults or the presence of an active nest. We conducted surveys of breeding birds between 0.5 hours before sunrise and the midday lull in bird activity, which varies from day to day but usually occurs in the early afternoon in our study area. We avoided censusing birds in adverse weather conditions (e.g., heavy precipitation, sustained winds stronger than 24 km/hr). Stewart and Kantrud (1972) used less restrictive standards related to wind speed in open grasslands to provide observers with more time and dates to complete bird surveys.

We conducted breeding bird surveys from late May to early July each year, which coincides with the peak breeding season of breeding birds in this region (Stewart and Kantrud 1972, Stewart 1975, Igl and Johnson 1997). To compensate for phenological differences, the sequence in which we surveyed counties progressed from south to north (Fig. 2). We surveyed the fields within each county within a 3–5 day period, and standardized the order that we surveyed the 9 counties.

Counts of birds were based primarily on the number of indicated breeding pairs on territories or home ranges. We recorded breeding pairs within the management treatment in which they occurred. For most species, nearly all indicated pairs were observed as territorial males or as segregated pairs. In the case of wide-ranging or colonial-nesting species that are not sexually dimorphic (e.g., most raptors, grouse, shorebirds, swallows), we considered 1 or 2 individuals to represent a pair, but if we observed >2 individuals on a study plot, we derived the number of indicated pairs by halving the number of individuals counted and rounding up to the nearest whole pair. For the polygynous red-winged blackbird (*Agelaius phoeniceus*), the number of breeding pairs was based on the number of males and represented, in terms of breeding mates, a minimum population. We based the number of indicated pairs of brown-headed cowbird (*Molothrus ater*) on the number of females. We counted birds that were flying overhead only if they were actually using the field (e.g.,

flycatching, courtship or communal displaying, hunting). We counted any pair or lone singing male that occurred on a field border or fence as 0.5 pair, based on the assumption that field edges divide the average edge territory into 2 equal parts (Verner 1985).

The procedures used to determine the number of pairs of breeding waterfowl followed Hammond (1969). In general, we considered single pairs, lone males of dabblers or divers, and lone females of diving ducks to be an indicated pair. Occasionally, the number of lone female ducks on a CRP field exceeded the number of males unaccompanied by females. In this case, we considered each excess lone female to represent a pair.

In this study, we did not consider certain birds observed during the surveys to be using the CRP fields or associated wetlands and excluded them from our results. These included migrant flocks, over-summering shorebirds (i.e., transient shorebirds remaining in the focal region during the boreal summer), wide-ranging colonial waterbirds (e.g., pelicans, cormorants, egrets, herons) passing high overhead, and other birds passing overhead in high, direct flight. We recorded lone juveniles but did not consider them part of the breeding population at a site; however, we counted a single adult or a pair of adults accompanied by $\geq$1 juvenile as a single pair.

Statistical Analyses

We conducted statistical analyses with SAS software (version 9.1) for Windows (SAS Institute 2004). We used mixed-effects linear models to evaluate differences in breeding bird densities between idle fields and those surveyed 1, 2, 3, and 4 years after haying. Prior to analysis, we transformed breeding bird densities using a $\ln(y + 1)$ transformation. We modeled variation in breeding bird densities using PROC MIXED in SAS with the PDIFF option in LSMEANS (SAS Institute 2004, Littell et al. 2006). We used PROC MIXED because our analyses included fixed effects (i.e., treatment, county, and their interaction) and random effects (i.e., field nested within county, treatment by field nested within county). The random effects structure of our model allowed us to account for spatial variation (fields nested within counties). Because of the wide range in field sizes, we used the square root of field area in the mixed model as a weighting factor. We investigated tests of main effects and interactions by computing estimates of model-adjusted least-squares means and standard errors. We used Fisher protected differences of least squares means (lsmeans) to evaluate significant main effects and interactions (Milliken and Johnson 1992). Unless stated otherwise, we used a significance level of 0.05 in all statistical analyses. We did not include year in the models because we had no control over when and which fields were hayed, and not all treatments occurred in every year. We did not expect breeding bird densities to be the same among counties (Johnson and Schwartz 1993*b*), and thus, we do not discuss differences in abundances among counties except in relation to significant treatment $\times$ county interactions (i.e., to evaluate differences in treatment effects among counties). For species showing treatment effects or treatment $\times$ county interactions, we summarized the strength and direction of a species' response to haying by generating *t*-statistics that compared idle fields and fields 1, 2, 3, and 4 years after haying.

RESULTS

Between 1993 and 2008, we surveyed breeding birds on 483 different grassland fields enrolled in CRP. On average, we surveyed 320 CRP fields/year (Table 1), including 25–41/county/year. The average size of a CRP field was 17.9 ha (SD = 4.1, range <1–110.3 ha). The average area surveyed/year was 5,631.0 $\pm$ 585.5 ha. Haying was the preferred management option for landowners in this region and accounted for 89% of 825 occurrences of haying, grazing, or burning during the 16-year period. The average number of disturbances per CRP field ranged from 0.35 disturbances per field in Grant County to 2.71 disturbances per field in Hettinger County (Table 2). Although all 9 counties were eligible for emergency haying or grazing in at least 5 years between 1988 and 2008 (Fig. 1), and all fields were eligible for managed haying or grazing beginning in 2003 (USDA 2003), 20–75% of the fields in a county were never hayed, grazed, or burned during the study period. Of the fields that were disturbed, 11–34% were hayed, grazed, or burned only once, 4–24% were disturbed twice, and 2–51% were disturbed 3 or more times between 1993 and 2008. The average number of years between disturbances for fields that had been disturbed more than once was less than 5 years in each county and ranged from 3.04 years in Day County to 4.75 years in Grant County. The maximum number of

Table 1. Average number of Conservation Reserve Program grassland fields surveyed/year, average area (ha) surveyed/year, and average field size (ha) surveyed/year for breeding birds in 9 counties in the northern Great Plains, USA, 1993–2008. The 9 counties are ordered from west to east.

County	Average no. fields surveyed/yr (SD)	Average area surveyed/yr (SD)	Average field size surveyed/yr (SD)
Sheridan, MT	36.5 (1.9)	668.0 (55.8)	18.3 (1.1)
Fallon, MT	31.9 (2.6)	559.5 (68.6)	17.6 (1.6)
Butte, SD	25.1 (4.2)	658.8 (104.6)	26.4 (2.0)
Hettinger, ND	36.1 (1.2)	717.8 (97.4)	19.9 (2.9)
Kidder, ND	39.8 (5.6)	691.8 (141.0)	17.3 (1.8)
McPherson, SD	36.3 (3.3)	694.6 (104.6)	19.1 (2.1)
Eddy, ND	40.7 (1.5)	704.4 (79.3)	17.3 (1.7)
Day, SD	37.8 (6.6)	481.4 (104.9)	12.8 (1.9)
Grant, MN	35.8 (1.5)	454.8 (38.8)	12.7 (1.0)
Total	319.9 (20.0)	5,631.0 (585.5)	17.9 (4.1)

Table 2. Disturbance history within Conservation Reserve Program (CRP) fields in 9 counties in 4 states in the northern Great Plains, USA, 1993–2008. The 9 counties are ordered from west to east.

County	Average haying or grazing events/field (SD)	Proportion of CRP fields that were hayed or grazed				$\bar{x}$ years between haying or grazing events[a] (SD)	Max. no. haying or grazing events in an individual field	No. years under emergency declaration (1988–2008)[b]
		Never	Once	Twice	Thrice or more			
Sheridan, MT	1.74 (1.74)	0.30	0.26	0.13	0.30	4.58 (1.98)	6	10
Fallon, MT	1.19 (1.48)	0.40	0.34	0.10	0.16	3.47 (1.14)	6	8
Butte, SD	1.22 (1.53)	0.41	0.26	0.22	0.11	4.44 (2.17)	6	8
Hettinger, ND	2.71 (2.27)	0.22	0.11	0.16	0.51	4.25 (1.89)	10	11
Kidder, ND	1.97 (1.82)	0.25	0.22	0.19	0.34	4.09 (1.95)	7	9
McPherson, SD	2.22 (2.20)	0.20	0.27	0.22	0.31	3.67 (2.24)	10	8
Eddy, ND	1.54 (1.73)	0.35	0.20	0.24	0.20	4.56 (1.83)	9	10
Day, SD	2.51 (2.74)	0.35	0.13	0.14	0.38	3.04 (1.47)	10	7
Grant, MN	0.35 (0.74)	0.75	0.19	0.04	0.02	4.75 (2.38)	4	5

[a] The average number of years between disturbances for fields that had been hayed or grazed more than once between 1993 and 2008.
[b] The number of years that a county had been authorized for haying or grazing under an emergency declaration (1988–2008).

disturbance events in an individual field ranged from 4 in Grant County to 10 in Hettinger, McPherson, and Day counties. Hereafter, we summarize data only for idle and haying treatments.

