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THE EFFECTS OF FIRE ON THE BREEDING ECOLOGY OF FLORIDA GRASSHOPPER SPARROWS (*Ammodramus savannarum floridanus*) AND BACHMAN'S SPARROWS (*Aimophila aestivalis*)

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Abstract.—The Florida dry prairie provides habitat for two rare grassland birds, the endangered Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*), and the Bachman's Sparrow (*Aimophila aestivalis*). We sought to determine the effects of fire frequency and seasonality of fire (summer vs. winter fires) on territory density and reproductive success of these two sparrows in the year of and years following fires. We conducted a six-year study at three breeding sites in central Florida from 1993-1998. Florida Grasshopper Sparrow densities increased on summer burned areas when the burns took place prior to 28 June, while densities declined when fires occurred after 28 June. If fires occurred prior to late June, the Florida Grasshopper Sparrow breeding season continued into late August, instead of finishing in mid-late July. Bachman's Sparrows densities increased on summer burned areas when burns took place after 20 June, but decreased when burns were conducted prior to 20 June. Florida Grasshopper Sparrows had higher densities on areas that were burned more recently and reproductive success was higher at the most recent burn at one of the three sites. Neither Bachman's Sparrow densities nor reproductive success differed with years post burn. Seasonality of fire did not affect territory density or reproductive success for either species in the years following the burn. Frequent fires (summer or winter), every 2-3 years, are essential to maintaining Florida Grasshopper Sparrow habitat. To optimize and to help stimulate a longer breeding season for Florida Grasshopper Sparrows, summer fires should be conducted before 28 June. This prescribed burn regime will maintain high-quality habitat for the Florida Grasshopper Sparrow but will not adversely affect Bachman's Sparrows.

Key Words: Bachman's Sparrow, dry prairie, Florida Grasshopper Sparrow, grassland birds, prescribed fire, reproductive success, territory density

Disturbance is a regular part of grassland ecosystems. Fire, an important form of disturbance, is an essential component of many grassland ecosystems that has a strong influence over species composition, diversity and phenology (Hulbert 1988, Bock and Bock 1992, Herkert 1994, Swengel 1996, Shriver et al. 1999, Shriver and Vickery 2001). The dry prairie of central Florida provides habitat for the federally Endangered, endemic Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*) (U.S. Fish and Wildlife Service 1986) and the Bachman's Sparrow (*Aimophila aestivalis*), a species that has experienced population declines and range contraction in recent years (Dunning and Watts 1990). Florida dry prairie is a fire-adapted assemblage of grasses, forbs, and shrubs that once occupied 5,000 km^2 in central Florida (Robbins and Myers 1992, Orzell and Bridges 1999, Orzell and Bridges 2006a, 2006b). Dry prairie evolved with frequent fires, occurring every one to three years, enabling this ecosystem to stay in an early successional stage and preventing encroachment by shrubs or pines (Harper 1927, Orzell and Bridges 1999, Platt et al. 2006). Historically, fires in south-central Florida occurred most frequently during the summer, from April to mid-June, when lightning strikes were most numerous (Komarek 1964, Chen and Gerber 1990). The flora and fauna of this ecosystem have likely evolved with frequent growing-season fires (Robbins and Myers 1992, Shriver et al. 1996). For example, the dominant grass in the dry prairie, wiregrass (*Aristida beyrichiana)*, flowers profusely following late spring or summer fire, but little flowering occurs following fires set during winter or early spring (Abrahamson 1984, Clewell 1989). Because the dry prairie is now limited to a few fragmented sites, prescribed fire has taken the place of naturally occurring fire. Prescribed burns have been traditionally conducted in the non-lightning (winter) season. However winter fires can shift communities towards woody species (Platt et al. 1991, Glitzenstein et al. 1995, Drewa et al. 2002), which could have detrimental effects on the flora and fauna that has evolved with summer fires.

The Florida Grasshopper Sparrow's breeding range is restricted to Florida dry prairie and is separated from the nearest breeding population of *A. savannarum* by approximately 480 km. Florida Grasshopper Sparrow populations have declined and contracted (Delany et al. 1985, 1999, 2007, Pranty and Tucker 2006), and at present there are only six known breeding populations. Presently, Florida Grasshopper Sparrows are known to exist in only four separate areas: three populations at Avon Park Air Force Range (Avon Park), Kissimmee Prairie Preserve State Park (Kissimmee Preserve), Three Lakes Wildlife Management Area (Three Lakes), and Beatty Ranch, a private ranch in Okeechobee County. The largest populations are at Kissimmee Preserve, Three Lakes, and two sites at Avon Park. At least 81% of the dry prairie habitat has been converted to improved pasture for cattle production or to citrus plantations (Shriver and Vickery 1999). Delany et al. (2007) estimate that there is now only 44,933 ha of potential Florida Grasshopper Sparrow habitat, most of which is unoccupied.

Bachman's Sparrow is restricted in distribution to the southeastern United States and is generally thought to be associated with mature longleaf pine (*Pinus palustris*) forests with grassy open understories (Brooks 1938, Stoddard 1978). These sparrows occupy areas that have a dense layer of vegetation in the first m above ground, and low volumes of vegetation two to four m above ground (Dunning and Watts 1990). This description of the ground vegetation is similar to that of Florida dry prairie, where they also occur. This species went through a major range expansion at the turn of the 20th century, but its northern range has contracted in recent years and it is now rare and locally distributed in many areas (Dunning and Watts 1990). Bachman's Sparrow is among the species of highest management concern in the southeastern United States (Hunter et al. 1994) and is considered to be potentially threatened throughout its range (Dunning and Watts 1990, Plentovich et al. 1998).

Florida Grasshopper Sparrows respond favorably to frequent fires and to summer fires in the year they occur. Areas that have been burned within the last year (0.5 years post-burn) have generally had higher densities and higher reproductive success for Florida Grasshopper Sparrows than areas burned 2.5 years earlier (Shriver and Vickery 2001). However, Delany et al. (2002) found no difference in territory densities among burn classes, but found higher reproductive success in 0.5 years post-burn than 1.5 and 2.5 years post-burn at Avon Park. Bachman's Sparrow responses to fire in Florida dry prairie are less dramatic than those of Florida Grasshopper Sparrows. Shriver and Vickery (2001) did not find any differences in territory density or indicators of reproductive success in winter burns 0.5, 1.5, and 2.5 years post-burn.

