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TRENDS IN ABUNDANCE OF GRASSLAND BIRDS FOLLOWING A SPRING PRESCRIBED BURN IN SOUTHERN ARIZONA

CHRIS KIRKPATRICK,* STEPHEN DESTEFANO, R. WILLIAM MANNAN, AND JOHN LLOYD

Arizona Cooperative Fish and Wildlife Research Unit, 104 Bio Science East, University of Arizona, Tucson, AZ 85721 (CK)
United States Geological Service Cooperative Fish and Wildlife Research Unit, University of Massachusetts, Amherst, MA 01003 (SD)
Wildlife and Fisheries Program, School of Renewable Natural Resources, 325 Bio Science East, University of Arizona, Tucson, AZ 85721 (RWM)
Cooperative Wildlife Research Unit, University of Montana, Missoula, MT 59812 (JL)
**Correspondent: kirkpatr@email.arizona.edu*

ABSTRACT—We examined short-term trends in relative abundance and species richness of breeding and wintering grassland birds before (1996) and after (1997, 1998) a prescribed burn in a mesquite-invaded, desert grassland at Buenos Aires National Wildlife Refuge, Arizona. We surveyed birds and sampled vegetation along 1-km line transects bisecting 14 (7 control, 7 burn) 25-ha plots located randomly within a burn and adjacent control unit. Following a spring burn that was moderate in intensity and patchy in areal extent, we observed that ground cover was affected more strongly by burning than mesquite (*Prosopis*) cover, smaller mesquite were affected more strongly by burning than larger mesquite, and mortality of mesquite was low. No change in total abundance of birds was detected on the burn unit following fire for either wintering or breeding birds; however, species richness of breeding birds decreased in the first year post-burn. During the breeding season, mourning doves (*Zenaida macroura*) increased, whereas Botteri's sparrows (*Aimophila botterii*), Cassin's sparrows (*Aimophila cassinii*), and cactus wrens (*Campylorhynchus brunneicapillus*) decreased in relative abundance following fire. During the wintering season, ladder-backed woodpeckers (*Picoides scalaris*) and vesper sparrows (*Pooecetes gramineus*) increased and cactus wrens decreased in relative abundance following fire. Beyond species-level trends, we found stronger evidence of trends and greater magnitudes of relative change for breeding species associated with open grasslands compared to those associated with shrubs. The use of spring burns on the Refuge will likely improve conditions for open-grassland species that were historically more abundant by killing smaller mesquite and reducing mesquite recruitment. However, more intense and extensive fires will be required to reduce the presence of larger mesquite. Such fires would likely have a greater impact on birds associated with shrubs, and consequently, a greater impact on the avian community as a whole.

RESUMEN—Examinamos las tendencias de corto plazo en la abundancia relativa y la riqueza de especies de aves de pastizal anidantes e invernales antes (1996) y después (1997, 1998) de una quema prescrita en un pastizal desértico invadido por mezquite en el Refugio Nacional de Vida Silvestre Buenos Aires, Arizona. Realizamos monitoréos de aves y muestréos de vegetación a través de transectos lineares de 1 km de largo, cruzando 14 parcelas (7 de control, 7 quemados) de 25 ha seleccionados al azar en una zona quemada y en una unidad de control adyacente. Después de una quema en la primavera, moderada en intensidad e irregular en su extensión areal, observamos que la cobertura del suelo fue más afectada por el fuego que la cobertura de mezquite (*Prosopis*), los mezquites pequeños fueron más afectados por el fuego que los mezquites de mayor tamaño, y la mortalidad de mezquites fue baja. No detectamos cambios en la abundancia total de aves anidantes ni invernales en la zona incendiada; sin embargo, la riqueza de especies de aves anidantes disminuyó en el primer año después de la quema. Durante la temporada de reproducción, las palomas huilotas (*Zenaida macroura*) se incrementaron, mientras que los zacatoneros de Botteri (*Aimophila botterii*), los zacatoneros de Cassin (*Aimophila cassinii*), y las matracas desérticas (*Campylorhynchus brunneicapillus*) disminuyeron en abundancia relativa después de la quema. Durante la temporada invernal, los carpinteros listados (*Picoides scalaris*) y los gorriones coliblancos

(*Pooecetes gramineus*) se incrementaron, mientras que las matracas desérticas disminuyeron en abundancia relativa después de la quema. Más allá de las tendencias a nivel de especie, encontramos mayor evidencia de las tendencias y mayores magnitudes en el cambio relativo de las especies anidantes asociadas con pastizales abiertos en comparación con aquellas especies asociadas con matorrales. El uso de quemas durante la primavera en el Refugio probablemente mejorará las condiciones para especies de pastizales abiertos que históricamente fueron más abundantes, al matar los mezquites más pequeños y reducir el reclutamiento de mezquite. Sin embargo, se requerirán quemas más intensas y extensas para reducir la presencia de mezquites de mayor tamaño. Dichas quemas probablemente tendrán un mayor impacto en las aves asociadas con matorrales, y consecuentemente, un mayor impacto en la comunidad de aves en general.

Populations of grassland birds have declined over the last quarter century at a rate greater than any other avian guild in North America (Knopf, 1994). Destruction and degradation of native grasslands have been implicated as major causes in the decline (DeSante and George, 1994; Vickery et al., 1999). In the southwestern United States, desert grasslands have been degraded substantially as a result of overgrazing, drought, invasion of exotic species, and fire suppression (Bahre, 1995). Before the arrival of Anglo-American settlers (ca. 1870), summer wildfires were extensive and relatively frequent, occurring at least once every 10 years (Humphrey, 1974; McPherson, 1995). The subsequent interruption of the natural fire regime has contributed to pronounced structural, compositional, and functional changes to desert grasslands (Bahre, 1991). No change has been more apparent than the dramatic increase of shrubs, primarily mesquite (*Prosopis*), in upland areas formerly dominated by native grasses (Humphrey, 1974; Brown, 1994).