Over the 16-year period, we observed 121 breeding bird species in the CRP grasslands that were idle or that had been hayed 1, 2, 3, or 4 years earlier (excluding wetlands, food plots, and tree plantings that were associated with the fields). For analyses, we selected 20 species that commonly use grasslands in this region during the breeding season (Table 3). Of these 20 species, Savannah (*Passerculus sandwichensis*), clay-colored (*Spizella pallida*), and grasshopper sparrows (*Ammodramus savannarum*) were the most abundant species, accounting for 44% of the breeding pairs in idle CRP fields and 31–51% of the breeding pairs in CRP fields 1–4 years after haying. Populations of 16 of the 20 species declined significantly in North America between 1966 and 2008, based on data from the North American

Table 3. General linear model tests for the effects of treatment (hayed 1, 2, 3, or 4 years previously), county, and the interaction of treatment and county on breeding densities of 20 bird species using idle and hayed Conservation Reserve Program grasslands in 9 counties in 4 states in the northern Great Plains, 1993–2008.

Species	Source of variation					
	Treatment		County		Treatment × county	
	$F_{4,316}$	P	$F_{8,316}$	P	$F_{32,316}$	P
No detectable response or weak response						
Ring-necked pheasant	1.31	0.266	22.37	<0.001	1.02	0.436
Upland sandpiper	1.40	0.233	12.27	<0.001	1.26	0.162
Grasshopper sparrow	2.08	0.083	28.96	<0.001	1.27	0.158
Western meadowlark	0.58	0.675	58.69	<0.001	1.28	0.147
American goldfinch	2.15	0.075	5.76	<0.001	0.61	0.952
Treatment effect						
Eastern kingbird	3.44	0.009	3.71	<0.001	1.09	0.348
Common yellowthroat	5.22	<0.001	31.71	<0.001	1.33	0.118
Song sparrow	3.13	0.015	8.15	<0.001	0.87	0.680
Bobolink	3.59	0.007	18.63	<0.001	1.21	0.205
Brown-headed cowbird	3.26	0.012	8.81	<0.001	1.22	0.199
Treatment effect varied geographically						
Northern harrier	3.54	0.008	3.02	0.003	1.50	0.043
Horned lark	8.71	<0.001	15.43	<0.001	3.04	<0.001
Sedge wren	19.39	<0.001	44.70	<0.001	2.80	<0.001
Clay-colored sparrow	15.11	<0.001	39.58	<0.001	1.49	0.048
Lark bunting	1.46	0.215	53.72	<0.001	1.79	0.007
Savannah sparrow	4.50	0.002	31.28	<0.001	1.53	0.036
Baird's sparrow	1.27	0.282	24.80	<0.001	1.61	0.022
Le Conte's sparrow	2.02	0.091	52.66	<0.001	2.55	<0.001
Dickcissel	1.02	0.396	6.39	<0.001	1.62	0.021
Red-winged blackbird	7.02	<0.001	14.61	<0.001	1.89	0.003

Breeding Bird Survey; populations of 1 species (sedge wren [*Cistothorus platensis*]) significantly increased (Sauer et al. 2009).

Treatment Effects on Grassland Birds

We found no detectable response or only a marginal response to treatments for 5 species (i.e., the main effect of treatment and the treatment × county interaction was not significant; Table 3). These species were ring-necked pheasant (*Phasianus colchicus*), upland sandpiper (*Bartramia longicauda*), grasshopper sparrow, western meadowlark (*Sturnella neglecta*), and American goldfinch (*Carduelis tristis*; Fig. 3). Differences in densities among treatments approached statistical significance ($0.05 < P < 0.10$) for the American goldfinch and the grasshopper sparrow (Table 3).

Five species showed consistent treatment effects over all counties (Table 3). Densities of 4 of these species, eastern kingbird (*Tyrannus tyrannus*), common yellowthroat (*Geothlypis trichas*), song sparrow (*Melospiza melodia*), and brown-headed cowbird, declined in the first year after haying, peaked above idle densities 2 or 3 years after haying, and returned to idle levels by the fourth year after haying (Fig. 4). Densities of the fifth species, bobolink (*Dolichonyx oryzivorus*), were higher in CRP fields that had been hayed than CRP fields that remained idle; these differences persisted for the 4 years after haying.

Ten species showed treatment × county interactions, indicating that the effects of haying varied geographically for these species (Table 3, Fig. 5, Appendix). Some species (e.g., sedge wren, clay-colored sparrow) showed consistent responses to haying among counties where they were most abundant and others (e.g., northern harrier [*Circus cyaneus*])

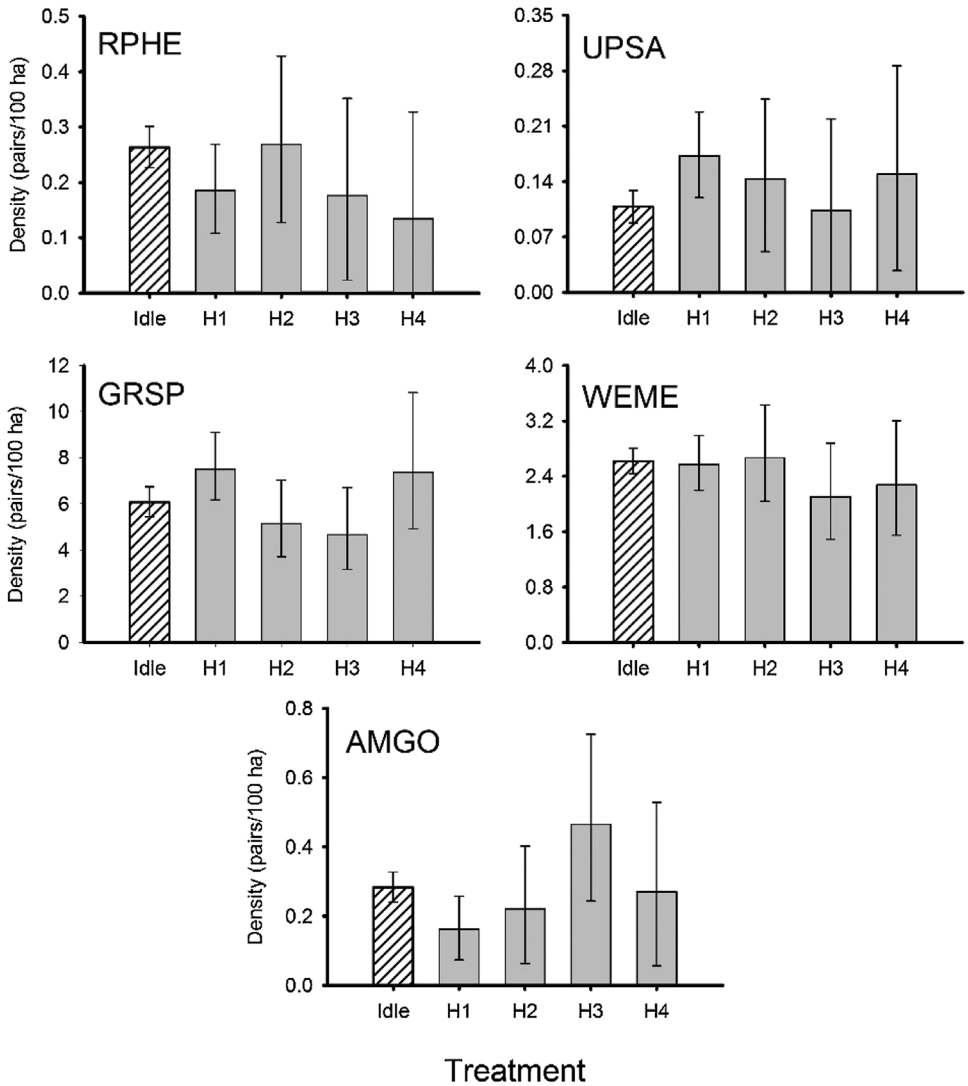

Figure 3. Breeding bird abundance in Conservation Reserve Program (CRP) grassland fields for species that showed no detectable response to treatment, northern Great Plains, USA, 1993–2008. Bars indicate back-transformed least squares mean densities (pairs/100 ha) for idle CRP fields and fields that had been hayed 1 (H1), 2 (H2), 3 (H3), and 4 (H4) years earlier. Error bars indicate upper and lower 95% confidence limits. Four-letter alpha codes for bird species are defined as ring-necked pheasant (RPHE), upland sandpiper (UPSA), grasshopper sparrow (GRSP), western meadowlark (WEME), and American goldfinch (AMGO).