Most of the above studies took place in areas that have a history of winter prescribed fires only. The few studies that address sparrow response to summer fires were conducted only in the year the burn occurred. Shriver et al. (1999) found that Bachman's Sparrows increased in densities after June fires but not after July fires. Shriver et al. (1996, 1999) found that summer burns conducted in June greatly increased the length of Florida Grasshopper Sparrow breeding activity, while fires conducted in July did not increase the length of the breeding season. However, it is not known if this extended breeding period affects actual reproductive success in the year of the burn and whether summer prescribed burns provide preferred breeding habitat in the breeding seasons following summer burns. Answering this question could provide valuable information leading to the positive management of this declining species.

The objectives of this study were to determine territory density and an index of reproductive success of Florida Grasshopper and Bachman's Sparrows with respect to time of burn. Specifically, we sought to compare breeding densities and reproductive success of Florida Grasshopper Sparrows and Bachman's Sparrows in 1) pre- and post-burned areas in the year of a summer fire, 2) summer-burned areas versus winter-burned areas in years after the burn took place, and 3) several different burn classes. We have incorporated data from earlier studies (Shriver et al. 1996, 1999, Shriver and Vickery 2001, Delany et al. 2002) and added approximately 50% more original data to present the most comprehensive data set known on the effects of fire on the breeding ecology of these two sparrows.

Methods

Study Sites

We conducted this study on three sites in the Kissimmee River dry prairie region in central Florida (Fig. 1). Dominant species include wiregrass, dwarf live oak (*Quercus minima*), saw palmetto (*Serenoa repens*), staggerbush (*Lyonia fruticosa*), gallberry (*Ilex glabra*), gopher-apple (*Licania michauxii*), and shiny blueberry (*Vaccinium myrsinites*) (Orzell and Bridges 2006b).

Avon Park Air Force Range (Avon Park). Avon Park is a 42,400 ha facility owned and managed by the Department of Defense, located east of Avon Park in Highlands and Polk Counties. There are approximately 4,200 ha of native prairie and three populations of Florida Grasshopper Sparrows at this site. The population at the 700-ha Delta Trail-OQ Range area (27°37' N 81°19' W) was used in this study. This site is burned in winter on a two- to three-year rotation. Twelve plots, each 8-22 ha in size, were divided among 0.5 (3-6 months post burn), 1.5 (15-18 months post burn) and 2.5 (27-30 months post burn) year burn classes from 1993-1998 (Table 1). An average of 150.00 ha was surveyed in these plots from 1993-1998. Cattle have grazed this site for at least 25 years at a density of <1 animal per 10 ha. The first summer fire occurred here in 1998 as a result of a firearms ignition.

Three Lakes Wildlife Management Area (Three Lakes). Three Lakes, located in Osceola County (27°47' N 81°06' W), has approximately 4,000 ha of dry prairie, and is owned and managed by the Florida Fish and Wildlife Conservation Commission. Burns are conducted in winter and summer on a three-year rotation. Summer burns were first initiated in 1994. Thirteen plots ranging from 6.75 to 15.25 ha were distributed between 0.0 (0-3 months post-burn), 0.5, 1.0 (12-15 months post burn), 1.5, 2.0 (24-27 months post-burn), and 2.5 year burn classes (Table 1). An average of 129.29 ha were surveyed each year from 1993-1998. There has been no cattle grazing since 1987.

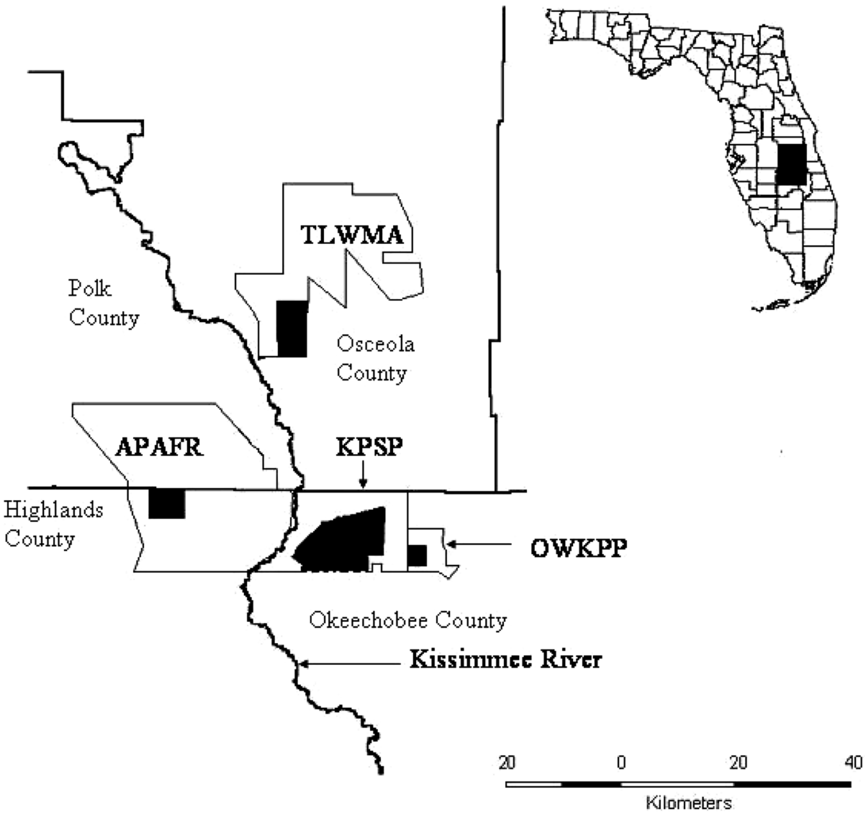

Figure 1. Location of dry prairie study sites in central Florida, 1993-1998 (APAFR = Avon Park Air Force Range, TLWMA = Three Lakes Wildlife Management Area, OWKPP = Ordway-Whittell Kissimmee Prairie Preserve, KPSP = Kissimmee Prairie Preserve State Park).