These mesquite-invaded grasslands currently support a different avian community than was present historically (Lloyd et al., 1998). Encroachment of mesquite seems to have facilitated the movement of shrub-dependent bird species into areas that were formerly open grasslands (Lloyd, 1997). Species typical of more open grasslands, such as Botteri's sparrows (*Aimophila botterii*) and Cassin's sparrows (*Aimophila cassinii*), are now less common, and shrub-dependent species, such as black-throated sparrows (*Amphispiza bilineata*) and Lucy's warblers (*Vermivora luciae*), currently dominate the composition and structure of these avian communities (Maurer, 1985; Lloyd et al., 1998).

In an effort to reverse these trends and promote self-sustaining populations of grassland birds, managers at Buenos Aires National Wildlife Refuge, Arizona use spring prescribed burns to halt the spread of mesquite and restore areas of open grassland. Despite the emphasis placed on this management technique, relatively little is known about the potential impacts of prescribed burning on grassland birds (Herkert, 1994), and thus, the efficacy of restoration efforts remains unclear. To address these questions, we examined the effects of a spring prescribed burn in a mesquite-invaded grassland on the Refuge to determine the direction and magnitude of short-term trends in relative abundance and species richness of breeding and wintering birds following fire.

Methods and Materials—*Study Area*—This study was conducted on Buenos Aires National Wildlife Refuge in the Altar Valley of southern Arizona. The 46,537-ha Refuge was established in 1985 and protects the largest, ungrazed grassland in the state. Despite the recent protected status, Refuge grasslands suffer the effects of decades of overgrazing and fire suppression; moreover, mesquite are well established in most upland areas (Lloyd, 1997). Refuge managers use prescribed burning to reduce the density of mesquite and encourage growth of native grasses. Starting in the early 1990s, approximately 5,700 ha of grasslands have been burned each spring on a 5-year rotation schedule.

Climate in Altar Valley is semi-arid and temperatures range from 44°C in summer to −13°C in winter with a monthly mean of 17°C. Average annual precipitation on the valley floor is 300 mm. Annual precipitation is bimodal with a brief summer season of localized thunderstorms and a longer winter season of widespread frontal storms.

The study site was located at an elevation of 1,100 m in an upland area of mesquite-invaded grassland on the northern half of the Refuge. Ground cover was characterized by a mix of perennial bunchgrasses, sub-shrubs, forbs, and large patches of bare ground. Lehmann lovegrass (*Eragrostis lehmanniana*), a fire-adapted species introduced from South Africa, was the dominant grass. Common native grasses included Arizona cottontop (*Digitaria californica*), gramas (*Bouteloua*), and three-awns (*Aristida*). Snakeweed (*Gutierrezia sarothrae*) and burroweed (*Isocoma tenuisecta*) were the common sub-shrub species. Shrub cover was dominated by velvet mesquite (*Prosopis velutina*), which comprised >90% of individual shrubs and varied in density from scattered individuals in open grasslands to relatively dense stands often associated with small washes and gullies. Some mesquite trees were >5.0 m in height; however, most mesquite were small enough (<3.0 m) to be classified as shrubs.

Experimental Design—In spring 1996, we chose 2 experimental units, a 1,596-ha burn and a 1,818-ha control, from a selection of fire management units on the Refuge. We matched the control to the burn unit based on similarities in size, topography, vegetation structure and composition, and distances to major landscape features (e.g., mountains, reservoirs, streams, and recent burns). In addition, we selected experimental units with similar disturbance histories; both units had not been grazed since 1985 and had not been burned in the preceding 4 years. Refuge records indicated that the control unit burned once in 1992.

Within each unit, we randomly located 7 25-ha plots (1,000 by 250 m) and bisected each plot with a 1-km long transect along which birds were surveyed and vegetation was sampled. The treatment unit was burned on 1 April 1997. Because large washes acted as firebreaks during the burn, we spot-burned several unaffected plots on 7 and 14 April 1997.

Because of the size of management units on the Refuge, we could not intersperse control and burn plots. Thus, inferences about causal relations between burning and changes in bird abundance must be viewed as tentative. Furthermore, we restrict our inferences to populations within the study area because experimental units were unreplicated.

Fire Monitoring—One week before the prescribed burn, we measured the pre-burn load of surface fuels by collecting all grasses, forbs, sub-shrubs, and organic surface litter from within a 0.5-m^2 area at 4 sub-sampling points located 5 m N, S, E, and W from 1 end-point of 6 burn transects. In addition, we clipped 6 grass samples (ca. 100 g) on the morning of the burn to determine the moisture content of the fine-fuel source. Samples were dried at 70°C for 48 h.

Managers on the Refuge conduct spring prescribed burns under the following prescription: temperatures of 21 to 35°C, relative humidity of 5 to 25%, and winds of 16 to 40 kph. During the burn we measured these variables hourly from an automatic weather station located about 2-km southeast of the burn unit. In addition, we estimated average and maximum values of flame height and rate of fire spread.

Vegetation Sampling—Following the burn, we estimated the areal extent of remnant patches of vegetation within the burn unit by noting whether vegetation had been burned or unburned at 40 points located randomly within each burn plot. Using the line intercept method (Canfield, 1941), we quantified percent cover of grasses, forbs, sub-shrubs, mesquite, and bare ground in March 1997 (pre-burn) and March 1998 (post-burn). On each of the 14 plots, we randomly selected 6 of 21 metal stakes demarcating the survey transect, and from these stakes we extended a 20-m sample line in a random direction. We measured basal cover of grasses and forbs and aerial cover of shrubs and sub-shrubs (Canfield, 1941).