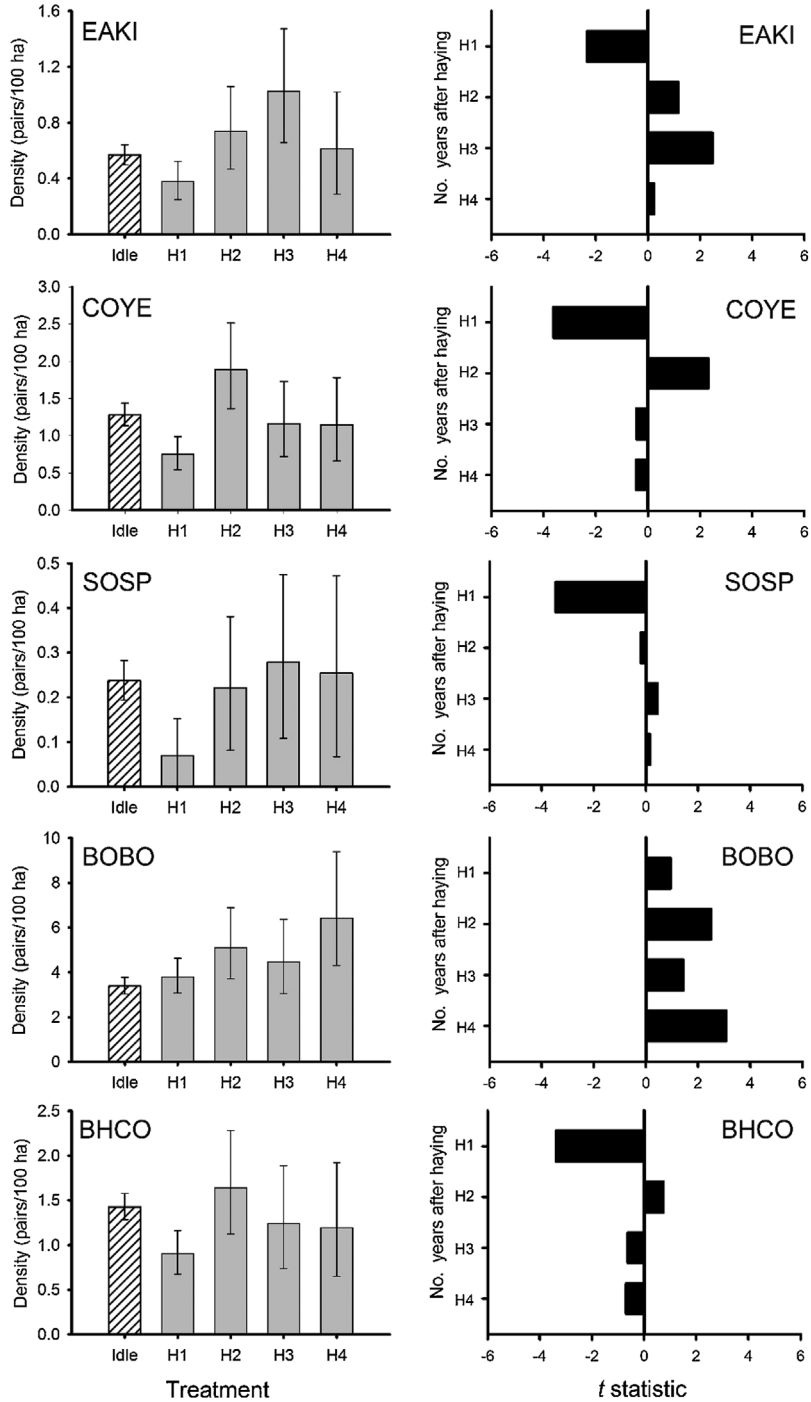

Figure 4. Breeding bird abundance in Conservation Reserve Program (CRP) grassland fields for species that showed a significant response to treatment, northern Great Plains, USA, 1993–2008. Bars indicate back-transformed least squares mean densities (pairs/100 ha) for idle CRP fields and fields that had been hayed 1 (H1), 2 (H2), 3 (H3), and 4 (H4) years earlier. Error bars indicate upper and lower 95% confidence limits. The strength and direction of a species' response to haying are summarized by *t*-statistics (df = 316) that show comparisons between idle and 1, 2, 3, and 4 years after haying (for reference, a *t*-statistic of 1.968 with 316 degrees of freedom has a *P*-value of 0.05). Four-letter alpha codes for bird species are defined as eastern kingbird (EAKI), common yellowthroat (COYE), song sparrow (SOSP), bobolink (BOBO), and brown-headed cowbird (BHCO).

did not show a consistent pattern. Northern harriers occurred in CRP fields in all 9 counties but at relatively low densities in each; compared to idle CRP fields, harrier densities were generally lower in the first year after haying in 8 of the 9 counties but responses were inconsistent in subsequent years. The horned lark (*Eremophila alpestris*) was most common in the westernmost counties, where densities increased the first year after haying but generally returned to near or below idle levels in the second through fourth years after haying. The sedge wren and clay-colored sparrow were most common in the 6 counties in the Prairie Pothole Region (excluding Fallon, Butte, and Hettinger counties), and both species

