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Received: 25 January 2022 | Revised: 2 August 2023 | Accepted: 4 August 2023

DOI: 10.1002/wsb.1488

RESEARCH ARTICLE

WILDLIFE SOCIETY BULLETIN Open Access

Potential impacts of land-management schedules on grassland bird nests and fledglings

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Funding information
Illinois Wildlife Preservation Fund; Nature Conservancy; Wisconsin Department of Natural Resources; U.S. Geological Survey; U.S. Fish and Wildlife Service; The National Fish and Wildlife Foundation; Audubon Council of Illinois; Illinois Department of Natural Resources

Abstract

Trade-offs exist between timing of grassland habitat management activities (e.g., weed and brush control) while also ensuring other conservation objectives (e.g., grassland bird reproductive success) are met. On land set aside for grassland conservation (e.g., lands enrolled in the U.S. Department of Agriculture Conservation Reserve Program and some state and federal wildlife management areas), federal and state agencies set time frames for land management based on avoiding disturbance of grassland bird nests. However, recent calls for considering the needs of dependent fledglings in conservation plans imply a need to evaluate whether current time frames are adequate. We used initiation and end dates for 3,257 nests of 8 obligate grassland bird species in Illinois and Wisconsin and a simulation approach for fledgling survival to estimate the potential proportion of active nests at risk when management (e.g., mowing, fire) occurred on the 1st and 15th day of May, June, July, and August during the breeding season. Management during June had the potential to impact 24–61% of nests, depending on the species. Management during July had the potential to impact 4–52% of nests, depending on the species. If disturbance occurred during August, proportionately few active nests were at risk for any species (0–9% of nests on 1 August, 0–<0.5% on 15 August). Potential proportions of fledglings at risk from management were greatest in July for 7

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of the 8 species (7–18%). Our study suggests that on lands where a primary conservation objective is to increase or ensure survival of grassland birds, delaying management activities until August could be beneficial for protecting both grassland bird nests and fledglings.

KEYWORDS
Conservation Reserve Program, disturbance dates, fledglings, grassland management, nesting activity, obligate grassland birds

Native grasslands in North America are disturbance-adapted systems that have evolved with fire and grazing (Vickery et al. 2000). However, in most of North America's grasslands landscape, alterations such as fire suppression, agriculture, and enclosed livestock grazing systems have interfered with natural processes since settlement by Europeans (Briggs et al. 2005, Askins et al. 2007). In the eastern tallgrass region, the loss of virtually all native grasslands to agriculture, human development, and succession has forced grassland-dependent wildlife to adapt to nonnative agricultural grasslands (e.g., pasture and hay) and to rely on publicly and privately-owned grasslands managed for conservation purposes (Askins et al. 2007). In the absence of natural disturbances, grasslands rapidly transition to shrublands or woodlands (Ratajczak et al. 2016). As a result, managers use strategies, such as prescribed fire, mowing, brush removal, livestock grazing, and herbicides, that mimic natural processes to maintain quality grassland habitat (Vogl 1979, MacDougall and Turkington 2007).

Management timing can affect both grassland vegetation and animal communities, including birds. For example, the timing of burning can affect plant physiognomy (Towne and Owensby 1984), plant species composition and cover (Howe 1994, Howe 1995, Copeland et al. 2002), and can impact whether birds use a site for nesting (Byers et al. 2017). Mowing during the breeding season can lead to abandonment of nesting areas (Harrison 1974, Sample 1989, Frawley and Best 1991, Igl 1991), decreased nesting success due to mortality of nestlings, fledglings, and adults (Bollinger et al. 1990, Perlut et al. 2006), and decreased population growth rates (Perlut et al. 2008). Management impacts on breeding are of conservation importance, as grassland bird species are regularly listed as Species of Greatest Conservation Need in states' Wildlife Action Plans across the region (Illinois Department of Natural Resources 2015, Missouri Department of Conservation 2015, Ohio Division of Wildlife 2015, Wisconsin Department of Natural Resources 2015).

Trade-offs exist for timing, intent, and type of management on both public and privately-owned grasslands. Grassland habitat management activities are necessary to ensure that goals related to restoration of prairie vegetation occur while meeting other conservation objectives (e.g., grassland bird reproductive success or provision of habitat for pollinators). For example, prescribed fire is a management practice which can impact nesting grassland birds across seasonal timing and intensity. Prescribed burning in the eastern tallgrass region is conducted in early spring (US Fish and Wildlife Service 2019), or sometimes during fall, to avoid disturbance during primary nesting seasons (USDA Farm Service Agency 2018). There is a trade-off between effective vegetation management and bird nesting success because research has shown that summer burns (i.e., during the primary nesting season) can be more effective in controlling some noxious weeds than fires conducted at other times of the year (Emery and Gross 2005, Pitman 2018), but could have potential negative impacts on bird nesting success.