Fifteen months after the burn (July 1998), we measured mesquite density, structure, and fire damage from within 10 10-m radius quadrats placed at 100-m intervals and at a random distance (<60 m) perpendicular to the transects in each of the burn plots. We quantified the total number of mesquite within each quadrat, and for each mesquite we used a graduated pole to record the maximum height (to the nearest 0.5 m) of live or dead vegetation. Maximum height of dead structures (usually fire-killed limbs and twigs) was recorded as a rough estimate of the pre-burn height of the mesquite canopy.

We placed mesquite into 1 of 3 height classes, <1.5 m, 1.5 to 3.0 m, and >3.0 m, and 1 of 4 fire-damage classes: no visible effect of fire, partial crown kill, complete crown kill with resprouting from base or stems, and crown and roots killed (DeBano et al., 1996). We combined fire-damage classes 1 and 2 into a single category to denote mesquite with less severe damage and fire-damage classes 3 and 4 into a single category to denote mesquite with more severe damage.

Bird Surveys—We quantified species relative abundance, total relative abundance, and species richness for breeding and wintering communities of grassland birds by surveying along 1-km line transects. Birds were surveyed for 2 to 3 h beginning 1/2 h after sunrise and typically 2 to 3 transects were completed by a single observer during the morning. As an index of relative abundance, we recorded all visual and auditory detections of birds within a band 125-m wide on either side of the transect. Observations of raptors, bird flyovers, and flocks of quail were not included in analyses. No surveys were performed during periods of rain or strong winds (>32 kph).

We surveyed breeding birds from 1 April to 30 July with an average of 7 surveys per plot in 1996 (pre-burn) and 10 surveys per plot in 1997 and 1998 (post-burn). From a previous study (Lloyd et al., 1998), we knew that mesquite density influenced the distribution of breeding grassland birds more than any other vegetation variable on our study site.

Therefore, we classified breeding species a priori into guilds (shrub-dependent or open-grassland species) based on the importance of shrubs as a component of each species' habitat (see Lloyd et al., 1998). We considered grassland obligate (e.g., Botteri's sparrows) and non-shrub-dependent species (e.g., mourning doves—*Zenaida macroura*) members of the open-grassland guild.

We surveyed wintering birds from 1 February to 30 March with an average of 6 surveys per plot in 1997 (pre-burn) and 1998 (post-burn). Because wintering sparrows often formed mixed-species flocks, we estimated the size and species composition of flocks with >5 individuals and analyzed these data separately from the relative abundance data for wintering species.

Statistical Analyses—We analyzed relative abundance data for species that were widely distributed (present on >50% of plots). For breeding species that showed a clear intraseasonal peak in detectability (>40% difference in frequency of observations between April–May and June–July), we limited analyses to the time period with the greater number of observations. For each species, we estimated a seasonal mean value of relative abundance for both the control and burn units using the average number of observations per plot (total number of observations/total number of survey efforts).

Before conducting analyses, we examined residual plots of bird and vegetation data for outlying values and assessed the need for transformations. A square root transformation +0.1 helped to stabilize nonconstant variances in most of the data. We report untransformed summary statistics (e.g., differences in means, 95% confidence intervals) in tables but used transformed data for analyses. We tested the null statistical hypothesis that there were no differences in relative abundance, species richness, and percent cover on the burn unit versus the control unit through time. Using a repeated measures ANOVA, we calculated a Wilks' Lambda *F*-statistic for within-subjects, time by treatment interactions.

We did not set a fixed significance level because *P*-values provide a continuous measurement scale of the strength of evidence against a specified null hypothesis (Cherry, 1998). Conclusions were based on the combined evidence of *P*-values from hypothesis testing and magnitudes of change generated from parameter estimates. To calculate magnitudes of change in relative abundance and percent cover values over time, we first found the difference in parameter estimates before and after the prescribed fire on the burn unit. To these values, we added correction factors equaling the difference in these parameter estimates before and after the prescribed fire on the control unit. The correction factor was used to account for general variability in grassland bird abundance through time across the study area.

RESULTS—Before the burn, surface fuels averaged 3,361 kg/ha (SE = 926, n = 6) and moisture content of fine fuels was 28% (SE = 1.3, n = 6). During the burn, air temperature was 20°C (SD = 1.5, n = 9), relative humidity was 37% (SD = 8.8, n = 9), and winds were 32 kph (SD = 4.8, n = 9) with gusts to 53 kph. Fire behavior was variable, but flame lengths averaged 1 m (maximum 6 m), and the rate of fire spread averaged 8 m/min (maximum 38 m/min).

Vegetation—Although we did not quantify vegetation cover immediately after the burn, virtually all ground cover was destroyed and many smaller shrubs were top-killed in the path of the fire. Despite the damage, 28% (SE = 2.8, n = 7) of the burn unit was unaffected by fire and variably-sized pockets of vegetation, roughly 5 to 100 m^2, persisted.

One year after the fire, bare ground increased on the burn unit relative to the control by 12%; whereas, grass cover was reduced by 28%, sub-shrub cover by 92%, and mesquite cover by 49% (Table 1). Although forb cover increased across the study area, the increase was substantially greater on the control, resulting in a relative decrease of 500% on the burn unit.

One percent (4 shrubs/ha, SE = 0.9, n = 7) of mesquite were killed outright, 56% (164 shrubs/ha, SE = 25.3, n = 7) were top-killed but resprouted from base or stems, 23% (64 shrubs/ha, SE = 13.6, n = 7) showed evidence of a partial crown kill, and 20% (63 shrubs/ha, SE = 22.0, n = 7) appeared to be unaffected by the burn. Moreover, smaller mesquite suffered proportionally greater damage than larger mesquite (Fig. 1), and no mesquite >3.5 m was killed outright by fire.

