Studies in Avian Biology No. 19:171–177, 1999.

RELATIONSHIP OF FIRE HISTORY TO TERRITORY SIZE, BREEDING DENSITY, AND HABITAT OF BAIRD'S SPARROW IN NORTH DAKOTA

MAIKEN WINTER

Abstract. Prescribed fire often is used to manage prairies, but its effects on many grassland birds are not well documented. In 1993 I compared breeding density, territory size, and habitat of Baird's Sparrows (*Ammodramus bairdii*) among three different fire regimes in mixed-grass prairie in North Dakota: areas not burned in more than 80 years, areas burned twice since the late 1970s, and areas burned four times since the late 1970s. Baird's Sparrows were absent on unburned areas. They occurred at moderate densities ($\bar{X}$ = 6.9 males/100 hectares) on two-burn areas; these areas were characterized by relatively high vegetation ($\bar{X}$ = 18.5 centimeters), relatively deep litter ($\bar{X}$ = 2.8 centimeters), and an absence of bare soil. Higher Baird's Sparrow densities ($\bar{X}$ = 20 males/100 hectares) were found on four-burn areas where litter was low ($\bar{X}$ = 0.08 centimeters), vegetation relatively short ($\bar{X}$ = 13.8 centimeters), and the percentage of canopy coverage by bare soil relatively large ($\bar{X}$ = 11.4 percent). Mean territory size was significantly smaller in four-burn areas ($\bar{X}$ = 1.2 hectares) than in two-burn areas ($\bar{X}$ = 1.5 hectares). Prescribed burning favorably changed habitat structure for Baird's Sparrow, as indicated by a clear tie between occurrence of burning and that of the species; observed changes in density and territory size with frequent burning further suggested a positive link between fire and Baird's Sparrows in northwestern North Dakota.

LA RELACIÓN DE LA HISTORIA DE FUEGO CON EL TAMAÑO DE TERRITORIO, CON LA DENSIDAD DE REPRODUCCIÓN Y CON EL HÁBITAT DEL GORRIÓN DE BAIRD EN DAKOTA DEL NORTE

Sinopsis. El fuego programado se usa con frecuencia para manejar llanuras, pero sus efectos no han sido bien documentados para muchas aves de pastizal. En 1993 comparé la densidad de reproducción, el tamaño de territorio y el hábitat de los Gorriones de Baird (*Ammodramus bairdii*) entre tres diferentes regímenes de fuego en llanura de hierbas mixtas en Dakota del Norte: áreas no quemadas en más de 80 años, áreas quemadas dos veces desde fines de los años 70, y áreas quemadas cuatro veces desde fines de los años 70. Los Gorriones de Baird estuvieron ausentes en las áreas no quemadas. Se detectaron en densidades moderadas ($\bar{X}$ = 6,9 machos/100 hectáreas) en áreas de dos quemadas; estas áreas se caracterizaron por una vegetación relativamente alta ($\bar{X}$ = 18,5 centímetros), una cobertura de hojas relativamente honda ($\bar{X}$ = 2,8 centímetros) y una ausencia de suelo abierto. Se encontraron densidades más altas de Gorriones de Baird ($\bar{X}$ = 20 machos/100 hectáreas) en áreas de cuatro quemadas donde la cobertura de hojas era menor ($\bar{X}$ = 0,08 centímetros), la vegetación relativamente baja ($\bar{X}$ = 13,8 centímetros) y el porcentaje de suelo abierto relativamente mayor ($\bar{X}$ = 11,4 por ciento). El tamaño promedio de territorio fue significativamente más pequeño en áreas de cuatro quemadas ($\bar{X}$ = 1,2 hectáreas) que en áreas de dos quemadas ($\bar{X}$ = 1,5 hectáreas). El fuego programado cambió favorablemente la estructura de hábitat para el Gorrión de Baird, indicado por una clara conexión entre la incidencia de quemadas y la presencia de la especie; los cambios observados en densidad y tamaño de territorio con quemadas frecuentes indicaron aun más una conexión positiva entre el fuego y los Gorriones de Baird en el noroeste de Dakota del Norte.

Key Words: *Ammodramus bairdii*; avian density; Baird's Sparrow; fire effects; mixed-grass prairie.

Baird's Sparrows (*Ammodramus bairdii*) are endemic to the northern Great Plains (Johnsgard 1978). Early reports indicate that the species was common in the northern mixed-grass prairie in the late 1800s (Coues 1878); it still is common in some areas, such as the Missouri Coteau of North Dakota (Stewart 1975, Kantrud 1981). Since the arrival of European farmers in the early 1900s, Baird's Sparrow abundance has decreased considerably (DeSmet and Conrad 1991). This decline has been attributed to the conversion of prairie to farmland, overgrazing, invasion by exotic plants, and fire suppression (Higgins et al. 1989, Dobkin 1992, Sauer and Droege 1992, Goossen et al. 1993, Jones and Green 1997).