Ordway-Whittell Kissimmee Prairie Sanctuary (Audubon). Audubon, located in Okeechobee County, approximately 20 km north of Basinger (27°34' N 80°58' W) has approximately 1,000 ha of dry prairie, and was owned and managed by the National Audubon Society during this study. Managers of this site began conducting summer burns on a three-year rotation in 1992. Eight plots, ranging from 6.0 to 16.5 ha, were divided between 0.0, 1.0, and 2.0-year burn classes (Table 1). An average of 86.70 ha were surveyed each year from 1993 to 1998. No grazing has occurred at this site since the mid-1980's.

BIRD SURVEY METHODS

We surveyed approximately 360 ha each year in permanent plots from 1993 to 1998 (Table 1). Efforts were made to study the same plots from year to year, but occasionally plots needed to be dropped or added due to changes in management. We marked and gridded permanent plots at 50-m intervals to determine sparrow breeding densities and reproductive success. We delineated territories of Florida Grasshopper and Bachman's Sparrows using

Table 1. Number of plots spot-mapped in each burn class in each year used in determining breeding territory densities and reproductive success of Florida Grasshopper and Bachman's sparrows in central Florida from 1996 to 1998

Year	0.0	0.5	1.0	1.5	2.0	2.5	Total
				Avon Park			
1993	0	6	0	6	0	0	12
1994	0	3	0	6	0	3	12
1995	0	3	0	3	0	6	12
1996	0	6	0	3	0	3	12
1997	0	6	0	6	0	0	12
1998	3	2	0	3	0	3	11
				Kissimmee Prairie			
1993	0	0	5	0	0	0	5
1994	3	0	2	0	3	0	8
1995	3	0	3	0	2	0	8
1996	2	0	3	0	3	0	8
1997	3	0	2	0	3	0	8
1998	0	0	3	0	2	0	8
				Three Lakes			
1993	0	3	0	6	0	3	12
1994	3	3	0	4	0	4	14
1995	3	3	3	3	0	1	13
1996	3	3	3	2	1	0	12
1997	2	1	3	3	2	1	12
1998	0	4	3	2	3	1	13

standard spot-mapping techniques (International Bird Census Committee 1970) and the flushing technique (Wiens 1969). We began surveying in early March and concluded in late August to early September. Territory density is useful as a determinant of patterns of habitat occupancy, but may be misleading as an indicator of habitat quality (Van Horne 1983, Vickery et al. 1992a), therefore we surveyed every territory 10-15 times to develop an index of reproductive success for each territory (Vickery et al. 1992b). We calculated sparrow densities as the number of territories per 10 ha by dividing the number of territories by the size of the plot and multiplying by 10. We included a territory in these calculations if more than 50% of its area lay within a plot.

We used reproductive success, determined by a reproductive index based on behavioral observations, to determine the importance of burn regime to breeding success. We ranked reproductive success from 1-4 as follows:, rank 1 = unpaired male present 4+ weeks; rank 2 = paired male and female present 4+ weeks, rank 3 = nest stage; adult carrying nesting material, adult giving distraction display, or observed adult sparrow chipping; rank 4 = nestling stage; sparrow carrying food to presumed nestlings or fledglings. For reproductive indices, we excluded the year 1993 because surveys did not extend throughout the breeding season.

Data and Statistical Analyses

Summer Fires. To examine the effects of summer burns on Florida Grasshopper and Bachman's Sparrows in the year of the burn we used data from six burns at Three

Lakes and Kissimmee Preserve (one from each site in each year) that took place from 1994-1996 and were reported by Shriver et al. (1999). We added new information from three additional burns that took place in 1997 at Kissimmee Preserve and Three Lakes and in 1998 at Avon Park. We then used linear regression to examine the effect of date of burn on territory densities on both burned and control plots (Zar 1984). Because we found distinctly different Florida Grasshopper Sparrow response to burns before and after 28 June, and for Bachman's Sparrows before and after 20 June (see Results), we tested all burns that were conducted prior to 28 June and 20 June, and those that were conducted after 28 June and 20 June in two separate ANOVAs for Florida Grasshopper and Bachman's Sparrows, respectively. We used a three-way ANOVA to test for differences among site, year, and treatment (burned and control plots). We defined the dependent variable as the difference between pre-fire densities and post-fire densities for burn plots and for control plots (e.g., plot A had three territories prior to the burn, and then four territories after the burn, difference = 1.0). Control plots were selected that matched the burn class that was present prior to that summer's burn. Control plots then examined the difference in territory densities before and after the burn date. Dates, number of plots, and number of hectares for burned and control plots are listed in Appendix 1.

For reproductive success, we also conducted separate analyses for burns prior to 28 June or 20 June, and after 28 June or 20 June for the two sparrows. We classified a territory as reproductively successful if it was rated a 4. We used a two-tailed Fisher exact test to determine differences between reproductive success between pre- and post-fire dates on burn and control plots with the index from an individual territory as the statistical unit.

Summer Versus Winter Fires. To examine the differences between summer and winter fires in the years following the burn we looked at data from 1995 to 1998 at Three Lakes, which were essentially all new data. Shriver and Vickery (2001) reported on winter burn data only from 1995 to answer a different question. Three Lakes was the only site that had winter and summer prescribed fires during the course of this study. To determine the effects of seasonality of fire on breeding ecology, we classified all burn classes as either summer or winter burns from 1995 to 1998 (Table 1). During 1995 we had data for only the 1.0 summer burn class; therefore we used only the corresponding 0.5 winter burn class in that year for comparisons. From 1996-1998 we used 1.0 and 2.0 burn classes for summer burns, and 0.5 and 1.5 burn classes for winter burn classes. We used a chi-square analysis of a 2×2 contingency table to determine differences between territory densities and reproductive indices between summer and winter burns.