Breeding Birds—During 3 years of breeding bird surveys, we detected 5,266 individuals of 45 species. Black-throated sparrow was the most abundant and widely distributed breeding species, accounting for 24% of total sightings. Other common breeding species, in order of decreasing relative abundance, were eastern meadowlark (*Sternella magna*), Lucy's warbler, cactus wren (*Campylorhynchus brunneicapillus*), mourning dove, and ash-throated flycatcher (*Myriarchus cinerascens*).

We observed an average of 15 birds (SD = 4.3, n = 42) and 7 species (SD = 1.5, n = 42) per survey route during 3 years of breeding

TABLE 1—Percent vegetation cover and outcomes of repeated measures ANOVA (time by treatment interactions) on 14 (7 control, 7 burn), 25-ha plots before and after a spring prescribed burn on Buenos Aires National Wildlife Refuge, Arizona. Grasses and forbs were measured basally and shrubs and sub-shrubs were measured aerially.

Vegetation cover	Experimental unit	1997 (pre-burn) $\bar{X}$ (*SE*)	1998 (post-burn) $\bar{X}$ (*SE*)	$F_{1, 12}$	P
Grass	control	3.35 (0.29)	2.93 (0.32)	7.38	0.02
	burn	2.81 (0.18)	1.61 (0.19)		
Forb[1]	control	0.17 (0.04)	1.05 (0.15)	5.84	0.03
	burn	0.10 (0.04)	0.48 (0.06)		
Sub-shrub[1]	control	2.41 (1.36)	2.91 (1.26)	42.19	<0.01
	burn	6.20 (0.88)	1.02 (0.33)		
Mesquite[1]	control	6.67 (2.12)	7.18 (1.73)	3.58	0.08
	burn	8.16 (2.16)	4.66 (1.19)		
Bare ground[1]	control	87.98 (2.56)	86.51 (2.54)	11.35	<0.01
	burn	83.74 (2.17)	91.97 (1.20)		

[1] *F*-statistic and *P*-value generated from square root transformed data.

bird surveys. No substantial change in total abundance of breeding birds was detected on the burn unit following the fire ($F_{2,11}$ = 0.12, P = 0.88). Species richness declined 24% (1.8 species/survey route) in the first year post-burn and 14% (1.0 species/survey route) in the second year post-burn on the burn unit relative to the control ($F_{2,11}$ = 8.05, P = 0.01).

There were sufficient data for statistical analyses of trends in relative abundance for 12 species of breeding grassland birds, comprising 85% of all bird observations (Tables 2 and 3).

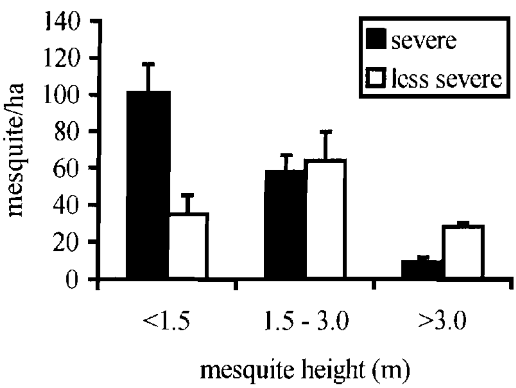

FIG. 1—Density ($\bar{X}$ and *SE*) of velvet mesquite (*Prosopis velutina*) in 3 height classes that suffered either severe fire-damage (killed outright or top-killed) or less severe fire-damage (partial crown-kill or no visible damage) 15 months after a spring prescribed burn on 7 25-ha burn plots at Buenos Aires National Wildlife Refuge, Arizona.

Compared to pre-burn levels, we observed the following post-burn trends in relative abundance on the burn unit relative to the control. Mourning doves increased 393% (1.4 birds per survey) in the first year post-burn. Botteri's sparrows decreased 288% (1.2 birds per survey) in the first year post-burn and 229% (0.9 birds per survey) in the second year post-burn. Botteri's sparrow was the only species to disappear from the burn unit with no individuals observed during the second year post-burn. Cactus wrens decreased 313% (0.7 birds per survey) in the first year post-burn, and Cassin's sparrows decreased 217% (1.7 birds per survey) in the second year post burn. In addition, pyrrhuloxias (*Cardinalus sinuatus*), loggerhead shrikes (*Lanius ludovicianus*), and black-throated sparrows displayed changes in relative abundance following fire; however, we could not clarify the nature of the changes because of increased variability and larger observed *P*-values (Tables 2 and 3). Beyond species-level trends, analyses revealed stronger evidence of trends and greater magnitudes of relative change for open-grassland as compared with shrub-dependent species, especially in the first year post-burn (Table 3).

Wintering Birds—During 2 years of wintering bird surveys, we detected 1,425 individuals, 57 mixed-species flocks, and 28 species. Outside of flocks, vesper sparrow (*Pooecetes gramineus*), black-throated sparrow, eastern meadowlark, verdin (*Auriparus flaviceps*), cactus wren, and

TABLE 2—Results of breeding bird surveys (April to August, 1996, 1997, and 1998) showing differences in mean relative abundance (burn unit − control unit), 95% confidence intervals, and outcomes of repeated measures ANOVA (time by treatment interactions) on 14 (7 control, 7 burn), 25-ha plots on Buenos Aires National Wildlife Refuge, Arizona. Burn occurred on 1 April 1997.