Fire suppression can decrease habitat suitability for grassland breeding birds by altering the dominant vegetation of prairies from grasses and forbs to mostly woody vegetation (Higgins et al. 1989). This deterioration of prairie ecosystems can be prevented or reversed by using prescribed burning (Wright and Bailey 1982, Collins and Wallace 1990). Wise use of prescribed burning, however, requires a knowledge of the habitat requirements of grassland species and of the effects of fire on habitat. The breeding habitat of Baird's Sparrow has been well characterized in

Canada (Dale 1983, Sousa and McDonal 1983, Wershler 1987, DeSmet and Conrad 1991, Anstey et al. 1995, Davis et al. 1996), but few studies have investigated the habitat needs of this species elsewhere (Green 1992, Winter 1994, Madden 1996, Jones and Green 1997). Moreover, there has been almost no documentation of fire effects on the distribution and habitat of the species, particularly where multiple burns have occurred over many years. The objective of my study was to describe the effect of fire history on density and territory size of Baird's Sparrow in the mixed-grass prairie of northwestern North Dakota. Knowledge of the impact of fire may aid in decisions on the use of prescribed burning as a management tool in this area.

STUDY AREA AND METHODS

The study was conducted at Lostwood National Wildlife Refuge (NWR), 109 km^2 of predominantly native mixed-grass prairie (*Stipa* spp., *Agropyron* spp.) on the Missouri Coteau in northwestern North Dakota (48°35′ N, 102°25′ W). Mean annual precipitation at Lostwood NWR is about 42 cm and occurs mostly as rainfall from April through September (Smith et al. 1993). The Missouri Coteau is characterized by rolling hills and numerous shallow wetlands which are relics of the last ice age (Freers 1973). Native mixed-grass prairie at Lostwood NWR has been greatly altered since the early 1900s. Only 30% of its land had been broken for agriculture before the refuge was established in 1935, but the native prairie has changed in plant species composition, mostly as a result of fire exclusion. Native fire-adapted grass and forb communities have been replaced by woody vegetation, especially western snowberry (*Symphoricarpos occidentalis*) and quaking aspen (*Populus tremuloides*), and by introduced grasses such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*). Since the late 1970s, the refuge's uplands have been managed mainly with prescribed fire and short-duration grazing. As a result, about 20% of its prairie currently approximates presettlement conditions (K. Smith, pers. comm.).

I selected study plots by subdividing each legal section (2.59 km^2) of Lostwood NWR into 16 subsections (each 16 ha in size). From those subsections I randomly selected 18 as study plots for each of three burn categories: five unburned areas (zero-burn), five areas burned twice since the late 1970s (two-burn), and eight areas burned four times since the late 1970s (four-burn). Each 16-ha plot was marked with wooden stakes at 50-m intervals along its 400- × 400-m border. Most two-burn plots were burned before 1992, whereas most four-burn plots were last burned in 1992. It was thus not possible to distinguish between the effect of the number of times an area had been burned and the time since an area had last been burned. I present analyses here based only on the number of times areas had been burned. These results closely parallel those of the effect of the time since areas were last burned (Winter 1994).

The available habitat in each study plot was characterized by measuring the vegetation in a randomly chosen 100- × 100-m subplot during 11–16 May 1993. I placed two perpendicular 80-m transects through the middle of each subplot, along which I quantified vegetation at 8-m intervals. The variables measured were mean vegetation height, maximum vegetation height, litter depth, and visual obstruction (Robel et al. 1970); vegetation height and litter depth were measured in centimeters, visual obstruction in decimeters. Litter was defined as horizontally lying dead plant material. The mean values of these vegetation characteristics in each plot were compared between burn areas using analysis of variance. Since the comparisons were not orthogonal, and thus not independent, I lowered the type I error of statistical significance by using the Tukey-Kramer procedure (Sokal and Rohlf 1995). One two-burn and two four-burn plots were excluded from this analysis because the time since they had last been burned, and thus their vegetation characteristics, greatly differed from all other plots (Winter 1994).