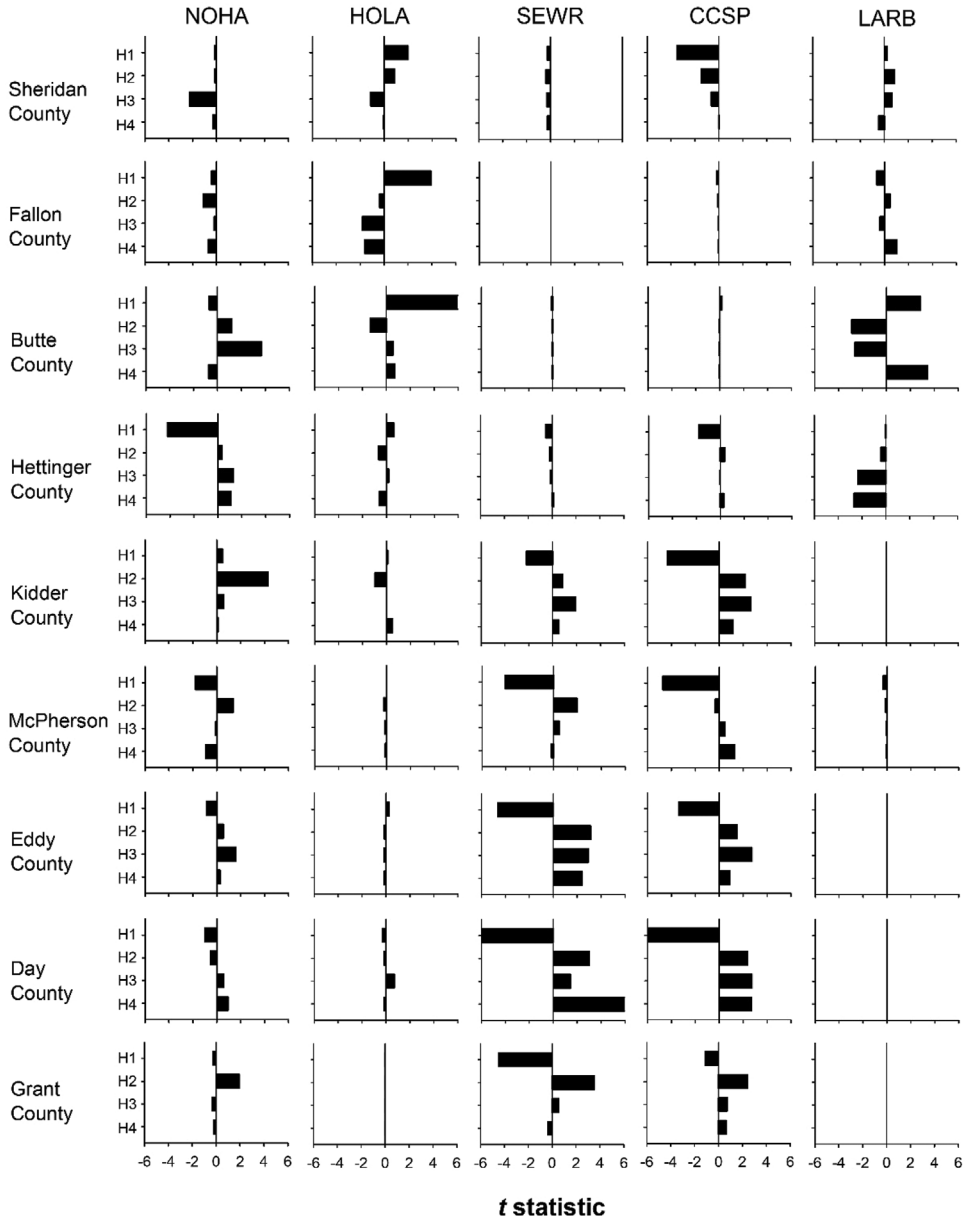

Figure 5. Species' response to haying in Conservation Reserve Program grasslands for species that showed a significant treatment × county interaction, northern Great Plains, USA, 1993–2008. The strength and direction of a species' response to haying are summarized by *t*-statistics (df = 316) that show comparisons between idle and 1 (H1), 2 (H2), 3 (H3), or 4 (H4) years after haying (for reference, a *t*-statistic of 1.968 with 316 degrees of freedom has a *P*-value of 0.05). Four-letter alpha codes for bird species are defined as northern harrier (NOHA), horned lark (HOLA), sedge wren (SEWR), lark bunting (LARB), Savannah sparrow (SAVS), Baird's sparrow (BAIS), Le Conte's sparrow (LCSP), dickcissel (DICK), and red-winged blackbird (RWBL). The 9 counties are ordered from west to east.

showed similar patterns in their response to haying among counties. Both species declined in the first year after haying and generally increased in the second through fourth years after haying; the magnitude of the difference in their response generally increased from west to east.

The lark bunting (*Calamospiza melanocorys*) occurred most commonly in the southwestern counties, where it showed no consistent pattern among counties in response to haying. Savannah sparrows were found in CRP fields in all 9 counties, with lowest densities occurring in the southwestern counties; Savannah sparrow also showed no consistent pattern among counties in response to haying although there was a tendency toward higher densities in fields that had been hayed compared to idle CRP fields. We observed Baird's sparrows (*Ammodramus bairdii*) in CRP fields in 7 of the 9 counties, with highest densities being the highest in the westernmost counties; in general, Baird's sparrow densities declined in all years after haying. Le Conte's sparrows (*Ammodramus leconteii*) occurred in 8 of the 9 counties, with highest densities in the north-central counties; although the species generally declined in the first year after haying in most counties, there was no consistent pattern in subsequent years. Dickcissels (*Spiza americana*) were present in CRP fields in 8 of the 9 counties but at relatively low densities; there was no consistent pattern among counties. Red-winged blackbirds were present in CRP fields in all 9 counties, and at

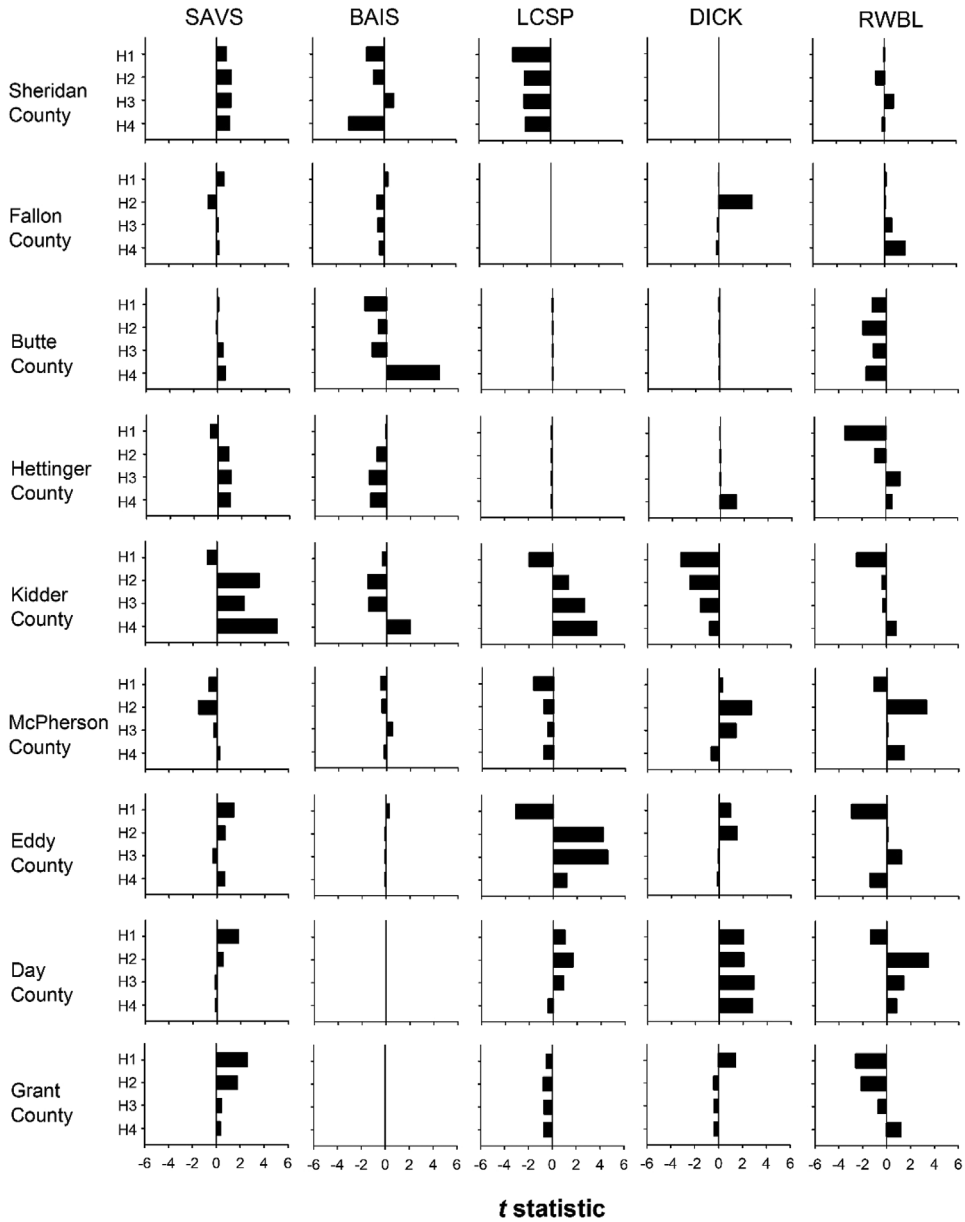

Figure 5. Continued.

highest densities in the easternmost counties. Compared to idle CRP, red-winged blackbird densities in most counties were lower in the first year after haying, but the responses in subsequent years were inconsistent among counties.

DISCUSSION

Conservation Reserve Program grasslands in the northern Great Plains support a wide variety of birds during the breeding season, including many species of grassland birds that have declined throughout their breeding ranges in North America (Sauer et al. 2009). Our study examined how haying disturbances influence changes in breeding bird populations in CRP grasslands by comparing breeding abundance within undisturbed (idle) fields and fields that had been hayed 1, 2, 3, or 4 years earlier. Despite the long history of repeated approval of emergency authorizations in CRP grasslands (Fig. 1), and the strong interest in the frequency of disturbances in these habitats (USDC 2006), surprisingly very few studies have evaluated short-term effects of haying on breeding birds in CRP grasslands, and even fewer have studied long-term effects. For example, in North Dakota, Horn and Koford (2000) compared the relative abundance of several bird species between CRP grasslands that had been emergency hayed 1 year earlier and CRP fields that remained idle. Murray and Best (2003) in Iowa and Roth et al. (2005) in Wisconsin compared grassland bird abundances in CRP switchgrass (*Panicum virgatum*) fields that had been cut and harvested the previous to those in idle CRP switchgrass fields. In North and South Dakota, Luttschwager et al. (1994) and Renner et al. (1995) compared waterfowl nest densities and reproductive success in CRP grasslands hayed the previous year and idle CRP fields. Our study is the longest evaluation on the effects of haying on breeding birds in CRP grassland fields.

Our results indicate that grassland bird response varied depending on the species, the county, and the number of years after the initial disturbance. Some species (e.g., western meadowlark) showed no detectable response to haying. Other species (e.g., horned lark, bobolink) responded positively after haying, and others (e.g., song sparrow) responded negatively. The responses of some species (e.g., common yellowthroat, sedge wren, clay-colored sparrow) changed direction as the fields recovered from haying. For some species (e.g., dickcissel, lark bunting), the effects of haying varied geographically. Below we compare our results to those from previous studies.