Species	1996 (pre-burn)		1997 (post-burn)		1998 (post-burn)			
	d	95% *CI*	*d*	95% *CI*	*d*	95% *CI*	$F_{2,11}$	*P*
Mourning dove[2]	−0.12	−0.62, 0.37	1.24	0.16, 2.40	0.81	0.20, 1.41	7.47	0.01
Ash-throated flycatcher[2]	0.42	−0.10, 0.94	0.50	−0.09, 1.10	0.64	0.11, 1.16	0.53	0.60
Cactus wren[2]	−0.76	−1.23, −0.30	−1.50	−2.34, −0.66	−0.50	−1.10, 0.10	5.27	0.02
Northern mocking-bird[1,2,3]	−0.16	−1.10, 0.80	−0.25	−0.66, 0.16	0.23	−0.62, 1.08	1.74	0.22
Loggerhead shrike[2]	0.18	−0.24, 0.60	0.27	−0.06, 0.61	0.68	0.22, 1.14	2.42	0.14
Lucy's warbler[2]	1.04	0.11, 1.97	0.84	−0.06, 1.75	0.89	0.12, 1.66	0.73	0.50
Eastern meadowlark[2]	−0.61	−1.32, 0.10	−1.16	−2.07, −0.24	−0.94	−1.75, −0.13	0.43	0.66
Pyrrhuloxia[2]	0.26	−0.23, 0.74	−0.37	−0.92, 0.19	−0.24	−0.54, 0.05	2.80	0.10
Blue grosbeak[1,2,3]	−0.04	−0.67, 0.59	−0.16	−0.63, 0.32	0.09	−0.22, 0.39	0.34	0.72
Botteri's sparrow[2,3]	0.16	−0.25, 0.56	−0.99	−1.42, −0.55	−0.77	−1.28, −0.26	8.18	0.01
Cassin's sparrow[3]	0.05	−0.94, 1.03	−0.76	−1.37, −0.16	−1.69	−2.64, −0.73	3.66	0.06
Black-throated sparrow	−0.18	−1.64, 1.27	1.08	−0.35, 2.51	1.50	0.21, 2.80	2.31	0.14

[1] Scientific names not mentioned in text: northern mockingbird (*Mimus polyglottus*) and blue grosbeak (*Guiraca caerulea*).
[2] *F*-statistic and *P*-value generated from square root transformed data.
[3] Late season breeder; only June/July data used.

Brewer's sparrow (*Spizella breweri*) were the most frequently detected species. Vesper sparrows were observed in 70% of mixed-species flocks, Brewer's sparrows in 60%, and white-crowned sparrows (*Zonotrichia leucophrys*) in 16%.

We observed an average of 9 birds ($SD = 4.0$, $n = 28$) and 5 species ($SD = 1.4$, $n = 28$) per survey route during 2 years of wintering bird surveys. There was no substantial change in total abundance (including individuals in flocks, square root transformed, $F_{1,12} = 1.46$, $P =$

TABLE 3—Direction and magnitude of changes (compared to 1996 pre-burn levels) in relative abundance of breeding species following a spring prescribed burn on Buenos Aires National Wildlife Refuge, Arizona. Species are listed in order of decreasing magnitude of change in relative abundance.

Species	Guild assignment[1]	Percent (absolute) change on burn unit	
		1997 (1 year post-burn)	1998 (2 years post-burn)
Mourning dove[2]	G	+393 (1.4)	+260 (0.9)
Cactus wren[2]	G	−313 (0.7)	+111 (0.3)
Botteri's sparrow[2]	G	−288 (1.2)	−229 (0.9)
Cassin's sparrow[3]	G	−102 (0.8)	−217 (1.7)
Pyrrhuloxia[4]	S	−107 (0.6)	−86 (0.5)
Loggerhead shrike[4]	S	+14 (0.1)	+78 (0.5)
Black-throated sparrow[4]	S	+43 (1.3)	+57 (1.7)
Eastern meadowlark[5]	G	−54 (0.5)	−32 (0.3)
Northern mockingbird[5]	S	−8 (0.1)	+34 (0.4)
Blue grosbeak[5]	S	−29 (0.1)	+29 (0.1)
Ash-throated flycatcher[5]	S	+8 (0.1)	+22 (0.2)
Lucy's warbler[5]	S	−12 (0.2)	−9 (0.2)

[1] Guild assignment: S = shrub-dependent species; G = open-grassland species. Initial *F*-test: [2] $P < 0.05$, [3] $0.05 < P < 0.10$, [4] $0.10 < P < 0.15$, [5] $P > 0.15$.

TABLE 4—Results of wintering bird surveys (February to April, 1997 and 1998) showing differences in mean relative abundance (burn unit − control unit), 95% confidence intervals, magnitude and direction of changes (percent and absolute), and outcomes of repeated measures ANOVA (time by treatment interactions) on 14 (7 control, 7 burn), 25-ha plots on Buenos Aires National Wildlife Refuge, Arizona. Burn occurred on 1 April 1997.