Burn Class. To examine the effects of time since burn on territory density and reproductive success, we included the three years (1993-1995) of data that were reported by Shriver and Vickery (2001) from Avon Park, Three Lakes, and Kissimmee Preserve for both species, and two years (1997 and 1998) of data on Florida Grasshopper Sparrows analyzed by Delany et al. (2002). We then added new data on both species for three years (1996-1998) at Three Lakes and Kissimmee Preserve, and one year (1996) and three years (1996-1998) for Florida Grasshopper and Bachman's Sparrows, respectively, from Avon Park. To determine the effects of burn class on breeding densities, we examined the differences in breeding densities as they changed from one burn class to another burn class. For example, at Avon Park, one statistical unit was the density in a plot of 0.5-year burn class in 1996, minus the density of that same plot in the following year when it was a 1.5-year burn class in 1997. We then used this difference as the statistical unit to conduct an ANOVA on the differences in densities between each burn class. If there was a difference, we conducted a Duncan-Multiple Range test to determine which burn classes differed.

At Avon Park, only winter burns were present, while at O-W Kissimmee Prairie only summer burns were present. Three Lakes had both summer and winter fires present.

Since we found no significant differences between the season of burn at Three Lakes (see results), we combined summer and winter data at Three Lakes into years post burn, so 0.5 and 1.0 year post- burn classes were combined into 1.0 year post-burn. At Avon Park and Three Lakes, we found no differences between second- and third-year post-burn classes. Thus, we grouped all second- and third-year burn plots that were subsequently burned and then classified in the 0.5-year burn class the following year. Thus, for all plots each treatment was represented as follows; treatment 1 = 1st growing season—2nd growing season post burn; treatment 2 = 2nd growing season—3rd growing season, and treatment 3 = 2nd or 3rd growing season—1st growing season.

To determine differences in reproductive success, because these were rank data, we conducted a separate non-parametric one-way Kruskal-Wallis ANOVA to test for differences between burn classes, and between years at each site. To protect against Type I error resulting from multiple comparisons, we set $\alpha = 0.05$ and adjusted our rejection level to $\alpha = 0.025$ using a Bonferroni correction factor based on the number of comparisons for each test (Beal and Khamis 1991).

Results

During the course of this study we mapped and estimated the reproductive success of 460 Florida Grasshopper and 350 Bachman's Sparrow territories occurring at the three study sites. Florida Grasshopper Sparrow territory density declined dramatically at Audubon in 1997 and 1998 as a result of flooding (Perkins and Vickery 2005). Populations were relatively stable at the other two sites although both declined slightly in 1998. Average Grasshopper Sparrow territory density was greatest at Three Lakes (2.84 territories per 10 ha average over all six years) and lowest at Audubon (1.13). Bachman's Sparrow territory density was relatively stable during the six years of this study. Average Bachman's Sparrow territory density was greatest at Three Lakes (2.37 territories per 10 ha average over all six years) and lowest at Audubon (1.15).

Summer Fires

Florida Grasshopper Sparrow. The change in Florida Grasshopper Sparrow densities on post-burned areas declined as burns took place later in the breeding season ($F = 35.61$, df = 1, $P < 0.001$, $r^2 = 0.61$, Fig. 2). Densities generally increased or stayed the same for all burns that took place prior to 28 June, while sparrow densities declined or stayed the same for all burns after 28 June. The change in densities on control plots also declined as burns took place later in the breeding season ($F = 6.23$, df = 1, $P = 0.02$, $r^2 = 0.25$, Fig. 2). Control plots never had higher densities after the burn date than before the burn date regardless of time of year (Fig. 2).

Florida Grasshopper Sparrow densities increased or remained the same on plots that were burned prior to 28 June (Fig. 2). Densities generally declined or remained the same on control plots. This change in

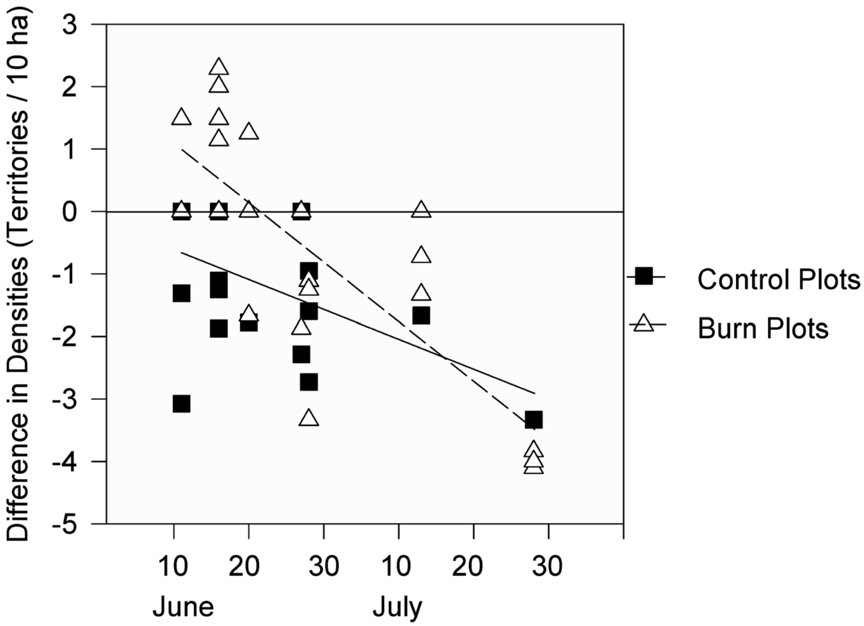

Figure 2. Florida Grasshopper Sparrow regression line in response to summer fires conducted during the breeding season at three sites in central Florida, 1994-1998. The figure shows a decline in the difference in the number of territories on burned plots as burns occurred later in the year.

territory densities differed between burn and control plots for burns conducted prior to 28 June (F = 15.28, df = 1, P = 0.001). Year and site differences were not significant, (F = 2.46, df = 2, P = 0.12; F = 1.27, df = 1, P = 0.27, respectively).