I determined density of Baird's Sparrows by linear transect censuses (Emlen 1977) conducted between 30 min before sunrise and about 1000 during 1–30 June. I defined density as the number of singing males per 100 ha and included only males whose territories were more than half inside the plot (Moore 1980). Censuses were not conducted on days with rain, fog, or wind velocities greater than about 25 km/hr. I used a modified flush technique to outline territory boundaries (Wiens 1969, Winter 1994). Each territory was mapped 2–5 times during the season (depending on the detectability of the territory holder) between 1 and 30 June, and its location was marked on an aerial photograph (1:7920). Territory size was determined by measuring the circumference of each territory with a digital planimeter (PLACOM, no. 50408, Los Angeles, California; Greer and Anderson 1989). The mean size of several outlines of the same territory was used in further analyses.

Between 30 June and 24 July, I measured vegetation attributes along a transect through the longest axis of each territory. A sampling point was located randomly in each 10-m interval of the transect by taking a random number of steps along the transect interval and then stepping a random distance to the left or right (selected by coin toss), perpendicular to the transect (Noon 1981). At each sampling point I quantified mean vegetation height, maximum vegetation height, litter depth, visual obstruction, and soil and vegetation cover, as well as the number of woody stems in a 20- × 50-cm Daubenmire frame (Daubenmire 1959). Because vegetation measurements in one territory were not independent of each other, data were pooled for each territory (Smith and Connors 1986).

Density and territory size in two- and four-burn areas were compared with a t-test. Relationships between density or territory size and vegetation parameters were investigated with simple and stepwise multiple regression (Sokal and Rohlf 1995). I calculated regressions of density on median vegetation values for each plot in which Baird's Sparrows were found (pooled vegetation values from one to three territory-transects per plot) and regressions of territory size on the median vegetation values for each territory. A principal component analysis (PCA) was used to summa-

TABLE 1. MEAN DENSITY AND TERRITORY SIZE OF SINGING MALE BAIRD'S SPARROWS ON TWO DIFFERENT BURN AREAS AT LOSTWOOD NWR, NORTH DAKOTA, 1993

	Density/100 ha				Territory size (ha)			
Area	Mean (SE)	N	t	P	Mean (SE)	N	t	P
2-burn	6.9 (4.11)	4	2.53	0.03	1.5 (0.33)	11	2.60	0.01
4-burn	20.0 (3.11)	7			1.2 (0.06)			

rize habitat characteristics of territories. The first two principal components were then used for principal component regression (Maurer 1986), with territory size as the dependent variable. All study plots where Baird's Sparrows did not occur (all unburned plots, one two-burn plot, and one four-burn plot; see Winter 1994) were excluded from regression and principal component analyses. I set alpha at 0.05 for all analyses.

RESULTS

Baird's Sparrow density and territory size differed significantly among areas with different fire histories (Table 1). The species was absent from all unburned plots and occurred in lower numbers and occupied larger territories in two-burn areas than in four-burn areas. Plot vegetation differed greatly among areas with different fire histories (Table 2); visual obstruction readings, vegetation height, and litter depth decreased with fire frequency. Density of Baird's Sparrows in two- and four-burn areas was related to several vegetation variables. Density was positively related to maximum and mean vegetation height (maximum height: $R^2 = 0.42$, $F = 6.47$, $P = 0.03$; mean height: $R^2 = 0.48$, $F = 6.44$, $P = 0.03$; $N = 11$), although maximum and mean height were not correlated to each other ($P > 0.05$). Litter depth and mean vegetation height were the only variables selected by the stepwise regression analysis. Litter depth alone accounted for more than half the total variance in density, with density decreasing with increasing litter depth (Fig. 1). This negative relationship between density and litter depth was only true at intermediate litter depths (0.5–2.5 cm), however, whereas density declined at minimum and maximum litter depths (Winter 1994). After mean height was added to the stepwise model, 82.8% of the variation in Baird's Sparrow density was explained.

Territories in two-burn areas were characterized by high scores on the first principal component (PC I) and large sizes (1.07–2.25 ha), whereas territories in four-burn areas mainly had negative scores on PC I and were smaller in size (0.8–1.69 ha; Fig. 2). PC I represented a continuum from low values representing relatively tall vegetation and little or no litter to high values representing low vegetation and relatively deep litter (Table 3). It explained 26.2% of the variation in territory size; the higher the scores of PC I, the larger the territories (Fig. 2). Almost as much variability was explained by simple linear regression with litter depth as the explanatory variable ($R^2 = 0.22$, $F = 7.97$, $P = 0.009$, $N = 30$ territories), suggesting that quantity of litter is an important factor influencing territory size. The second principal component (PC II), which reflected a continuum from low to high cover by forbs, woody plants, and introduced grasses, did not explain any variation in territory size ($R^2 = 0.00$, $F = 0.00$, $P = 0.98$). The amount of dead plant material, which is summarized in PC I (Table 3), thus seemed to influence territory size more than did vegetation height or types of vegetation cover. Plot B, a