	1997 (pre-burn)		1998 (post-burn)		Change on burn unit		
Species	d	95% CI	d	95% CI	1997 to 1998	$F_{1,12}$	P
Ladder-backed woodpecker[2]	0.09	−0.11, 0.30	0.59	−0.03, 1.20	+261 (0.5)	5.88	0.03
Cactus wren[2]	−0.43	−0.93, 0.08	−1.04	−1.85, −0.23	−274 (0.6)	3.90	0.07
Loggerhead shrike	0.13	−0.20, 0.46	0.18	−0.36, 0.71	+14 (0.05)	0.04	0.83
Eastern meadowlark[2]	−1.03	−1.90, −0.16	−1.87	−4.01, −0.27	−150 (0.8)	1.32	0.27
Verdin[2]	0.57	0.09, 1.04	0.35	−0.27, 0.97	−29 (0.2)	1.56	0.24
Canyon towhee[1]	−0.07	−0.47, 0.32	−0.10	−0.46, 0.25	−16 (0.03)	0.02	0.89
Grasshopper sparrow[1,2]	−0.76	−1.80, 0.28	−0.09	−0.18, −0.08	+129 (0.7)	1.17	0.30
Vesper sparrow	−0.99	−2.53, 0.55	0.82	−0.33, 1.97	+68 (1.8)	3.30	0.09
Black-throated sparrow	−0.40	−1.37, 0.56	0.15	−0.52, 0.81	+42 (0.6)	1.15	0.30
Brewer's sparrow	−0.23	−1.14, 0.68	−0.14	−0.51, 0.22	+10 (0.1)	0.04	0.85
Flocks[3]	−0.32	−0.85, 0.20	0.17	−0.07, 0.40	+147 (0.5)	2.42	0.14

[1] Scientific names not mentioned in text: canyon towhee (*Pipilio fuscus*) and grasshopper sparrow (*Ammodramus savannarum*).

[2] F-statistic and P-value generated from square root transformed data.

[3] Flocks = groups with >5 individuals. F-statistic and P-value generated from ln transformed data.

0.25) or species richness ($F_{1,12}$ = 0.73, P = 0.41) of wintering birds on the burn unit as compared with the control following fire.

There were sufficient data for statistical analyses of trends in relative abundance for 10 species of wintering grassland birds (Table 4). Compared to pre-burn levels, we observed the following post-burn trends in relative abundance: ladder-backed woodpeckers increased 261% (0.5 birds per survey); vesper sparrows increased 68% (1.8 birds per survey); and cactus wrens decreased 274% (0.6 birds per survey) on the burn unit relative to the control. In addition, we observed a change in the relative abundance of mixed-species flocks on the burn unit following fire; however, we could not clarify the nature of the change because of increased variability and a larger observed P-value (Table 4).

DISCUSSION—Effects of fire on wildlife populations and habitats vary with characteristics of the fire regime including the frequency, season, extent, and intensity of burning (Whelan, 1995; DeBano et al., 1998). We observed a prescribed burn that was patchy in areal extent; an outcome we attribute to the highly variable distribution of surface fuels (range 655 to 6,435 kg per ha) and to the presence of intervening washes that acted as natural firebreaks during the burn. Moreover, the burn occurred in the early spring when weather conditions were near the lower limits of the Refuge's burning prescription (i.e., cool and wet) and moisture content of fine fuels was relatively high. The combination of weather conditions, fuel conditions, and fire behavior variables observed during the burn were indicative of a fire of only moderate intensity (Whelan, 1995; DeBano et al., 1998).

Effects of the burn on the vegetation community were generally moderate and of short duration, an outcome typical of fires that burn with lesser severity (DeBano et al., 1998). Most ground cover was removed and many smaller mesquite were top-killed in the path of the fire; however, perennial grasses and mesquite resprouted quickly and in less than 2 years the physiognomy of the burn unit resembled that of the control. Although difficult to compare directly because of differences in measurement technique, we believe ground cover was affected more strongly by burning than shrub cover, especially in the first year post-burn. Subshrubs, for instance, comprised a substantial portion of ground cover on the burn unit and, as with similar studies of fire in desert grasslands (Reynolds and Bohning, 1956; Cable, 1967), were affected by fire more strongly than other vegetation.

Despite a nearly 50% reduction in mesquite cover, we found that mesquite mortality was low and smaller mesquite suffered proportionally greater fire damage than larger mesquite. This finding is consistent with previous research showing that smaller mesquite are more susceptible than larger mesquite to fire damage and mortality (Reynolds and Bohning, 1956; Blydenstein, 1957; Cable, 1965). Because we did not collect pre-burn measurements of mesquite, we likely overlooked some smaller shrubs and seedlings that were killed by fire but were not evident during post-burn sampling. Therefore, we may have underestimated mesquite mortality, especially for mesquite <1 m in height.

The response of birds to fire is closely related to the effect of fire on vegetation (McPherson, 1995; Whelan, 1995). In our study, the prescribed fire was incomplete in its coverage and affected vegetation only temporarily where it did burn; we believe this outcome contributed to the limited and ephemeral changes observed in the avian community as a whole. Species richness of breeding birds decreased by nearly 25% in the first year post-burn, but unlike findings from similar studies of fire and birds in desert grasslands (Bock et al., 1976; Bock and Bock, 1992), we observed no substantial change in total bird abundance following fire during either the wintering or breeding seasons.

Instead, we detected primarily species-level trends in relative abundance that varied in both direction and magnitude. Previous research in desert grasslands suggests that the response of breeding birds to the effects of fire is closely related to the natural history requirements of each species (Bock and Bock, 1992; Ganey et al., 1996). For example, mourning doves, whose abundance increased after burning during our study, prefer to forage on bare ground where excessive litter does not conceal food items (Mirarchi and Baskett, 1994) and are often associated with recently burned areas (Bock et al., 1976; Bock and Bock, 1988; Reynolds and Krausman, 1998). Cassin's and Botteri's sparrows, 2 species that decreased following burning during our study, prefer grasslands with sufficient ground cover for foraging and nesting (Bock and Webb, 1984; Rising and Beadle, 1996; Webb and Bock, 1996), and both are reported to be affected adversely by burning in the short term (Bock and Bock, 1992).

Changes in relative abundance of wintering bird species also concurred with the general habitat affinities of each species. For example, woodpeckers are known to move into burned areas, possibly in response to the increased abundance or availability of insects that inhabit dead trees (Bendell, 1974; Horton and Mannan, 1988; Breininger and Smith, 1992). Similarly, we found that relative abundance of ladder-backed woodpeckers increased following burning. Vesper sparrows, whose abundance also increased following fire during our study, show a strong affinity for burned areas both in the winter (Bock and Bock, 1988, 1992) and during the breeding season (Petersen and Best, 1987; Pylypec, 1991).