Current recommendations (i.e., avoiding disturbance during the primary nesting season) based on nesting activity does not address potential impacts on fledglings. Recent evidence demonstrates that fledged grassland birds have limited mobility (Kershner et al. 2004, Berkeley et al. 2007, Hovick et al. 2011, Ribic et al. 2019) and, as a result, young could be vulnerable to management activities such as mowing that occur during the mid- to late-summer post-fledging period (Bollinger et al. 1990, Giovanni et al. 2015).

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The objective of our study was to determine how the timing of management activities may impact both grassland bird nests and fledglings, using data on obligate grassland bird breeding activity in Wisconsin and Illinois. Due to the complexity of impacts from continuous management activities (e.g., grazing), we focused on assessing the impacts of discrete activities (e.g., fire, mowing). Specifically, we used the nest initiation and end dates to define the activity period of nests, used a simulation approach to define the activity period of fledglings, and then calculated total proportions of nests and fledglings active at various points in time during the breeding season to assess potential impacts of disturbance from discrete land management activities.

METHODS

We used nest records from grassland bird studies completed in Wisconsin and Illinois. Study sites were clustered in southwestern Wisconsin near Mt. Horeb (43.0167°N, 89.7500°W) and, in northern Illinois, 9 sites in Lee, Ogle, Will, Grundy, Carroll, and Jo Daviess counties (40.9822 to 42.2356°N, −87.5433 to −90.3489°W) were used. The north-south distance between the centroids of the Wisconsin and Illinois study areas was 225 km.

Wisconsin nest records came from Basili (1997), Temple et al. (1999), Renfrew et al. (2005), Ribic et al. (2012), Ellison et al. (2013), Vos and Ribic (2013), and Byers et al. (2017). The years covered by the Wisconsin nest records were 1991–1995 and 1998–2011. Illinois nest records came from Herkert et al. (2003) and unpublished data collected using protocols established in Herkert et al. (2003; J. Herkert, Illinois Audubon Society, unpublished data). Illinois nest records covered 1995–1998 and 2007–2009. Four habitat types were evaluated: pasture, prairie, cool-season grass fields, and warm-season grass fields (File S1, available in Supporting Information). Specific habitat types sampled in a year depended on the objectives of the individual studies (Table S1, available in Supporting Information). The cool-season grass fields, warm-season grass fields, and prairie sites were not managed during the study periods. Pastures were used for beef cattle and stocking rates ranged from 0.61 to 4.33 animal units/ha.

For each study, nest searching occurred between the beginning of May and early August. All nests were assigned a fate (success or failure) by the original researchers. If video surveillance systems were used, digital records were used to assign the fate of the nest. For nests without video surveillance systems, the original researchers used cues such as egg remains, missing or destroyed nest and/or nest contents, flooded nests, cold eggs, punctured eggs, eye witnessed predation events, and dead nestlings to indicate nest failure while presence of feather dust/sheaths, feces in the nest, chipping adults, recently fledged young near nest, and eye witnessed fledging events indicated nest success (Table S2, available in Supporting Information).

We focused on the 8 obligate grassland bird species that had more than 50 total nests in the database: bobolink (*Dolichonyx oryzivorus*), dickcissel (*Spiza americana*), eastern meadowlark (*Sturnella magna*), grasshopper sparrow (*Ammodramus savannarum*), Henslow's sparrow (*Centronyx henslowii*), savannah sparrow (*Passerculus sandwichensis*), vesper sparrow (*Pooecetes gramineus*), and western meadowlark (*Sturnella neglecta*). All 8 of these species are Species of Greatest Conservation Need in Wisconsin (Wisconsin Department of Natural Resources 2015). In Illinois, grasshopper sparrow, bobolink, Henslow's sparrow, and eastern meadowlark are Species of Greatest Conservation Need (Illinois Department of Natural Resources 2015).