Species Showing No Detectable Response or a Weak Response to Haying

Our results indicated that 5 species had no detectable response (ring-necked pheasant, upland sandpiper, and western meadowlark) or a weak response (grasshopper sparrow and American goldfinch) to haying. The American goldfinch nests in shrubs and small trees and forages in open grasslands, and the ring-necked pheasant, upland sandpiper, western meadowlark, and grasshopper sparrow are strongly dependent on grassland habitats during the breeding season (Giudice and Ratti 2001, Johnson et al. 2004). Murray and Best (2003) also reported no differences in abundances of pheasant, upland sandpiper, meadowlarks (*Sturnella* spp.), and American goldfinch between CRP grasslands that had been cut and harvested the previous year and CRP grasslands that remained idle. Murray and Best (2003), however, reported that grasshopper sparrow abundance was higher in switchgrass CRP grasslands that had been hayed the previous year than in those that remained idle; the grasshopper sparrow also was the only species in their study that preferred hayed over idle strips in strip-harvested plots. In Wisconsin, Roth et al. (2005) reported no differences in abundances of pheasants and goldfinches in switchgrass CRP fields that had been harvested the previous year and those that remained idle. Grasshopper sparrow, western meadowlark, and upland sandpiper occurrence, however, increased in transects in the year after switchgrass harvest. In North Dakota, Horn and Koford (2000) reported no difference in grasshopper sparrow and American goldfinch abundances in CRP grasslands that had been idle or emergency hayed the previous year. In Pennsylvania, grasshopper sparrows showed no consistent response to previous-year mowing (Brauning et al. 2001). In Missouri, Winter (1998) reported that grasshopper sparrow densities increased above idle levels in tallgrass prairie fragments that had been hayed 1 year earlier but decreased with the number of years since haying.

Frawley and Best (1991) suggested that the western meadowlark's large territory size may confound evaluations of management because the male's territory may overlap both disturbed and undisturbed habitats. Hays and Farmer (1990) reported that vegetation changes associated with emergency haying of CRP fields 1 year earlier could favor the western meadowlark and its congener, the eastern meadowlark (*Sturnella magna*). In mixed-grass prairies in North Dakota, western meadowlark abundance was higher in plots that had been hayed the previous year than in lightly, moderately, or heavily grazed plots (Kantrud 1981). In Saskatchewan, Dale et al. (1997) reported that western meadowlarks were more abundant in hay fields that had been hayed 1 year earlier than in hay fields that had been hayed several years earlier.

Species Showing Treatment Effects

In our study, 5 species showed a significant response to haying: eastern kingbird, common yellowthroat, song sparrow, bobolink, and brown-headed cowbird (Fig. 4). Of these 5 species, the yellowthroat, song sparrow, and cowbird are habitat generalists with fairly broad habitat preferences during the breeding season, including marshes, tall grasslands, and areas with shrubs and small trees (Stewart 1975, Johnson 1997), and the eastern kingbird forages in open grasslands and nests in open areas with low to moderate cover of woody vegetation (Askins et al. 2007). All 4 species, thus, might be expected to show at least short-term declines as a result of changes in vegetation associated with haying, and indeed our results indicate that these species favored idle fields over those that had been hayed 1 year earlier. For all 4 species, their densities returned to idle levels by the fourth year after haying. Bobolinks, on the other hand, prefer grasslands that are moderately tall and dense with moderately deep litter and sparse woody vegetation (Johnson et al. 2004). In our study, bobolinks favored CRP fields that had been hayed in previous years, and their densities remained above idle levels up to the fourth year after haying.

In contrast, in Iowa, Murray and Best (2003) reported no differences in abundances for the above 5 species between CRP plots that had been cut and harvested the previous year and CRP plots that remained idle. For fields that had been strip-harvested, however, Murray and Best (2003) reported that use by yellowthroats and song sparrows was greater in idle strips than in strips that had been cut the previous year. In North Dakota, Horn and Koford (2000) also did not detect differences in abundance for yellowthroats, song sparrows, cowbirds, and bobolinks between idle CRP grasslands and CRP grasslands that had been emergency hayed 1 year earlier. In Saskatchewan, bobolink abundance was higher in annually or periodically (idle for 4–8 years) hayed grasslands than in idle mixed-grass prairie (Dale et al. 1997). In mixed-grass prairies in North Dakota, bobolink abundance was much higher in plots that had been hayed the previous year than in lightly, moderately, or heavily grazed plots (Kantrud 1981).

Species Showing Treatment Effects That Varied Geographically

For 10 species, treatment effects varied geographically. Five of those species (i.e., northern harrier, lark bunting, Baird's sparrow, Le Conte's sparrow, dickcissel) have irruptive tendencies during the breeding season; their distributions and abundances may fluctuate dramatically from 1 year to the next in relation to precipitation patterns, food availability, or habitat conditions elsewhere in their breeding ranges (Hibbard 1965, Kantrud and Faanes 1979, Roth 1979, Grant et al. 1991, Igl and Johnson 1999). These fluctuations might confound detecting a consistent management response.

The northern harrier generally prefers grasslands characterized by tall, dense vegetation and abundant residual cover (Johnson et al. 2004). Harrier response to haying was generally inconsistent among counties. In our study, harrier densities declined slightly (McPherson County) to significantly (Hettinger County) in the first year after haying. In Iowa CRP fields, harrier abundance did not differ between plots that had been cut and harvested the previous year and plots that remained idle (Murray and Best 2003). Herkert et al. (1999) reported that northern harriers tended to place their nests in grasslands that had not been disturbed by management (haying, seed harvesting, burning, or grazing) within the previous year.

Horned larks breed in areas with short, sparse herbaceous vegetation (Johnson et al. 2004). In our study, horned larks consistently favored CRP grasslands 1 year after haying in the 3 westernmost counties, where the species was most abundant. The species' densities returned to idle levels or lower in the second through fourth years after haying. Similarly, Dale et al. (1997) reported that horned larks were common in hayland that had been hayed once annually in July in Saskatchewan. Kantrud (1981), however, reported that the species was absent from a native mixed-grass prairie in North Dakota that had been hayed during the previous year.

The sedge wren and clay-colored sparrow showed similar and relatively consistent responses to haying among the counties in which they were most abundant. In those counties, both species declined in abundance the first year after haying and increased in the second through fourth years after haying. During the breeding season, both species prefer mesic or upland habitats with tall, dense herbaceous vegetation, often with abundant residual cover (Sample, 1989, Johnson et al. 2004). Clay-colored sparrows also prefer grasslands with a shrubby or woodland-edge component. Consistent with our results, Horn and Koford (2000) in North Dakota, Murray and Best (2003) in Iowa, and Roth et al. (2005) in Wisconsin reported that sedge wrens were more abundant in idle portions of CRP fields than in portions that had been hayed 1 year earlier. Horn and Koford (2000) reported that clay-colored sparrow abundance was marginally more abundant in idle CRP fields than in those that had been hayed 1 year earlier. In Nebraska, sedge wrens avoided CRP fields that had been recently burned or mowed (Delisle and Savidge 1997).

Lark buntings use grasslands of low-to-moderate height, high vegetative cover, some bare ground, and usually with a shrub component (Johnson et al. 2004). In our study, the lark bunting's response to haying varied geographically, and we found no consistent response to haying among counties. Kantrud (1981) reported that lark buntings avoided haylands that had been hayed the previous year.

Savannah sparrows prefer a wide variety of grasslands, especially those with vegetation that is short to intermediate in height, intermediate in density, and with a well-developed litter layer (Johnson et al. 2004). Savannah sparrow densities in fields that had been hayed 1–4 years earlier were generally near, or slightly higher than, densities in undisturbed fields in most counties. In North Dakota, Horn and Koford (2000) reported that Savannah sparrows were more abundant in CRP grasslands that had been hayed 1 year earlier than in CRP grasslands that remained idle, and in Wisconsin, Roth et al. (2005) reported that Savannah sparrows occurred only along CRP switchgrass transects that had been harvested the previous year. In Pennsylvania, Brauning et al. (2001) found that Savannah sparrows were twice as common on mowed grasslands than unmowed grasslands. In Saskatchewan, however, the species was more abundant in hay fields that had been idle for >3 years than in hay fields that had been hayed annually or in idle native prairies (Dale et al. 1997). In Alberta, Savannah sparrow abundance was higher in grasslands that had not been hayed for ≥3 years than in grasslands that had been hayed the previous year (Owens and Myres 1973).

Baird's sparrows prefer idle or lightly-to-moderately grazed native grasslands and avoid grasslands that have been idle for many years and that support dense vegetation and litter (Johnson et al. 2004). In our study, Baird's sparrow generally declined in CRP grasslands that had been hayed 1–4 years previously. In Alberta, Owens and Myres (1973) reported that Baird's sparrows avoided mixed-grass areas 1 year after haying, but in Saskatchewan, Dale et al. (1997) reported that Baird's sparrows were more abundant in hay fields that had been hayed annually than hay fields that had been hayed every 3–8 years.