For burns conducted after 28 June, Florida Grasshopper Sparrow densities declined on both burned and control plots (Fig. 2). The difference in the change of densities did not differ between burn and control plots for Florida Grasshopper Sparrows (F = 0.05, df = 1, P = 0.83). Site differences were significant (F = 14.73, df = 1, P = 0.002), but year differences were not (F = 0.16, df = 2, P = 0.69). Reproductive success as classified by the reproductive index did not differ between pre- and post-burn areas for burns conducted prior to 28 June (n = 34, P = 0.54), or after 28 June (n = 32, P = 0.07, Fig. 3). Reproductive success did not differ on control plots between pre-fire dates and post-fire dates when burns were conducted prior to 28 June (n = 35, P = 0.64), or after 28 June (n = 21, P = 1.0). We documented reproductive success in post-burn areas; 33% of the territories (seven of 21) in post-burned plots received a rank of 3 or 4 for burns prior to 28 June, and 75% territories (three of

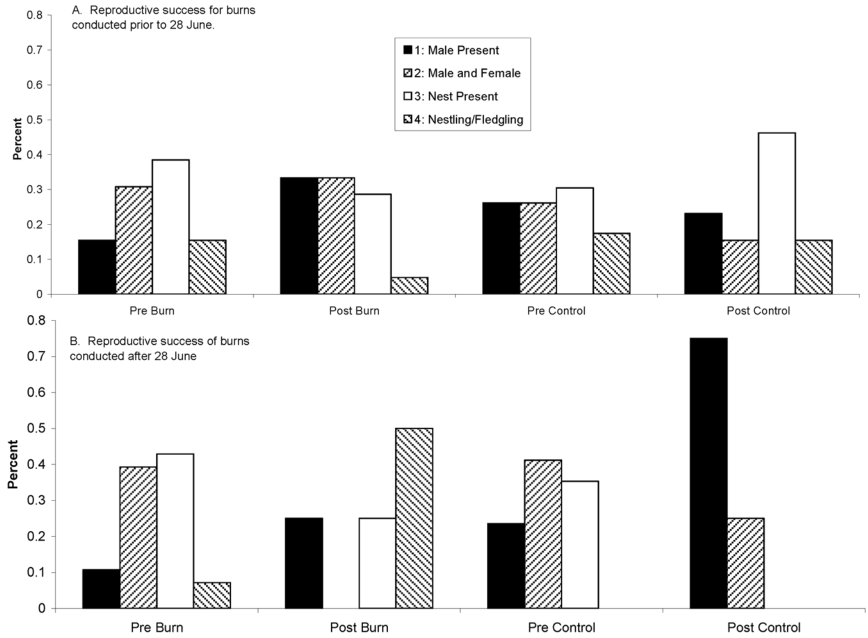

Figure 3. Florida Grasshopper Sparrow reproductive indices based on behavioral observations on plots from five fires conducted A) prior to 28 June, and B) later than 28 June in central Florida, 1995-1997. Figure shows no difference in reproductive success among treatments.

four) were ranked a 3 or 4 for burns after 28 June. In addition, in 1996, we found a nest on 23 July with four nestlings that successfully fledged on 5 August in a summer-burned area (Perkins et al. 1998).

Bachman's Sparrow. Bachman's Sparrow densities increased on burned plots as burns took place later in the breeding season ($F = 5.58$, df = 1, $P = 0.03$, $r^2 = 0.20$, Fig. 4). There was no relationship between change in densities on control plots as burns took place later in the breeding season ($F = 0.002$, df = 1, $r^2 = 0.01$, $P = 0.96$, Fig. 4).

There was no clear trend in breeding densities on plots burned prior to 20 June (Fig. 4). In general, densities declined or remained the same on control plots, and fluctuated on burn plots (Fig. 4). This change in territory densities did not differ between burned and control plots ($F = 0.46$, df = 1, $P = 0.51$). Years and sites did not differ, ($F = 0.35$, df = 1, $P = 0.56$; $F = 0.10$, df = 1, $P = 0.76$). For burns conducted after 20 June, densities increased on burned plots, while they decreased on control plots (Fig. 4). The change of densities did not differ between burned and control plots ($F = 1.45$, df = 1, $P = 0.25$). Years and sites did not differ ($F = 0.86$, df = 1, $P = 0.37$; $F = 0.12$, df = 1, $P = 0.74$).

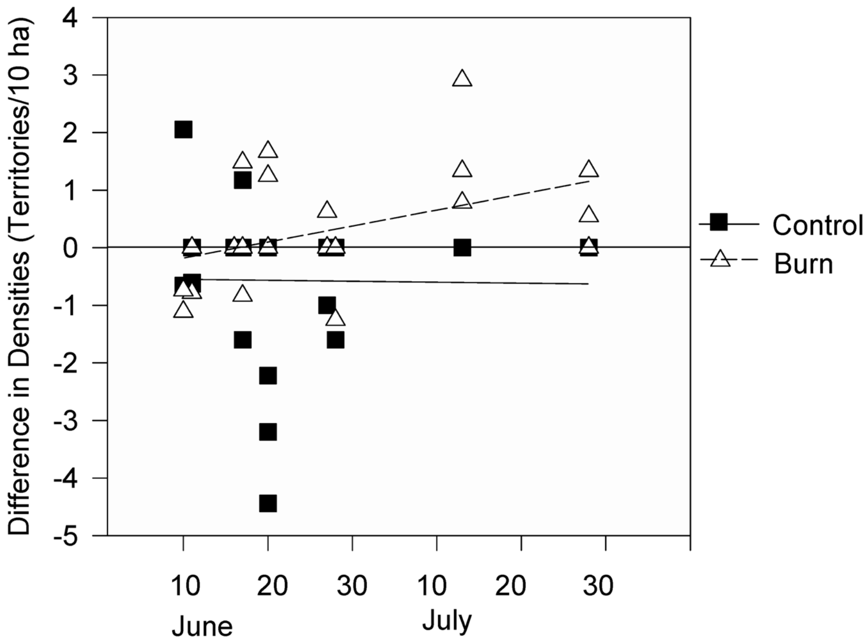

Figure 4. Bachman's Sparrow regression line in response to summer fires conducted during the breeding season at three sites in central Florida, 1994-1998. Figure shows an increase in the difference in the number of territories on burned plots when burns occurred later in the year.

Reproductive indices in pre- and post-fire burned plots did not differ for fires that took place prior to 20 June (n = 27, P = 1.00, Fig. 5). For burns after 20 June, there was higher reproductive success on pre-burn plots than post-burn plots (n = 69, P < 0.001, Fig. 5). Control plots did not differ between pre-fire and post-fire dates when burns were conducted before 20 June (n = 33, P = 0.60), or after 20 June (n = 21, P = 1.00, Fig. 5). Sixteen percent of the territories (2 of 12) were rated a 3 or 4 in post-burn areas for burns conducted prior to 20 June, and 50% of the territories (20 of 40) in post-burn areas for burns conducted after 20 June.