Beyond species-level trends, we found stronger evidence of trends and greater magnitudes of relative change for breeding species associated with open grasslands. In general, the trends were more pronounced immediately after the burn. This pattern was consistent with the observation that fire impacted ground cover more strongly than shrub cover, especially in the first year post-burn. With hindsight, it appears that several open-grassland species used mesquite to some degree as a component of their habitat on the Refuge (e.g., song perches for Cassin's and Botteri's sparrows; nest sites for cactus wrens). Nevertheless, most open grassland species use ground cover as their primary source for foraging and nest sites (Ehrlich et al., 1988), or, as in the case of cactus wrens, are correlated negatively with increasing mesquite density (Maurer, 1985; Lloyd et al., 1998).

In contrast, shrub-dependent species displayed weaker evidence of trends and smaller magnitudes of relative change following burning. This pattern may reflect the differential susceptibility to burning of mesquite in different size-classes. Following prescribed burning in a Texas grassland, fire appeared to have only a minimal affect on larger mesquite, a resource that was preferred for nest sites by mesquite-dwelling species (Renwald, 1978). During the current study, the majority of medium and larger-sized mesquite suffered no or only minimal structural damage; thus, foraging and nesting opportunities for shrub-dependent species may not have been substantially reduced. Other research indicates that fire has only a minimal effect on shrub-dwelling birds, especially when fires are less intense or incomplete in coverage (Breininger and Smith, 1992; Fitzgerald and Tanner, 1992).

Prescribed burns that are patchy in extent and moderate in intensity are not uncommon in mesquite-invaded grasslands on the Refuge. In 1998, for example, an estimated 25% of the area within treated fire management units was unaffected by burning (R. Madsen, pers. comm.). Moreover, unlike the intense wildfires that historically burned during summer, fires on Refuge grasslands now occur in the early spring when weather conditions favor burns of lesser intensity. Although these burns are capable of reducing mesquite recruitment (Blydenstein, 1957; Humphrey, 1974), we believe that more intense fires will be required to reduce the presence of larger mesquite. Such fires would likely have a greater impact on birds associated with shrubs (especially pyrrhuloxias, loggerhead shrikes, and black-throated sparrows), and consequently, a greater impact on the avian community as a whole.

Grassland birds that require adequate ground cover for foraging and nesting, including species of management concern like Botteri's and Cassin's sparrows, are likely to be affected negatively by spring burning in the short-term. Although some individuals may persist in recently burned areas by using remnant patches of habitat, many will be forced to relocate. Managers currently use a rotational system of burning that creates a mosaic of post-fire vegetation types across Refuge grasslands. Thus, habitat loss is localized and species that are displaced by fire may find habitat in adjacent unburned areas, assuming it is unoccupied. Despite some short-term negative effects, we believe the continued use of spring burning will ultimately benefit open-grassland species by removing some of the invasive shrub component and restoring areas of open grassland. However, until prescribed burns are conducted under conditions favoring more intense fires, these changes will be slow to develop.

Results from this study contribute to our understanding of the effects of fire on grassland birds, particularly those species inhabiting degraded desert grasslands in the southwestern United States. We confirmed trends for several species of breeding and wintering grassland birds reported in other unreplicated fire studies (Bock et al., 1976; Petersen and Best, 1987; Bock and Bock, 1988, 1992; Pylypec, 1991). In addition, we documented a broad pattern during the breeding season suggestive of a differential susceptibility of open-grassland versus shrub-dependent species to spring prescribed burning of moderate intensity. Future research should focus on clarifying observed relationships between bird populations and fire through the use of randomized experimental designs, move beyond tracking bird abundance to focus on measures of avian productivity, and examine the effects of burns of varying intensities and frequencies on grassland bird communities.

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Literature Cited

Bahre, C. J. 1991. A legacy of change: historic human impact on vegetation in the Arizona borderlands. University of Arizona Press, Tucson.

Bahre, C. J. 1995. Human impacts on the grasslands of southeastern Arizona. In: McClaran, M. P., and T. R. Van Devender, editors. The desert grassland. University of Arizona Press, Tucson. Pp. 230–264.

Bendell, J. F. 1974. Fire in the deserts and desert grasslands of North America. In: Kozlowski, T. T., and C. E. Ahlgren, editors. Fire and ecosystems. Academic Press, London, United Kingdom. Pp. 73–125.

Blydenstein, J. 1957. The survival of velvet mesquite (*Prosopis juliflora* var. *velutina*) after fire. Unpublished M.S. thesis, University of Arizona, Tucson.

Bock, C. E., and J. H. Bock. 1988. Grassland birds in southeastern Arizona: impacts of fire, grazing, and alien vegetation. In: Goriup, P. D., editor. Ecology and conservation of grassland birds. Girton, Cambridge, United Kingdom. Pp. 43–58.

BOCK, C. E., AND J. H. BOCK. 1992. Response of birds to wildfire in native versus exotic Arizona grassland. Southwestern Naturalist 37:73–81.

BOCK, J. H., C. E. BOCK, AND J. R. MCKNIGHT. 1976. A study of the effects of grassland fires at the research ranch in southeastern Arizona. Journal of the Arizona Academy of Science 11:49–57.

BOCK, C. E., AND B. WEBB. 1984. Birds as indicator species in southeastern Arizona. Journal Wildlife Management 48:1045–1049.

BREININGER, D. R., AND R. B. SMITH. 1992. Relationship between fire and bird density in coastal scrub and slash pine flatwoods in Florida. American Midland Naturalist 27:233–240.