Nesting data collation

Nest data from all studies consisted of nest initiation date (date first egg laid), nest fate, number of nestlings, and nest end date (date the nest either failed or fledged at least one nestling). We used the fate (success or failure) as assigned by the original researchers. We used the nest initiation and failure dates if recorded by the original researchers. In general, nest initiation dates were estimated based on field notes or digital video (i.e., video-surveillance of nests). In some instances, nests failed within the same nesting stage (laying, incubation, or nestling) in

which they were first found. For said cases, nest initiation dates were estimated following Cox et al. (2012) using average species-specific incubation times from Ehrlich et al. (1988). Nest end dates (date when nest failed or fledged at least one nestling) were either known (e.g., forced fledging during nest checks, digital video, field observations) or estimated using the midpoint between the dates when the nest was last observed with eggs/nestlings present and when the nest was next observed empty. Time between visits varied among the studies: 1–4 days (Renfrew et al. 2005, Ribic et al. 2012, Ellison et al. 2013, Byers et al. 2017), 1–5 days (Temple et al. 1999), 3–5 days (Vos and Ribic 2013), and 2–7 days (Herkert et al. 2003, Herkert unpublished data). Data used in this study can be found in Ribic and Herkert (2023).

Simulation of fledgling activity

To add a daily fledgling phase to the successful nests (i.e., extend the days the nest was considered active by incorporating the presence of the fledglings associated with the nest), we used a simulation approach to simulate species specific fledgling survival for the length of time fledglings might be vulnerable to land management. Because none of the studies in Wisconsin or Illinois included the fledgling stage, we based our fledgling parameters on literature values.

First, we determined the length of time a fledgling might be vulnerable to land management activities. Studies about parental care in grassland birds indicate that by 2–3 weeks post-fledging, young have developed basic foraging skills and sustained flight ability (Wheelwright and Templeton 2003, Kershner et al. 2004, Suedkamp Wells et al. 2008, Hovick et al. 2011), which we assumed would allow them to evade harvesting machinery or fire. In addition, most grassland bird fledgling mortality occurs within the first 2 weeks after leaving the nest (Kershner et al. 2004, Suedkamp Wells et al. 2007, Hovick et al. 2011, Naef-Daenzer and Grüebler 2016, Young et al. 2019). Therefore, we used 14 days for the length of time fledglings might be vulnerable to land management. A 14-day period allows for most fledglings to receive parental care, be mobile enough to escape land management events, and to achieve daily survival rates nearing 100%.

Second, we looked for survival estimates for the 14-day period for each species. Generally, fledgling survival is lowest when the fledglings are 1–6 days old (i.e., first week after leaving the nest) with subsequent increases as the fledglings age (Naef-Daenzer and Grüebler 2016), and we used a similar survival pattern in our simulation. We used survival probabilities by fledgling age for dickcissel and eastern meadowlark (Suedkamp Wells et al. 2007), grasshopper sparrow (Hovick et al. 2011), and western meadowlark (Giovanni et al. 2015). We did not find survival probabilities by fledgling age for bobolink, Henslow's sparrow, savannah sparrow, or vesper sparrow, so we matched these species with others that possessed similar life-history characteristics. For bobolink we used probability of survival by fledgling age from eastern meadowlark, and for Henslow's sparrow, savannah sparrow, and vesper sparrow we used probability of survival by fledgling age from grasshopper sparrow. Daily species-specific values used within the 14-day simulation ranged from 0.90–1.00 (bobolink and eastern meadowlark), 0.81–1.00 (dickcissel), 0.85–1.00 (grasshopper sparrow, Henslow's sparrow, savannah sparrow, vesper sparrow), and 0.88–0.98 (western meadowlark; Table S3, available in Supporting Information).

With the time period and probability of survival by day defined, the simulation was run on all fledglings, independent of nest. For each day in the simulated 14-day period, a random binomial draw determined the fate of each fledgling. The probability of success for the binomial was the daily probability of survival. We reaggregated all fledglings into their original nest and then defined the fledgling phase end date for each nest by the maximum number of days survived by fledglings per nest during the simulation. All aspects of the simulation and subsequent linking of surviving individuals back to nest identity were conducted in R (v. 3.4.3; R Core Team 2017).

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Analysis

Nest initiation and end dates

Before combining data across the states, we first checked for latitudinal differences in initiation dates. All species in the current study were migratory, so the prediction was that birds in Wisconsin should nest later than birds in Illinois because birds migrating from their wintering grounds will settle in Illinois first. We tested 6 of the 8 species; there were too few Henslow's sparrow and savannah sparrow nests found in the Illinois data (5 and 13 nests, respectively) to make the test meaningful for these species. For each of the remaining 6 species, we tested that the empirical cumulative distribution function of initiation dates for Wisconsin fell below that of Illinois with a one-tailed Kolmogorov-Smirnov test using R (v. 3.4.3; R Core Team 2017) and an alpha level of 0.05. If there was no evidence that birds in Wisconsin were significantly later in initiating nests compared to Illinois, we combined the state data, otherwise we analyzed each species by state in subsequent analyses. Due to low sample sizes (e.g., less than 20 nests) across grassland types and years, we combined the data over grassland types and years (File S2, available in Supporting Information).