TABLE 2. MEANS AND STANDARD ERRORS FOR VEGETATION VARIABLES MEASURED IN RANDOM SUBPLOTS AT LOSTWOOD NWR, NORTH DAKOTA, 1993

Plots	Visual obstruction (dm)	Maximum height (cm)	Mean height (cm)	Litter depth (cm)
0-burn (N = 5)	1.63 (0.42)	42.8 (6.03)	23.9 (3.53)	3.3 (0.46)
2-burn (N = 4)	1.37 (0.20)	39.5 (3.18)	18.5 (1.30)	2.8 (0.39)
4-burn (N = 6)	0.63 (0.22)	30.2 (4.48)	13.8 (2.37)	0.08 (0.05)
F (df = 14)	4.16*	1.93	3.85*	31.34**
Differences[a]	0b > 4b	–	0b > 4b	0b > 2b > 4b

Note: Means from 20 vegetation measurements in each plot were compared among all burn areas using analysis of variance, adjusting for non-independence with the Tukey-Kramer procedure.

[a] 0b = no burns, 2b = burned twice since the late 1970s, 4b = burned 4 times since the late 1970s.

* $P \leq 0.05$, ** $P \leq 0.001$.

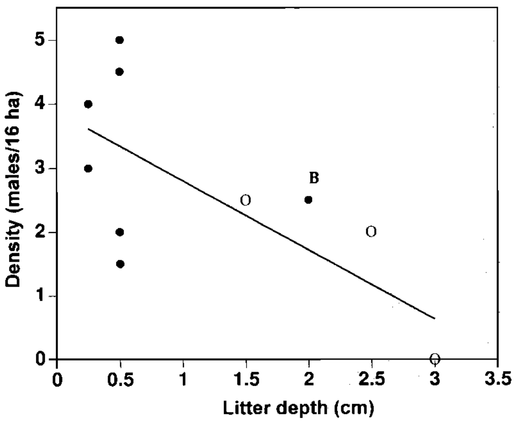

FIGURE 1. Regression of Baird's Sparrow density on litter depth in two-burn areas (open circles) and four-burn areas (solid circles; $R^2 = 0.55$, $F = 11.11$, $P = 0.009$, $df = 1, 9$). Only plots in which Baird's Sparrows occurred were included in the analysis. Plot B deviated from other four-burn areas because it had last been burned before 1992.

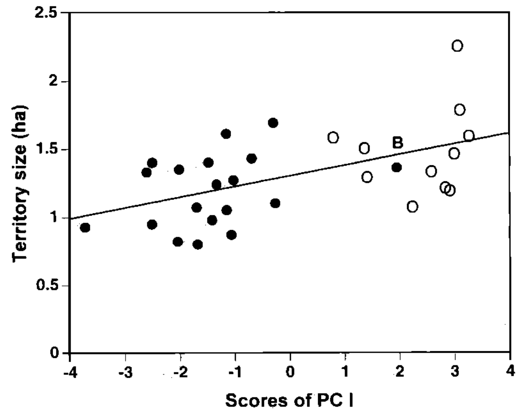

FIGURE 2. Regression of territory size on PC I in territories in two-burn areas (open circles) and four-burn areas (solid circles; $R^2 = 0.26$, $F = 9.96$, $P = 0.004$, $df = 1, 28$). Plots with high scores on PC I are characterized by relatively deep litter and little or no cover by bare soil. Plot B deviated from other four-burn areas because it had last been burned before 1992.

four-burn area that was only partly burned in 1992, deviated from the otherwise consistent separation between two- and four-burn areas. The high accumulation of litter in this plot (median = 2 cm vs. 0.25–0.61 cm in all other four-burn areas in which Baird's Sparrows occurred) accounted for the similarity of this plot with two-burn areas.

DISCUSSION

The prescribed fire regime at Lostwood NWR had a profound effect on the distribution of Baird's Sparrow. The species was absent from unburned areas, where litter and vegetation were higher than in two- and four-burn areas. Highest densities were found on four-burn areas, where litter depth and vegetation height were relatively low. This result is surprising since most four-burn areas had been burned the previous year, and vegetation cover, and thus nesting sites and concealment from predators, is reduced by fire (Pylypec 1991; but see Johnson and Temple 1990 for other grassland birds). Therefore, densities of many grassland birds are usually low the first year after a fire (Madden 1996, Johnson 1997). This typical short-term fire effect may have been overridden by the unusually wet year of 1993, which resulted in relatively lush vegetation at Lostwood NWR (K. Smith, pers. comm.). Although many bird species do not immediately respond to habitat change because of site tenacity (Rotenberry and Wiens 1980, Wiens 1989), such "tracking inertia" (Wiens et al. 1987) does not seem to apply to Baird's Spar-