SUMMER VERSUS WINTER FIRES

Territory densities did not differ between summer- and winter-burned areas at Three Lakes for Florida Grasshopper Sparrows (S = 357, n_1 = 18, n_2 = 18, P = 0.46) or Bachman's Sparrows (S = 340.5, n_1 = 18, n_2 = 18, P = 0.82) (Fig. 6). Similarly, reproductive success did not differ between winter- and summer-burned areas for Florida

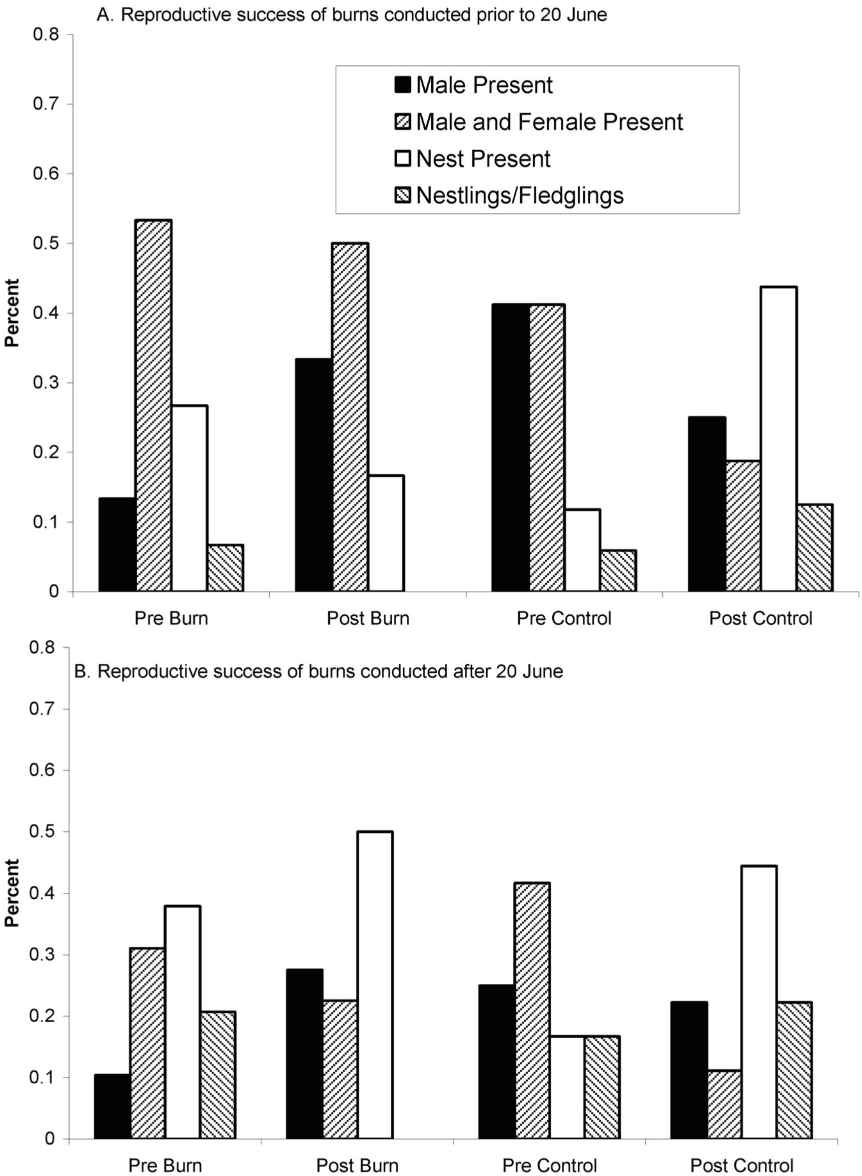

Figure 5. Bachman's Sparrow reproductive indices based on behavioral observations from four fires conducted A) prior to 20 June, and B) later than 20 June in central Florida, 1995-1997.

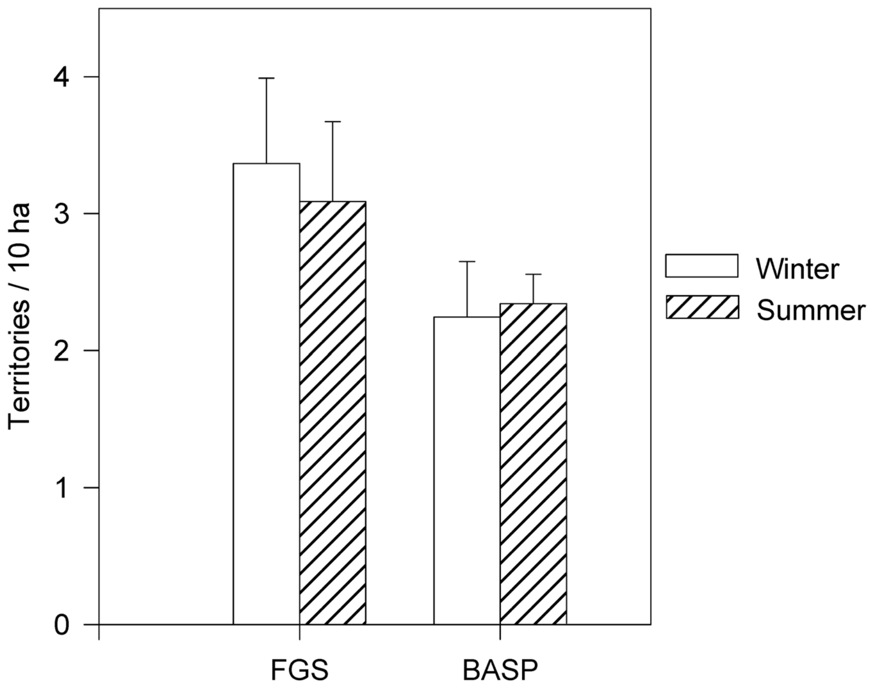

Figure 6. Florida Grasshopper Sparrow (FGS) and Bachman's Sparrow (BASP) breeding densities (number of territories per 10 hectares), mean and SE, in summer- and winter-burned areas at Three Lakes Wildlife Management Area, Florida, 1995-1998.