We calculated summary statistics for nest initiation of all nests and the end date of successful nests (i.e., the start of the fledgling stage) by species (either combined over the 2 states or by state). To organize the results, we ranked the species by median initiation date. We considered species that had median initiation dates near the end of May to be early nesters and species that had median initiation dates mid-June or later to be late nesters.

Timing of management activity

We examined 8 dates within the breeding season spanning the primary nesting season (USDA Farm Service Agency 2018) to evaluate potential losses of nests and fledglings due to discrete land-management activities: 1 May, 15 May, 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August. We calculated the daily proportions of nests in the active nest phase (nests with eggs and/or young) and those in the simulated fledgling phase (after the young leave the nest) for each species for each of the 8 dates.

To calculate the daily proportions of nests, we calculated the number of nests in the active nest phase and the fledgling phase for each management date and each species. For the active nest phase, we used the initiation and end dates of each nest, coding the nest as 1 for every day between the nest initiation and end dates. For the fledgling phase, we used the simulation results over the 2 weeks post-fledging period in a similar way, assigning a 1 (for active) for the days between the day of fledging and the end date of the longest surviving fledgling from a nest. For any one of the 8 dates, the number of nests active in either phase for any species is the sum of the nests with a 1 on that date. We calculated the species' daily proportion of nests by phase and date as the daily total number of nests in the phase divided by the total number of nests for the species. We assumed that nests that were active on the date when a discrete management activity occurred would be lost due to direct impacts of the management activity or indirect impacts from elevated nest predation rates after the initial disturbance (Bollinger et al. 1990).

To understand yearly variation in proportion of active nests potentially affected by management, we calculated daily proportions of active nests using yearly subsets of data. The daily proportions for the fledgling phase for the yearly subsets could not be calculated due to low sample sizes of nests that survived in the individual years. We used species that had 3 or more years with each year having 50 or more nests (the same criteria we used for the species patterns). The species were eastern meadowlark with 5 years, savannah sparrow with 4 years, grasshopper sparrow with 6 years, and dickcissel in Illinois with 3 years. For each species, we calculated means, standard deviations, and coefficients of variation for the daily proportions of active nests for each management date. We used the coefficients of variation to compare the variability in the proportions of active nests among the management dates (Heumann et al. 2002).

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RESULTS

Our data set contained 3,257 nests of 8 grassland bird species (Table 1). Number of nests by species ranged from a high of 726 for eastern meadowlark to a low of 72 for Henslow's sparrow and 68 for western meadowlark. Approximately 67% of nests were in Wisconsin (n = 2,184) and 33% of nests were in Illinois (n = 1,073).

The only species with a latitudinal difference in nest initiation was dickcissel (KS test statistic = 0.179, P < 0.001). The median date for nest initiation in Wisconsin was 6 days later than for nests in Illinois (Table 1).

Henslow's sparrow and bobolink had the earliest median initiation dates (Table 1) and the highest rates of nest initiation (60–64%) in May. Dickcissel in both Wisconsin and Illinois had the latest median initiation dates and the highest percentage of late nests, with almost 40% of nests in Wisconsin and 27% of nests in Illinois initiated in July. Grasshopper sparrow had a median initiation date of mid-June (Table 1) but had the broadest temporal nesting distribution with 29% of all nests initiated early (April–May) and 19% initiated late (July–August). Over all species, June was the month with the most nest initiations (48%), followed by May (36%).

Impact of land management activity

Land management activities during the month of June had the highest potential impacts to the active nest phase for 7 of the species. Management during June had the potential to impact 24–61% of nests produced within a season, depending on the species (Figure 1). Nests of bobolink and Henslow's sparrow, the earliest nesting species, were more at risk if management occurred on 1 June (impact 61% and 47% of nests, respectively) with the other 5 species (eastern and western meadowlark, grasshopper sparrow, vesper sparrow, savannah sparrow) at risk on 15 June (impact 28–45% of nests). Eastern and western meadowlark, grasshopper sparrow, vesper sparrow, and savannah sparrow were also at risk if management occurred on 1 July with the potential to impact 23–32% of active nests (Figure 1). Dickcissel in both Illinois and Wisconsin was the species most at risk from management in July with about half of active nests at risk to disturbance. In Illinois, management on 1 July had the highest proportion of potential active nests at risk (52%), while the risk was high for the entire month of July for dickcissel in Wisconsin (49% on 1 July and 50% on 15 July). If disturbance occurred during August, proportionately few active nests were at risk for any species (impact 0–9% of nests on 1 August, 0–<0.5% on 15 August; Figure 1).