Le Conte's sparrows use mesic grasslands with tall, dense herbaceous vegetation and thick litter (Johnson et al. 2004). In our study, Le Conte's sparrow response to haying varied geographically. In Sheridan County, Le Conte's sparrows favored idle CRP grasslands over those that had been hayed within the previous 4 years. In Kidder and Eddy counties, Le Conte's sparrow abundance was higher in idle CRP fields than fields that had been hayed 1 year previously; the opposite pattern was detected in the second, third, and fourth years after haying. Consistent with our results, other authors have suggested that annual haying often negatively affects breeding Le Conte's sparrows (e.g., Murray 1969, Lowther 1996). For example, in Saskatchewan, Dale et al. (1997) reported that Le Conte's sparrows preferred hay fields that had been idle for ≥3–8 years to those that were hayed annually or idle. In contrast, in North Dakota, Horn and Koford (2000) reported that Le Conte's sparrow abundance was marginally higher in CRP grasslands that had been hayed the previous year than in those that remained idle, and Kantrud (1981) reported that the highest abundances of Le Conte's sparrows occurred on hay fields that had been hayed the previous year.

Dickcissels prefer grasslands with dense, moderate-to-tall vegetation, particularly with a well-developed forb component, and moderately deep litter (Johnson et al. 2004). We found that the effects of treatment on dickcissel abundance varied geographically but with no consistent pattern among the counties. For example, in Kidder County, dickcissels favored idle CRP fields over those that had been hayed 1–4 years earlier, whereas in Day County, the species occurred at lower densities in idle fields than those that had been hayed 1–4 years earlier. In Nebraska, dickcissels preferred CRP fields that had not been mowed or burned (Delisle and Savidge 1997). In Iowa CRP fields planted to switchgrass, Murray and Best (2003) reported no differences in dickcissel

abundance between plots that had been cut and harvested the previous year and plots that remained idle. McCoy et al. (2001) reported that dickcissel abundance was highest on CRP fields that had been mowed within the past 2 years and lowest in CRP fields that had not been recently disturbed. In tallgrass prairies, Winter (1998) reported that dickcissel densities increased with the number of years since the latest haying treatment, and Westemeier and Buhnerkempe (1983) reported that the species preferred grasslands that had been hayed every 2–3 years over grasslands that had been idle.

Red-winged blackbirds use a variety of habitats during the breeding season, and we found no consistent pattern among counties in this species' response to haying. There was a tendency for densities in idle CRP fields to be lower than those in fields that had been hayed 1 year earlier. Murray and Best (2003) in Iowa and Roth et al. (2005) in Wisconsin reported no differences in red-winged blackbird abundance in switchgrass plots that had been cut and harvested the previous year and plots that remained idle. In North Dakota, Horn and Koford (2000) reported that red-winged blackbird abundance was marginally higher in idle CRP grasslands than in those that had been emergency hayed 1 year earlier.

Frequencies of Disturbance in CRP Grasslands

Decisions regarding the frequency of management on CRP grasslands depend on many factors, including the field location, the breeding-bird community, weather, soil conditions, land-owner incentives, and livestock forage needs (Jones-Farrand et al. 2007). Of the management alternatives in this region, haying was the option preferred by landowners in our study, representing nearly 90% of the disturbances. We found that an individual CRP field experienced, on average, fewer than 3 disturbances between 1993 and 2008. For fields that had been disturbed more than once by haying or grazing, the average number of years between disturbances ranged from 3–5 years. This frequency generally mirrors the once-in-three-year frequency that was established in the original provisions in the 2002 Farm Bill (USDA 2003), as well as the frequency recommendations reported in the literature for CRP and other grasslands. For example, Renner et al. (1995) suggested that vegetative quality and habitat diversity for CRP could be achieved by haying 20% of a CRP field per year on a rotational basis over a 5-year period. Allen et al. (2001) suggested haying CRP fields with established vegetation over 2 years (i.e., 50% of the field per year) during the mid-contract period (4–6 years after establishment). Burger et al. (1990) recommended that haying in CRP fields should be restricted to a 3-year rotation to maintain early successional habitats for northern bobwhite (*Colinus virginianus*). To benefit bobolinks, Bollinger et al. (1990) recommended that haying of CRP fields should be limited to once every 2–3 years and only after the middle of July. Hays and Farmer (1990) recommended that haying of CRP fields should occur no more often than once every 3–5 years. Herkert (2007) concluded that a 3-year management rotation for CRP grasslands is within the recommended disturbance cycle for Henslow's sparrow (*Ammodramus henslowii*) breeding areas.

Similar recommendations have been reported for non-CRP grasslands. For example, Vorhees and Cassel (1980) recommended haying one-third of an area each year (i.e., 3-year disturbance cycle) to enhance waterfowl production on highway rights-of-way in North Dakota. Herkert et al. (1996) recommended haying 20–30% of a grassland patch every 3–5 years to balance the positive and negative effects of haying on grassland birds. To maximize benefits for nesting waterfowl, Duebbert and Kantrud (1974) recommended leaving planted grasslands idle for 5–6 years and then manipulating the vegetative cover through mechanical harvesting, prescribed burning, or other means to rejuvenate the stand.

MANAGEMENT IMPLICATIONS

Findings from our study will be valuable for the future management of perennial grasslands enrolled in long-term cropland retirement programs, including future programs that emphasize planting perennial grasslands for the production of cellulosic ethanol (Murray and Best 2003, Robertson et al. 2012). Our long-term, regional study illustrates potential shortcomings of studies conducted over a short period or in a single area and the importance of replication in space and time (Shaver 1993, Johnson 1999). For example, our study indicates that densities of many species declined during that first year after haying, including northern harrier, eastern kingbird, sedge wren, common yellowthroat, clay-colored sparrow, Baird's sparrow, Le Conte's sparrow, song sparrow, red-winged blackbird, and brown-headed cowbird. Had we restricted our analyses to a single year after haying, we might have concluded that haying negatively affected many grassland birds. However, by also evaluating long-term effects of haying, we found that long-term (i.e., $\geq$2 yr after haying) increases might compensate for short-term (1 yr after haying) declines for some species (e.g., clay-colored sparrows, sedge wrens, and common yellowthroats). Our study also found regional variation in responses to haying for some species. For example, if we had restricted our study to Kidder County, North Dakota, we might have concluded that dickcissel densities were reduced in all 4 years after haying. Conversely, we might have reached the opposite conclusion for dickcissels in Day County, South Dakota. Interregional variation in the responses of some grassland birds to management may reflect a number of factors, including differences in precipitation, soils, and vegetation structure (Vickery et al. 1999, Igl and Johnson 2001).

What is the most effective disturbance cycle to benefit breeding bird populations in CRP fields and other conservation grasslands? Given limited government budgets, ideally, such a disturbance cycle should balance the needs of wildlife and the interests of agricultural producers. Litter accumulation and encroachment of trees, shrubs, and noxious weeds have degraded many idle CRP grasslands in this region, which necessitate some management to maintain the conservation benefits of the CRP for grassland birds. Maintaining a mosaic of CRP grasslands, including some that have been idle long-term and some

that had been hayed or disturbed periodically (3–5-yr intervals), appears to be a more suitable management strategy than an approach that includes only annually haying or only long-term idling. The retention of some idle fields guarantees some undisturbed nesting cover in the landscape for some bird species. The release of some CRP grasslands for periodic haying may have long-term benefits for other species.

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APPENDIX

Back-transformed least squares mean bird densities (pairs/100 ha) and 95% confidence limits (CL) for species that showed treatment × county responses to haying actions, northern Great Plains, USA, 1993–2008. Treatments (Trt) included idle fields and fields that were hayed 1 (H1), 2 (H2), 3 (H3), and 4 (H4) years earlier. The 9 counties are ordered from west to east.