Grasshopper Sparrows (n = 120, df = 1, chi-square = 1.65 P = 0.20) or Bachman's Sparrows (n = 84, df = 1, chi-square = 1.01, P = 0.31) (Fig. 7).

BURN CLASS

Florida Grasshopper Sparrow. In general, densities were greater in early burn classes at Avon Park (F = 3.80, df = 2, P = 0.03), O-W Kissimmee Prairie (F = 51.03, df = 2, P < 0.001), and Three Lakes, (F = 28.52, df = 2, P < 0.001) (Fig. 8). At Avon Park the 3rd treatment (2nd and 3rd growing seasons—1st growing season) differed from the 2nd treatment (1st and 2nd growing seasons). At O-W Kissimmee Prairie all treatments differed from one another. At Three Lakes, the 3rd treatment (2nd and 3rd growing seasons—1st growing season) differed from the other two treatments (Table 2).

Reproductive success did not differ between burn classes for Florida Grasshopper Sparrows at O-W Kissimmee Prairie (H = 1.74, df = 2,

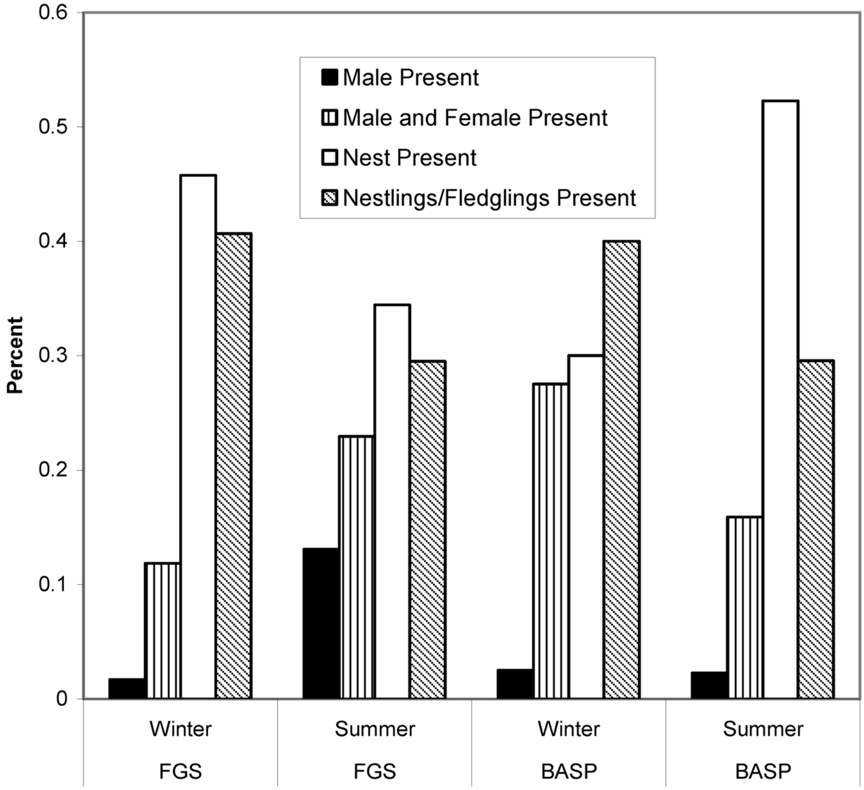

Figure 7. Florida Grasshopper and Bachman's Sparrow reproductive indices at Three Lakes Wildlife Management Area, Florida, 1995-1998.

P = 0.42), or Three Lakes (H = 3.16, df = 4, P = 0.53). Reproductive success was highest in the 0.5 year burn class at Avon Park, then declined in the 1.5 and 2.5 year burn classes (H = 9.79, df = 2, P = 0.008; Table 3). Florida Grasshopper Sparrows showed a significant year effect for the reproductive success at Avon Park (H = 15.76, df = 4, P = 0.003; Table 4). Reproductive success did not differ in years at O-W Kissimmee Prairie (H = 7.01, df = 4, P = 0.14) and Three Lakes (H = 3.52, df = 4, P = 0.48).

Bachman's Sparrow. Territory densities did not differ between burn classes at Avon Park (F = 1.06, df = 2, P = 0.35), O-W Kissimmee Prairie (F = 1.77, df = 2, P = 0.19), or Three Lakes (F = 0.26, df = 2, P = 0.77) (Fig. 8). Reproductive success did not differ between burn classes at O-W Kissimmee Prairie (H = 2.62, df = 2, P = 0.27) or Three Lakes (H = 7.11, df = 4, P = 0.13) (Table 3). Bachman's Sparrow reproductive success was highest in the 0.5-year burn class at Avon Park, followed