Potential impacts on fledglings from management were greatest in July for 6 of the 8 species (7–18%; Figure 1). For Henslow's sparrow, maximum potential impact to the fledgling phase was when management occurred on 15 June (18%). While maximum potential impact from management was greatest on 15 July for dickcissel in Illinois (13%), the maximum potential impact to the fledgling phase occurred on 1 August for dickcissel in Wisconsin (22%; Figure 1). Management on 15 August produced relatively little risk to any of the grassland bird species in the fledgling phase (0–<5%; Figure 1).

For the active nest and fledgling phases combined, land management on 1 and 15 June had the highest potential impact on Henslow's sparrow, bobolink, eastern meadowlark, and vesper sparrow (34–64%; Figure 1). Land management on 15 June and 1 July had the greatest potential impact on savannah sparrow, western meadowlark, and grasshopper sparrow (32–48%; Figure 1). Management on either 1 and 15 July would potentially have the greatest impact on dickcissel in both Illinois and Wisconsin (42–61%; Figure 1).

The average yearly proportions of active nests were similar to the proportions of active nests calculated from all the data, regardless of species (Table 2). For eastern meadowlark, the highest average yearly proportion of active nests occurred on 15 June, the same date as found when using all the data. Variation among the yearly estimates for active nests of eastern meadowlark was the lowest on 15 June, with a coefficient of variation of 0.21 (Table 2). The 5 years of data for eastern meadowlark encompassed 362 nests (49.9% of the nests in the combined data).

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TABLE 1 Summary statistics for earliest, latest, and median dates and the number of nests by month for nest initiation and successful nests for 8 obligate grassland bird species from data collected in southwest Wisconsin, USA (1991–1995, 1998–2011), and northern Illinois, USA (1995–1998, 2007–2009). Start of the fledgling stage is the end date of successful nests. Species are ordered by median date of nest initiation for all nests. Summary statistics for dickcissel are reported by state because of a significant difference between the state initiation date distributions. Start of the fledgling stage is the same as end of the nesting period (i.e., date at least one young fledged). N1 = total number of nests, min = earliest date, med = median date, max = latest date; N2 = number of nests that fledged at least 1 nestling.

		Nest Initiation			Nests initiated by month				
Species	**N1**	**min**	**med**	**max**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Henslow's sparrow (*Centronyx henslowii*)	72	6-May	25-May	14-Jul	0	43	16	13	0
Bobolink (*Dolichonyx oryzivorus*)	390	10-May	27-May	4-Jul	0	250	138	2	0
Eastern meadowlark (*Sturnella magna*)	726	17-Apr	1-Jun	22-Jul	44	311	323	48	0
Savannah sparrow (*Passerculus sandwichensis*)	664	30-Apr	5-Jun	21-Jul	2	283	293	86	0
Vesper sparrow (*Pooecetes gramineus*)	174	2-May	6-Jun	25-Jul	0	67	81	26	0
Western meadowlark (*Sturnella neglecta*)	68	22-Apr	7-Jun	16-Jul	2	21	33	12	0
Grasshopper sparrow (*Ammodramus savannarum*)	693	5-May	12-Jun	25-Jul	0	201	361	131	0
Dickcissel (*Spiza americana*)									
Illinois	314	22-May	22-Jun	1-Aug	0	8	220	85	1
Wisconsin	156	21-May	28-Jun	25-Jul	0	2	92	62	0
All Species	3257				48	1186	1557	465	1

		Start of fledgling stage			Nests fledged by month				
Species	**N2**	**min**	**med**	**max**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Henslow's sparrow (*Centronyx henslowii*)	28	2-Jun	16-Jun	31-Jul	0	0	16	12	0
Bobolink (*Dolichonyx oryzivorus*)	184	3-Jun	19-Jun	26-Jul	0	0	144	40	0
Eastern meadowlark (*Sturnella magna*)	233	20-May	21-Jun	12-Aug	0	44	107	76	6
Savannah sparrow (*Passerculus sandwichensis*)	196	26-May	26-Jun	8-Aug	0	21	94	77	4
Vesper sparrow (*Pooecetes gramineus*)	60	30-May	26-Jun	13-Aug	0	2	34	23	1
Western meadowlark (*Sturnella neglecta*)	29	30-May	1-Jul	12-Aug	0	1	12	13	3
Grasshopper sparrow (*Ammodramus savannarum*)	280	27-May	6-Jul	18-Aug	0	2	116	142	20
Dickcissel (*Spiza americana*)									
Illinois	94	17-Jun	15-Jul	11-Aug	0	0	7	74	13
Wisconsin	69	26-Jun	21-Jul	14-Aug	0	0	2	58	9
All Species	1173				0	70	532	515	56