		Sheridan, MT	Fallon, MT	Butte, SD	Hettinger, ND	Kidder, ND	McPherson, SD	Eddy, ND	Day, SD	Grant, MN
Species[a]	Trt	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)	$\bar{x}$ (CL)
NOHA	Idle	0.39 (0.29, 0.48)	0.29 (0.20, 0.39)	0.12 (0.04, 0.20)	0.47 (0.36, 0.60)	0.16 (0.08, 0.24)	0.26 (0.18, 0.36)	0.10 (0.02, 0.17)	0.17 (0.08, 0.26)	0.08 (0.01, 0.15)
	H1	0.37 (0.18, 0.58)	0.07 (0.00, 0.29)	0.17 (0.00, 0.42)	0.08 (0.00, 0.22)	0.19 (0.07, 0.34)	0.11 (0.00, 0.26)	0.03 (0.00, 0.17)	0.09 (0.00, 0.21)	0.00 (0.00, 0.41)
	H2	0.36 (0.06, 0.74)	0.02 (0.00, 0.53)	0.34 (0.00, 0.81)	0.54 (0.23, 0.92)	0.72 (0.45, 1.05)	0.53 (0.17, 1.00)	0.16 (0.00, 0.41)	0.11 (0.00, 0.33)	0.98 (0.07, 2.64)
	H3	0.00 (0.00, 0.32)	0.55 (0.00, 1.58)	0.00 (0.00, 0.41)	0.49 (0.17, 0.90)	0.33 (0.08, 0.63)	0.23 (0.00, 0.80)	0.01 (0.00, 0.25)	0.20 (0.00, 0.51)	0.01 (0.00, 0.95)
	H4	0.32 (0.00, 0.75)	0.04 (0.00, 0.91)	0.00 (0.00, 0.45)	0.74 (0.29, 1.34)	0.18 (0.00, 0.47)	0.00 (0.00, 0.64)	0.14 (0.00, 0.47)	0.35 (0.00, 0.82)	0.01 (0.00, 0.95)
HOLA	Idle	0.16 (0.05, 0.29)	0.66 (0.51, 0.83)	1.05 (0.84, 1.28)	0.10 (0.00, 0.23)	0.05 (0.00, 0.16)	0.06 (0.00, 0.17)	0.02 (0.00, 0.13)	0.05 (0.00, 0.16)	0.01 (0.00, 0.11)
	H1	0.43 (0.20, 0.70)	1.61 (1.13, 2.20)	5.79 (4.34, 7.64)	0.17 (0.00, 0.35)	0.06 (0.00, 0.22)	0.06 (0.00, 0.22)	0.05 (0.00, 0.23)	0.02 (0.00, 0.17)	0.00 (0.00, 0.42)
	H2	0.29 (0.01, 0.65)	0.55 (0.05, 1.27)	0.68 (0.25, 1.25)	0.02 (0.00, 0.28)	0.00 (0.00, 0.15)	0.02 (0.00, 0.34)	0.01 (0.00, 0.22)	0.03 (0.00, 0.24)	0.00 (0.00, 0.79)
	H3	0.00 (0.00, 0.32)	0.05 (0.00, 0.72)	1.27 (0.59, 2.24)	0.13 (0.00, 0.44)	0.06 (0.00, 0.29)	0.02 (0.00, 0.47)	0.01 (0.00, 0.24)	0.14 (0.00, 0.42)	0.00 (0.00, 0.86)
	H4	0.15 (0.00, 0.51)	0.03 (0.00, 0.85)	1.38 (0.58, 2.59)	0.01 (0.00, 0.34)	0.12 (0.00, 0.39)	0.03 (0.00, 0.63)	0.01 (0.00, 0.29)	0.03 (0.00, 0.37)	0.00 (0.00, 0.86)
SEWR	Idle	0.11 (0.00, 0.36)	0.00 (0.00, 0.21)	0.03 (0.10, 0.27)	0.11 (0.00, 0.38)	1.20 (0.81, 1.66)	1.64 (1.15, 2.24)	3.30 (2.54, 4.21)	7.09 (5.64, 8.87)	6.89 (5.51, 8.57)
	H1	0.05 (0.00, 0.48)	0.00 (0.00, 0.51)	0.00 (0.00, 0.62)	0.00 (0.00, 0.34)	0.52 (0.16, 0.99)	0.26 (0.00, 0.69)	0.80 (0.32, 1.47)	1.73 (1.10, 2.55)	0.45 (0.00, 1.97)
	H2	0.00 (0.00, 0.69)	0.00 (0.00, 1.30)	0.01 (0.00, 0.97)	0.04 (0.00, 0.69)	1.60 (0.76, 2.82)	3.82 (1.69, 7.61)	7.66 (4.69, 12.18)	14.26 (9.38, 21.44)	75.98 (20.94, 269.13)
	H3	0.00 (0.00, 0.87)	0.00 (0.00, 1.90)	0.01 (0.00, 1.27)	0.07 (0.00, 0.82)	2.45 (1.21, 4.39)	2.22 (0.47, 6.06)	7.53 (4.46, 12.33)	10.71 (6.21, 18.03)	10.37 (1.97, 42.58)
	H4	0.02 (0.00, 0.84)	0.00 (0.00, 2.61)	0.01 (0.00, 1.55)	0.15 (0.00, 1.17)	2.87 (1.37, 5.30)	1.38 (0.00, 5.47)	7.55 (3.97, 13.71)	9.33 (4.54, 18.28)	5.20 (0.62, 22.77)
CCSP	Idle	6.36 (4.56, 8.75)	0.06 (0.00, 0.37)	0.04 (0.00, 0.39)	1.20 (0.63, 1.97)	12.32 (9.30, 16.24)	4.72 (3.31, 6.59)	13.19 (9.91, 17.45)	9.53 (7.11, 12.68)	19.49 (14.71, 25.72)
	H1	1.90 (0.87, 3.50)	0.00 (0.00, 0.65)	0.11 (0.00, 1.07)	0.40 (0.00, 1.06)	4.17 (2.65, 6.32)	0.83 (0.25, 1.69)	5.25 (3.19, 8.32)	2.71 (1.63, 4.22)	11.32 (4.26, 27.88)
	H2	3.74 (1.59, 7.67)	0.02 (0.00, 1.63)	0.02 (0.00, 1.19)	1.45 (0.40, 3.30)	20.82 (12.93, 33.16)	4.08 (1.58, 8.98)	19.34 (11.50, 32.11)	17.18 (10.61, 27.46)	115.73 (27.54, 476.47)
	H3	4.91 (1.92, 10.96)	0.02 (0.00, 2.41)	0.02 (0.00, 1.55)	1.38 (0.29, 3.40)	25.33 (14.81, 42.85)	8.01 (2.73, 20.76)	27.78 (16.22, 47.12)	21.73 (12.10, 38.44)	34.18 (6.93, 155.04)
	H4	6.47 (2.84, 13.53)	0.02 (0.00, 3.30)	0.02 (0.00, 1.90)	1.44 (0.20, 3.96)	17.38 (9.54, 31.04)	11.01 (2.96, 35.41)	17.79 (9.18, 33.68)	26.45 (12.69, 54.03)	32.24 (6.49, 146.55)
LARB	Idle	0.06 (0.00, 0.22)	7.31 (6.27, 8.50)	5.62 (4.71, 6.68)	0.81 (0.55, 1.11)	0.00 (0.00, 0.14)	0.04 (0.00, 0.20)	0.00 (0.00, 0.14)	0.00 (0.00, 0.15)	0.00 (0.00, 0.15)
	H1	0.10 (0.00, 0.40)	6.48 (4.61, 8.98)	10.30 (7.08, 14.82)	0.80 (0.46, 1.21)	0.00 (0.00, 0.21)	0.00 (0.00, 0.23)	0.00 (0.00, 0.25)	0.00 (0.00, 0.20)	0.00 (0.00, 0.64)
	H2	0.22 (0.00, 0.73)	8.40 (4.42, 15.32)	2.60 (1.36, 4.48)	0.10 (0.00, 0.51)	0.00 (0.00, 0.29)	0.01 (0.00, 0.50)	0.00 (0.00, 0.32)	0.00 (0.00, 0.29)	0.00 (0.00, 1.31)
	H3	0.21 (0.00, 0.82)	6.13 (2.51, 13.52)	2.36 (1.01, 4.60)	0.20 (0.00, 0.70)	0.00 (0.00, 0.34)	0.02 (0.00, 0.71)	0.00 (0.00, 0.34)	0.00 (0.00, 0.38)	0.00 (0.00, 1.44)
	H4	0.00 (0.00, 0.42)	11.92 (4.57, 28.98)	17.46 (9.25, 32.23)	0.04 (0.00, 0.57)	0.00 (0.00, 0.37)	0.02 (0.00, 0.98)	0.00 (0.00, 0.43)	0.00 (0.00, 0.51)	0.00 (0.00, 1.44)