BROWN, D. E. 1994. Biotic communities: southwestern United States and northwestern Mexico. University of Utah Press, Salt Lake City.

CABLE, D. R. 1965. Damage to mesquite, Lehmann lovegrass, and black-grama by a hot June fire. Journal of Range Management 18:326–329.

CABLE, D. R. 1967. Fire effects on semi-desert grasses and shrubs. Journal of Range Management 24: 170–176.

CANFIELD, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388–394.

CHERRY, S. 1998. Statistical tests in publications of the Wildlife Society. Wildlife Society Bulletin 26: 947–953.

DEBANO, L. F., G. J. GOTTFRIED, J. VILLANUEVA-DIAZ, P. F. FFOLLIOTT, AND D. VALDEZ-ZAMUDIO. 1996. Initial assessment of fire damaged mesquite trees following an illegal burn. In: Effects of fire on Madrean province ecosystems. United States Department of Agriculture Forest Service General Technical Report RM-GTR-289. Pp. 226–228.

DEBANO, L. F., D. G. NEARY, AND P. F. FFOLLIOTT. 1998. Fire's effects on ecosystems. John Wiley & Sons, New York.

DESANTE, D. F., AND T. L. GEORGE. 1994. Population trends in the landbirds of western North America. In: Jehl, J. R., Jr., and N. K. Johnson, editors. A century of avifaunal change in western North America, Studies in Avian Biology, Vol. 15. Cooper Ornithological Society, Sacramento, California. Pp. 173–190.

EHRLICH, P. R., D. S. DOBKIN, AND D. WHEYE. 1988. The birder's handbook. Simon & Schuster, New York.

FITZGERALD, S. M., AND G. W. TANNER. 1992. Avian community response to fire and mechanical shrub control in south Florida. Journal of Range Management 45:496–400.

GANEY, J. L., W. M. BLOCK, AND P. F BOUCHER. 1996. Effects of fire on birds in Madrean forests and woodlands. In: Effects of fire on Madrean province ecosystems. United States Department of Agriculture Forest Service General Technical Report RM-GTR-289. Pp. 144–154.

HERKERT, J. R. 1994. Breeding bird communities of midwestern prairie fragments: the effects of prescribed burning and habitat-area. Natural Areas Journal 14:128–135.

HORTON, S. P., AND R. W. MANNAN. 1988. Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. Wildlife Society Bulletin 16:37–44.

HUMPHREY, R. R. 1974. Fire in the deserts and desert grasslands of North America. In: Kozlowski, T. T., and C. E. Ahlgren, editors. Fire and ecosystems. Academic Press, London, United Kingdom. Pp. 365–400.

KNOPF, F. L. 1994. Avian assemblages on altered grasslands. In: Jehl, J. R., Jr., and N. K. Johnson, editors. A century of avifaunal change in western North America, Studies in Avian Biology, Vol. 15. Cooper Ornithological Society, Sacramento, California. Pp. 247–257.

LLOYD, J. 1997. Large-scale vegetation features affecting the distribution and abundance of grassland birds. Unpublished. M.S. thesis, University of Arizona, Tucson.

LLOYD, J., R. W. MANNAN, S. DESTEFANO, AND C. KIRKPATRICK. 1998. The effects of mesquite invasion on a southeastern Arizona grassland bird community. Wilson Bulletin 110:403–408.

MAURER, B. A. 1985. Avian community dynamics in desert grasslands: observational scale and hierarchical structure. Ecological Monographs 55: 295–312.

MCPHERSON, G. R. 1995. The role of fire in desert grasslands. In: McClaran, M. P., and T. R. Van Devender, editors. The desert grassland. University of Arizona Press, Tucson. Pp. 130–151.

MIRARCHI, R. E., AND T. S. BASKETT. 1994. Mourning dove (*Zenaida macroura*). In: Poole, A., and F. Gill, editors. The birds of North America, No. 117. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

PETERSEN, K. L., AND L. B. BEST. 1987. Effects of prescribed burning on nongame birds in a sagebrush community. Wildlife Society Bulletin 15: 317–329.

PYLYPEC, B. 1991. Impacts of fire on bird populations in a fescue prairie. Canadian Field-Naturalist 105: 346–349.

RENWALD, D. J. 1978. The effects of fire on woody plant selection by nesting nongame birds. Journal of Range Management 31:467–468.

REYNOLDS, H. G., AND J. W. BOHNING. 1956. Effects of burning on a desert grass-shrub range in southern Arizona. Ecology 37:769–777.

REYNOLDS, M. C., AND P. R. KRAUSMAN. 1998. Effects of winter burning on birds in mesquite grassland. Wildlife Society Bulletin 26:867–876.

RISING, J. D., AND D. D. BEADLE. 1996. A guide to the identification and natural history of the sparrows of the United States and Canada. Academic Press, London, United Kingdom.

VICKERY, P. D., P. L. TUBARO, J. M. CARDOSA DA SILVA, B. G. PETERJOHN, J. R. HERKERT, AND R. B. CAVALCANTI. 1999. Conservation of grassland birds in the Western Hemisphere. In: Vickery, P. D., and J. R. Herkert, editors. Ecology and conservation of grassland birds of the Western Hemisphere, Studies in Avian Biology, Vol. 19. Cooper Ornithological Society, Sacramento, California. Pp. 2–26.

WEBB, E. A., AND C. E. BOCK. 1996. Botteri's sparrow (*Aimophila botterii*). In: Poole, A., and F. Gill, editors. The birds of North America, No. 216. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

WHELAN, R. J. 1995. The ecology of fire. Cambridge University Press, Cambridge, United Kingdom.

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