For savannah sparrow, the highest average yearly proportions of active nests occurred on 1 June and 15 June; 15 June had the highest proportion of active nests and 1 June had the second highest proportion of active nests when using all the data (Table 2). Variation among the yearly estimates for active nests of savannah sparrow was the lowest on 1 June and 15 June, with both coefficients of variation less than 0.10 (Table 2). The 4 years of data for

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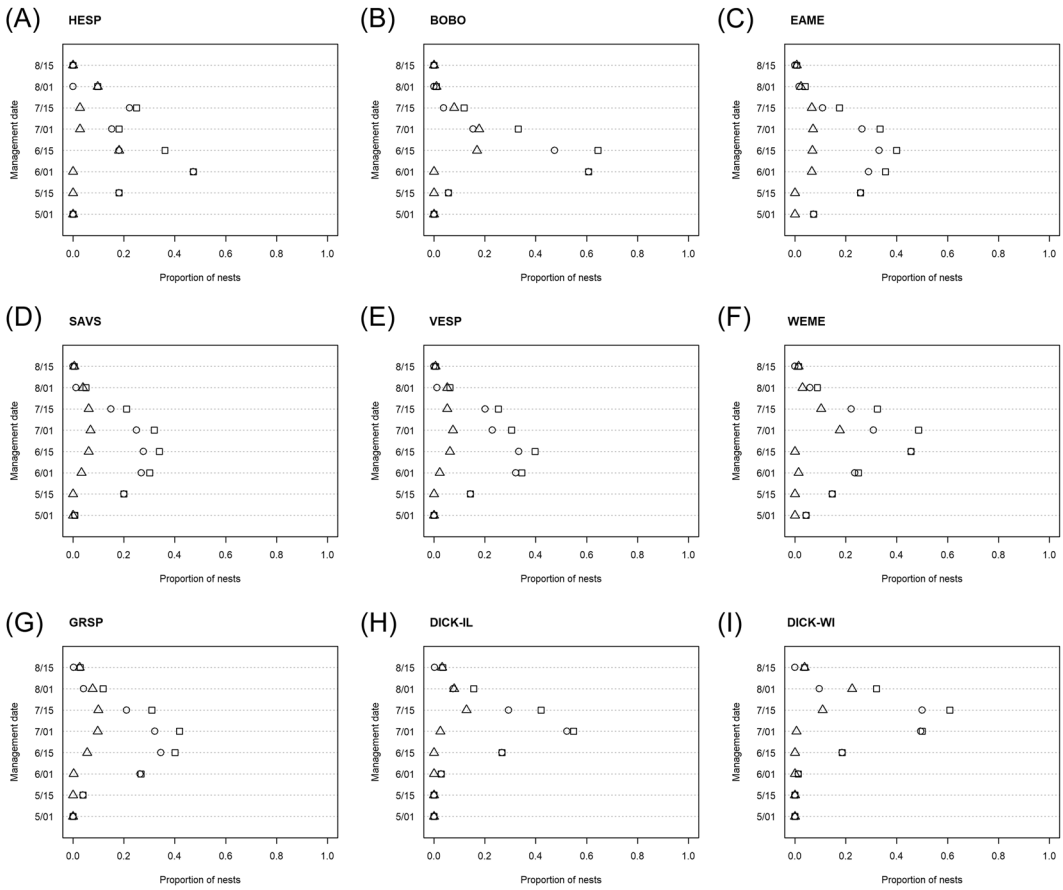