SAVS	Idle	41.90 (30.95, 56.60)	0.65 (0.26, 1.15)	0.60 (0.19, 1.17)	23.90 (17.17, 33.14)	6.80 (4.96, 9.22)	16.02 (11.66, 21.89)	10.28 (7.56, 13.86)	8.97 (6.58, 12.11)	3.98 (2.77, 5.59)
	H1	52.21 (32.61, 83.26)	0.98 (0.17, 2.36)	0.66 (0.00, 2.19)	20.21 (13.16, 30.78)	23.77 (16.19, 34.69)	13.45 (8.66, 20.59)	15.18 (9.63, 23.63)	14.03 (9.50, 20.51)	16.00 (5.96, 40.55)
	H2	60.80 (32.18, 114.11)	0.15 (0.00, 2.05)	0.56 (0.00, 2.38)	31.24 (17.05, 56.60)	16.26 (9.87, 26.41)	8.81 (3.87, 18.76)	12.33 (7.06, 21.05)	10.24 (6.06, 16.88)	17.17 (3.23, 77.12)
	H3	64.49 (30.69, 134.34)	0.75 (0.00, 5.13)	0.98 (0.00, 4.03)	34.18 (17.69, 65.23)	13.08 (7.33, 22.81)	15.30 (5.54, 39.60)	9.32 (5.07, 16.55)	8.56 (4.41, 15.91)	5.86 (0.47, 31.05)
	H4	60.41 (29.93, 120.92)	0.91 (0.00, 7.37)	1.28 (0.00, 5.61)	35.11 (16.38, 74.03)	31.65 (17.42, 56.87)	18.63 (5.23, 60.90)	12.82 (6.35, 25.01)	8.65 (3.71, 18.79)	5.39 (0.37, 28.90)
BAIS	Idle	2.50 (2.08, 2.99)	0.25 (0.11, 0.40)	0.34 (0.17, 0.53)	0.22 (0.06, 0.40)	0.10 (0.00, 0.24)	0.11 (0.00, 0.26)	0.01 (0.00, 0.14)	0.00 (0.00, 0.13)	0.00 (0.00, 0.13)
	H1	1.92 (1.38, 2.57)	0.30 (0.03, 0.64)	0.00 (0.00, 0.33)	0.21 (0.01, 0.44)	0.06 (0.00, 0.25)	0.04 (0.00, 0.25)	0.04 (0.00, 0.25)	0.00 (0.00, 0.17)	0.00 (0.00, 0.48)
	H2	2.10 (1.35, 3.08)	0.09 (0.00, 0.67)	0.20 (0.00, 0.69)	0.10 (0.00, 0.42)	0.00 (0.00, 0.16)	0.04 (0.00, 0.42)	0.00 (0.00, 0.25)	0.00 (0.00, 0.23)	0.00 (0.00, 0.90)
	H3	2.97 (1.88, 4.47)	0.07 (0.00, 0.86)	0.04 (0.00, 0.58)	0.00 (0.00, 0.31)	0.00 (0.00, 0.17)	0.05 (0.00, 0.57)	0.00 (0.00, 0.26)	0.00 (0.00, 0.29)	0.00 (0.00, 0.97)
	H4	1.25 (0.66, 2.05)	0.09 (0.00, 1.10)	2.86 (1.41, 5.19)	0.00 (0.00, 0.35)	0.41 (0.10, 0.82)	0.05 (0.00, 0.74)	0.00 (0.00, 0.32)	0.00 (0.00, 0.37)	0.00 (0.00, 0.97)
LCSP	Idle	0.85 (0.57, 1.19)	0.00 (0.00, 0.18)	0.01 (0.00, 0.20)	0.03 (0.00, 0.24)	1.12 (0.81, 1.49)	0.53 (0.29, 0.81)	5.92 (4.90, 7.11)	0.62 (0.37, 0.92)	0.46 (0.25, 0.71)
	H1	0.06 (0.00, 0.44)	0.00 (0.00, 0.46)	0.00 (0.00, 0.51)	0.01 (0.00, 0.31)	0.59 (0.26, 1.02)	0.18 (0.00, 0.53)	3.15 (2.15, 4.47)	0.87 (0.49, 1.35)	0.23 (0.00, 1.39)
	H2	0.06 (0.00, 0.73)	0.00 (0.00, 1.16)	0.00 (0.00, 0.83)	0.00 (0.00, 0.55)	1.70 (0.91, 2.83)	0.22 (0.00, 1.08)	15.14 (10.01, 22.66)	1.21 (0.55, 2.14)	0.00 (0.00, 2.03)
	H3	0.00 (0.00, 0.70)	0.00 (0.00, 1.69)	0.00 (0.00, 1.09)	0.00 (0.00, 0.62)	2.75 (1.50, 4.62)	0.28 (0.00, 1.66)	17.29 (11.18, 26.48)	0.98 (0.27, 2.11)	0.00 (0.00, 2.29)
	H4	0.02 (0.00, 0.76)	0.00 (0.00, 2.28)	0.00 (0.00, 1.32)	0.00 (0.00, 0.78)	4.02 (2.22, 6.85)	0.05 (0.00, 1.68)	8.27 (4.63, 14.24)	0.43 (0.00, 1.55)	0.00 (0.00, 2.29)
DICK	Idle	0.00 (0.00, 0.07)	0.00 (0.00, 0.07)	0.01 (0.00, 0.08)	0.00 (0.00, 0.08)	0.23 (0.15, 0.31)	0.14 (0.06, 0.22)	0.00 (0.00, 0.07)	0.15 (0.07, 0.23)	0.11 (0.04, 0.19)
	H1	0.00 (0.00, 0.13)	0.00 (0.00, 0.16)	0.00 (0.00, 0.18)	0.00 (0.00, 0.11)	0.02 (0.00, 0.12)	0.16 (0.04, 0.28)	0.07 (0.00, 0.19)	0.29 (0.18, 0.41)	0.36 (0.04, 0.77)
	H2	0.00 (0.00, 0.22)	0.56 (0.15, 1.12)	0.00 (0.00, 0.28)	0.00 (0.00, 0.19)	0.02 (0.00, 0.18)	0.53 (0.24, 0.89)	0.13 (0.00, 0.32)	0.34 (0.17, 0.55)	0.01 (0.00, 0.61)
	H3	0.00 (0.00, 0.26)	0.00 (0.00, 0.44)	0.00 (0.00, 0.35)	0.00 (0.00, 0.22)	0.08 (0.00, 0.27)	0.40 (0.05, 0.88)	0.00 (0.00, 0.17)	0.51 (0.26, 0.80)	0.01 (0.00, 0.67)
	H4	0.00 (0.00, 0.24)	0.00 (0.00, 0.53)	0.00 (0.00, 0.41)	0.18 (0.00, 0.49)	0.14 (0.00, 0.37)	0.00 (0.00, 0.45)	0.00 (0.00, 0.21)	0.60 (0.27, 1.02)	0.01 (0.00, 0.67)
RWBL	Idle	0.21 (0.00, 0.63)	0.77 (0.35, 1.30)	5.64 (3.90, 7.98)	9.57 (6.71, 13.49)	3.45 (2.40, 4.83)	3.88 (2.63, 5.56)	3.53 (2.44, 4.97)	5.32 (3.81, 7.31)	3.76 (2.60, 5.29)
	H1	0.19 (0.00, 0.88)	0.83 (0.09, 2.08)	3.32 (1.25, 7.29)	3.36 (1.92, 5.51)	1.52 (0.75, 2.62)	2.71 (1.49, 4.53)	1.14 (0.41, 2.25)	3.64 (2.25, 5.63)	0.42 (0.00, 2.41)
	H2	0.00 (0.00, 0.84)	0.81 (0.00, 3.85)	1.96 (0.32, 5.65)	6.93 (3.39, 13.30)	3.09 (1.55, 5.55)	15.64 (7.23, 32.67)	3.62 (1.77, 6.69)	13.70 (8.21, 22.46)	0.00 (0.00, 3.21)
	H3	0.63 (0.00, 2.40)	1.59 (0.00, 8.09)	2.90 (0.48, 9.29)	14.50 (7.12, 28.57)	3.13 (1.42, 6.05)	4.07 (1.03, 11.69)	5.30 (2.68, 9.78)	8.52 (4.37, 15.90)	1.69 (0.00, 11.62)
	H4	0.15 (0.00, 1.30)	5.53 (0.46, 28.26)	1.54 (0.00, 6.67)	11.79 (5.08, 25.89)	4.69 (2.18, 9.20)	10.50 (2.64, 35.31)	1.87 (0.51, 4.45)	7.50 (3.11, 16.55)	11.24 (1.61, 56.45)

[a] Four-letter alpha codes for bird species are defined as northern harrier (NOHA), horned lark (HOLA), sedge wren (SEWR), lark bunting (LARB), Savannah sparrow (SAVS), Baird's sparrow (BAIS), Le Conte's sparrow (LCSP), dickcissel (DICK), and red-winged blackbird (RWBL).