TABLE 3. FACTOR LOADINGS OF PRINCIPAL COMPONENTS DERIVED FROM VARIABLES MEASURED ALONG TERRITORY TRANSECTS (N = 30 TERRITORIES) AT LOSTWOOD NWR, NORTH DAKOTA, 1993

	PC I	PC II
Eigenvalue	4.62	2.58
Percentage of total variance	0.27	0.15
Correlations with original variable:		
Topography		
Elevation	0.13	−0.03
Slope	0.12	0.07
Structure		
Visual obstruction	0.16	0.11
Maximum height	−0.29	0.18
Mean height	−0.21	0.44
Litter depth	0.43	0.17
Total number of hits	0.33	0.36
Hits at the first 10 cm of the Wiens pole	0.40	0.21
Cover		
Bunchgrass	−0.01	0.18
Native rhizomatous grass	0.06	−0.42
Introduced rhizomatous grass	0.03	−0.35
Forb	0.03	−0.35
Wood	0.19	−0.22
Litter	0.36	0.12
Soil	−0.34	0.09
Distance to:		
Shrub	0.01	0.14
Woodland	−0.00	0.05

rows. This species appears to be highly nomadic (Green 1992), and therefore its density and territory size probably directly reflect its annual habitat choice. Such high plasticity in habitat choice has also been reported for other grassland-nesting birds (Cody 1985, Igl and Johnson 1995) and is assumed to be an adaptation to the highly dynamic habitat of the Great Plains.

Territory size and density of Baird's Sparrows were inversely related; territories in two-burn areas were larger than in four-burn areas, whereas density was lower in two- than in four-burn areas. Although density does not necessarily indicate habitat quality (Van Horne 1983), high densities and small territories in four-burn areas suggest that vegetation in areas with several prescribed burns is more suitable for breeding Baird's Sparrows than in areas with few or no prescribed burns. This notion was supported by the significant relationship between density or territory size and vegetation variables on two- and four-burn areas. Low litter depth, as was typical in four-burn areas, was consistently associated with high Baird's Sparrow densities and small territories. Baird's Sparrows were absent, however, from areas where litter was not present at all. They thus preferred an intermediate litter depth, which may be a compromise between foraging efficiency and availability of nest cover (Winter 1994). Litter depth thus strongly influenced the distribution of Baird's Sparrows, as described in other studies (Sousa and McDonal 1983, Renken and Dinsmore 1987, Anstey et al. 1995, Madden 1996).

My observations support those of previous studies that have described Baird's Sparrow as sensitive to vegetation characteristics of its habitat and thus as a highly restricted grassland bird (Kantrud and Kologiski 1983, Goossen et al. 1993). Recent observations of Baird's Sparrows in alfalfa (*Medicago sativa*) fields and other cultivated areas, however, suggest the species may be more adaptable to habitat change than previously thought (DeSmet and Conrad 1991, Davis et al. 1996), but it is not known if these areas support successful breeding. It is also not known if the effect of fire on Baird's Sparrow differs between large and small prairie fragments, as has been shown by Herkert (1994) for bird communities in tall-grass prairie fragments in Illinois. The absence of Baird's Sparrow on unburned habitats in my study clearly documents that prescribed fire is necessary to sustain populations of Baird's Sparrow at Lostwood NWR in northwestern North Dakota. These findings may not apply to more western parts of the species' breeding range, where annual precipitation and thus plant growth and litter accumulation are less. One must thus be cautious when applying results of a spatially restricted study to a broader scale (Raphael et al. 1987, Wiens et al. 1987, Fox 1992). These results, however, should compel land managers to further explore prescribed burning as a management tool for Baird's Sparrow throughout the eastern part of its breeding range in the northern mixed-grass prairie.

ACKNOWLEDGMENTS

I thank K. Schmidt-Koenig and H. Wiley for advising this study. Special thanks are due K. Smith and B. Murphy who helped during the field season, B. Madden who shared both joys and frustrations, M. Green who introduced me to one of the most beautiful places I know, and B. Stewart whose delicious pancakes maintained my energy. B. Murphy, K. Smith, D. Johnson, S. Jones, M. Green, H. Wiley, J. Faaborg, W. Hochachka, and F. Uhlman made many suggestions that greatly improved the manuscript. My work was supported by the U.S. Fish and Wildlife Service and a stipend given by the Tübinger Studentenstiftung/Germany.

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