FIGURE 1 Proportion of nests potentially impacted by a discrete land management activity on 8 dates within the grassland bird breeding season based on 3,257 nests of grassland birds from southwest Wisconsin, USA (1991–1995, 1998–2011), and northern Illinois, USA (1995–1998, 2007–2009). Total proportion (active nest phase plus fledgling phase) is an open square, proportion of nests in the active nest phase is an open circle, and proportion of nests in the fledgling phase is an open triangle. Species, ordered by median initiation date, are Henslow's sparrow (*Centronyx henslowii*; (A) HESP), bobolink (*Dolichonyx oryzivorus*; (B) BOBO), eastern meadowlark (*Sturnella magna*; (C) EAME), savannah sparrow (*Passerculus sandwichensis*; (D) SAVS), vesper sparrow (*Pooecetes gramineus*; (E) VESP), western meadowlark (*Sturnella neglecta*; (F) WEME), grasshopper sparrow (*Ammodramus savannarum*; (G) GRSP), and dickcissel (*Spiza americana*) in Illinois ((H) DICK-IL) and in Wisconsin ((I) DICK-WI).

savannah sparrow encompassed 595 nests (89.6% of the nests in the combined data). For grasshopper sparrow, the highest average yearly proportions of active nests occurred on 1 July with the second highest occurring on 15 June; 15 June had the highest proportion of active nests and 1 July had the second highest proportion of active nests when using all the data (Table 2). Variation among the yearly estimates for active nests of grasshopper sparrow was the lowest on 1 July and 15 June, with coefficients of variation of 0.23 and 0.27, respectively (Table 2). The 6 years of data for grasshopper sparrow encompassed 491 nests (70.8% of the nests in the combined data). For dickcissel in Illinois, the highest average yearly proportion of active nests occurred on 1 July, the same date as found when using all the data (Table 2). Variation among the yearly estimates for active nests of dickcissel in Illinois on 1 July was 0.43 (Table 2). The 3 years of data for dickcissel in Illinois encompassed 193 nests (61.5% of the nests in the combined Illinois data).

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TABLE 2 Proportions of active nests potentially impacted by a discrete land management activity on 8 dates within the grassland bird breeding season for 4 obligate grassland bird species from data collected in southwest Wisconsin, USA (1991–1995, 1998–2011), and northern Illinois, USA (1995–1998, 2007–2009). Number of years (No. years) is the number of years where >50 nests were found, Proportion (all data) is the proportion of active nests using nests from all years, SD = standard deviation, and CV = coefficient of variation. CV was coded as NA when SD was zero.

Species	No. years	Metric	Management Date							
			1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug
Eastern meadowlark (*Sturnella magna*)		Proportion (all data)	0.07	0.26	0.29	0.33	0.26	0.11	0.02	0
	5	Average	0.07	0.23	0.25	0.31	0.28	0.1	0.01	0
		SD	0.11	0.13	0.06	0.06	0.09	0.05	0.01	0
		CV	1.67	0.61	0.27	0.21	0.32	0.5	1.44	NA
Savannah sparrow (*Passerculus sandwichensis*)		Proportion (all data)	0.01	0.2	0.27	0.28	0.25	0.15	0.01	0
	4	Average	0.01	0.22	0.26	0.26	0.25	0.14	0.01	0
		SD	0.01	0.06	0.01	0.02	0.04	0.04	0.01	0
		CV	1	0.3	0.04	0.06	0.18	0.3	1	NA
Grasshopper sparrow (*Ammodramus savannarum*)		Proportion (all data)	0	0.04	0.26	0.34	0.32	0.21	0.04	<0.01
	6	Average	0	0.03	0.2	0.33	0.35	0.24	0.04	<0.01
		SD	0	0.03	0.07	0.08	0.08	0.07	0.03	0.01
		CV	NA	1.06	0.38	0.27	0.23	0.32	0.86	2.5
Dickcissel (Illinois) (*Spiza americana*)		Proportion (all data)	0	0	0.03	0.27	0.52	0.29	0.08	<0.01
	3	Average	0	0	0.02	0.12	0.54	0.4	0.07	0
		SD	0	0	0.02	0.06	0.22	0.02	0.05	0
		CV	NA	NA	0.97	0.49	0.43	0.04	0.8	NA

DISCUSSION

By using species-specific phenological data, we were able to provide an assessment of the potential risk posed by discrete management activities to multiple grassland bird species at different times during the primary breeding season. Our study found that management during June had the potential to impact the largest proportion of nests for 7 of the 8 grassland bird species we considered. This is not surprising as mid-May to June is the peak of the midwestern bird nesting season (Temple et al. 1999). Our finding is consistent with research that has investigated the impact of haying on grassland bird productivity (Perlut et al. 2006, Diemer and Nocera 2016) and supports the idea of avoiding management activities such as mowing or burning during June. However, our study also found that management at the beginning of July had the potential to impact a quarter to a third of nests for 5 of the grassland bird species we studied. One species, dickcissel, had the largest proportions of nests at risk if management took place in either early or mid-July. Considering the fledglings, our simulations suggest that a higher proportion of fledglings for 7 of the 8 grassland bird species might be at risk if management occurred in early or mid-July. August had little breeding activity with only dickcissel fledglings in Wisconsin at a higher potential risk from management in

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early August. We know of no other study that has assessed potential impacts to grassland birds from management in July and August, but our results suggest that Wisconsin and Illinois land managers might want to consider potential impacts to grassland birds before carrying out management in July.

Nesting phenology varied among the grassland bird species we evaluated, and the timing of management activities needed to avoid disrupting the nesting cycle of specific target species might be further refined based on the specific assemblage of grassland bird species present on a given field or site. The vegetation structure preferred by each bird species we evaluated varies along a continuum, and a particular site is likely to support only a subset of the species. For example, bobolink, eastern meadowlark, and savannah sparrow overlap in their structural preferences (Sample and Mossman 1997) and are often found nesting in the same fields. Based on our results, bobolink, eastern meadowlark, and savannah sparrow may tolerate disturbances that occur in late July compared to fields supporting species that have fledglings later into the season such as grasshopper sparrow or dickcissel.

Our analysis focused on the timing of a single disturbance in grasslands and thus is most informative for management actions like haying and burning which occur as discrete events and has limited applicability to continuous management applications like grazing. Our results might inform the potential initial impacts of grazing (i.e., when cattle are put on the pastures) but additional factors such as stocking rate (e.g., Churchwell et al. 2005, Perlut and Strong 2011) also influence nest success in grazed grasslands. Thus, assessments of potential impacts of continuous management practices, like grazing, should consider a wide range of factors in addition to timing.

MANAGEMENT IMPLICATIONS

The data from our study allow land managers in Wisconsin and Illinois, and geographic areas with breeding bird phenology and plant phenology similar to Wisconsin and Illinois, to assess potential impacts of discrete land management activities on grassland bird nests. The inclusion of fledglings in our analysis suggests that the primary nesting season extends longer than previously considered and that managers may want to avoid discrete disturbances in grasslands during July to benefit grassland birds, especially recently fledged young. The extension of previously recommended disturbance dates suggested by our study aligns better with management recommendations for other taxa that are dependent on grasslands. For pollinators, recommendations suggest that mowing and fire needed to control invasive species (e.g., Locke et al. 2016) be done after the first frost. To avoid harming reptiles and amphibians that depend on grasslands, it is generally recommended that burning and mowing be avoided between 1 April and 1 November, and for these taxa it is also recommended that management activities be rotated among fields (Kingsbury and Gibson 2011, Stoner 2017). Vaughan et al. (2012) recommended that at least 70% of the field be left undisturbed each year.

ACKNOWLEDGMENTS

We thank our research collaborators, T. J. Anderson, C. Byers, J. Dadisman, H. Doyle, K. S. Ellison, M. J. Guzy, J. L. Nack, and D. Schneider, who ran the field projects, and all the field technicians who helped collect the data in Wisconsin, and S. K. Robinson and J. D. Brawn who collaborated on the nesting studies in Illinois. We thank S. Temple for access to original nest records from his and his students' studies. We thank the funders of the original projects (U.S. Fish and Wildlife Service and Wisconsin Department of Natural Resources for the Wisconsin projects; The Audubon Council of Illinois, the Illinois Department of Natural Resources, the Illinois Wildlife Preservation Fund, The Nature Conservancy, and The National Fish and Wildlife Foundation for the Illinois project).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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ETHICS STATEMENT

No new data were collected for this study. However, the original projects were conducted in compliance with the Guidelines to the Use of Wild Birds in Research. Data collection for the projects in Wisconsin was done under protocols A01023, A01410, and A01210 approved by the Animal Care and Use Committee of the University of Wisconsin-Madison. Data collection for the projects in Illinois was done under protocol 07096 and 07016 approved by the Animal Care and Use Committee of the University of Illinois.

DATA AVAILABILITY STATEMENT

Ribic, C. A., and J. Herkert. 2023. Nest initiation and end dates for eight grassland bird species in Wisconsin and Illinois. Dryad Dataset. <https://doi.org/10.5061/dryad.cjsxksnb8>.

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Associate Editor: Thomas J. Benson.

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How to cite this article: Wolcott, D. M., J. R. Herkert, C. A. Ribic, R. B. Renfrew, and D. W. Sample. 2023. Potential impacts of land-management schedules on grassland bird nests and fledglings. Wildlife Society Bulletin 47:e1488. https://doi.org/10.1002/wsb.1488

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