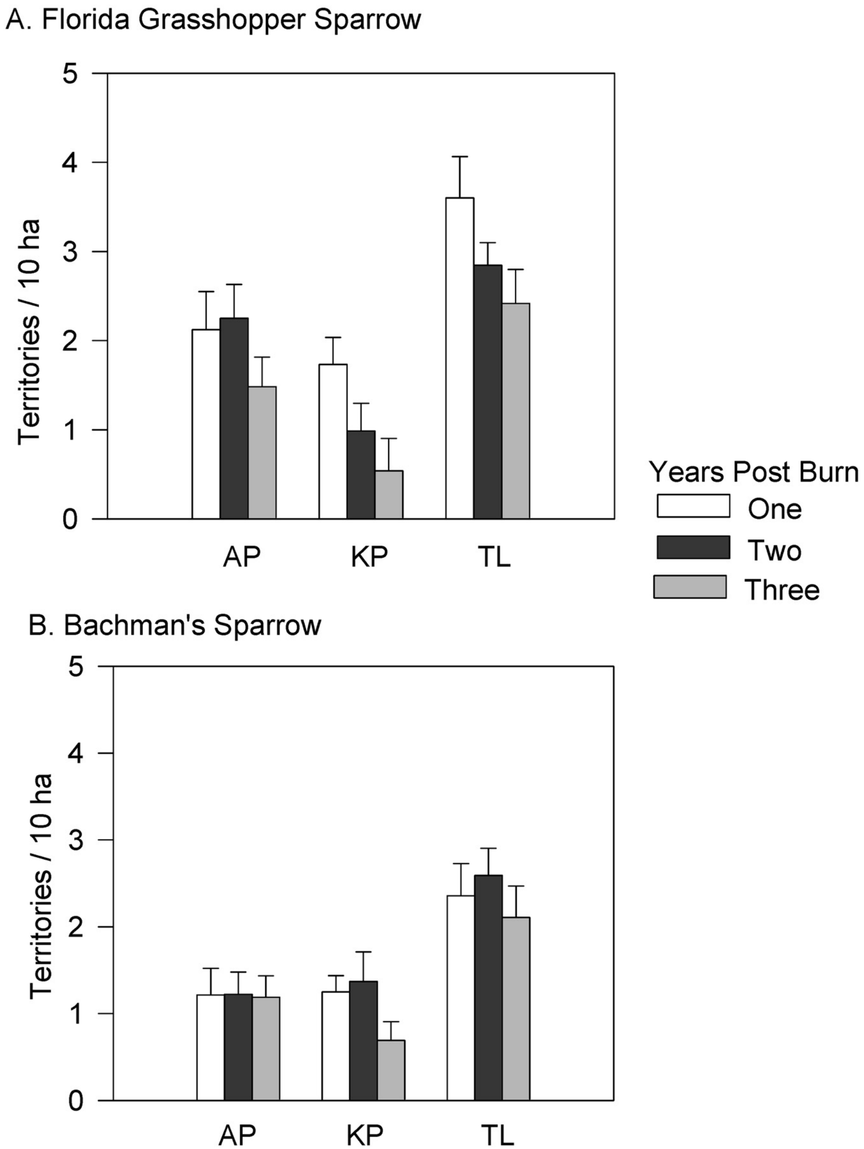

Figure 8. Territory densities (number per 10 hectares) of A) Florida Grasshopper Sparrows, and B) Bachman's Sparrows, mean and SE, at Avon Park Air Force Range (AP), Ordway-Whittell Kissimmee Prairie Sanctuary (KP) and Three Lakes Wildlife Management Area (TL), from 1993-1998 central Florida.

Table 2. Results of Duncan Multiple Range Test of Florida Grasshopper Sparrow breeding densities from three burn treatments at Avon Park Air Force Range (AP), Ordway-Whittell Kissimmee Prairie Sanctuary (KP), and Three Lakes Wildlife Management Area (TL), Florida, 1993-1998. Table shows higher densities in early burn classes.

Site	Treatment	Mean[a]	Duncan
AP	1	0.09	A
AP	2	0.64	AB
AP	3	-0.28	B
KP	1	1.37	A
KP	2	0.58	B
KP	3	-1.07	C
TL	1	1.48	A
TL	2	0.65	A
TL	3	-1.45	B

[a]The change in territory density (number of territories per 10 ha) from that burn class from the previous one, e.g., treatment 1 = territories in 3rd year burn class - territories in 1st year burn class.

by 2.5- and 1.5-year burn classes (Table 3). Reproductive indices showed a year effect at Three Lakes ($H = 19.16$, df = 4, $P < 0.001$) (Table 4). There was no year effect at Avon Park ($H = 5.24$, df = 4, $P = 0.26$) or O-W Kissimmee Prairie ($H = 2.59$, df = 4, $P = 0.63$).

Discussion

Summer Fires

Fire has important consequences for grassland birds nesting in Florida prairies. The timing of summer fires clearly affected the two species differently. In particular, they responded in dissimilar ways to burns conducted before and after late June, which may be due to differences in their reaction to reduced cover and rapid vegetative re-growth in post-burn areas.

Florida Grasshopper Sparrow. We think that the timing of summer fires is critical for Florida Grasshopper Sparrows. We found that territory densities generally increased on all plots that were burned prior to 28 June, but decreased on all plots burned after that date. Lightning strikes were historically most frequent in the summer months (Komarek 1964, Chen and Gerber 1990), however, there were probably fewer fires later in the summer as increased precipitation may have saturated soils and plants, making them less susceptible to burns (Platt et al. 2006). Our results demonstrated that birds in summer-burned areas (burned prior to 28 June) were reproductively active in July and August.

Table 3. Florida Grasshopper and Bachman's sparrow reproductive indices of territories (% of total) in different burn classes at Avon Park Air Force Range (AP), Ordway-Whittell Kissimmee Prairie Sanctuary (KP), and Three Lakes Wildlife Management Area (TL), Florida, 1994-1998.

		Reproductive Index Rank			
Site	Burn Class	One	Two	Three	Four
Florida Grasshopper Sparrow					
AP	0.5[1]	7 (10.1)	9 (13.0)	29 (42.0)	24 (34.8)
AP	1.5	15 (19.5)	13 (16.9)	36 (46.8)	13 (16.9)
AP	2.5	5 (16.7)	6 (20.0)	9 (30.0)	10 (33.3)
KP	1	5 (13.9)	14 (38.9)	15 (41.7)	2 (5.6)
KP	2	6 (54.5)	1 (9.1)	3 (2.7)	1 (9.1)
TL	0.5	9 (13.8)	11 (16.9)	26 (40.0)	19 (29.2)
TL	1	3 (6.7)	12 (26.7)	16 (35.6)	14 (31.1)
TL	1.5	12 (18.8)	9 (14.1)	25 (39.1)	18 (28.1)
TL	2	5 (31.3)	2 (12.5)	5 (31.3)	4 (25.0)
TL	2.5	3 (23.1)	0 (0.0)	6 (46.2)	4 (30.8)
Bachman's Sparrow					
AP	0.5	6 (15.0)	10 (25.0)	18 (45.0)	6 (15.0)
AP	1.5	7 (15.6)	13 (28.9)	11 (24.4)	14 (8.9)
AP	2.5	2 (7.4)	3 (11.1)	11 (40.7)	11 (40.7)
KP	1	2 (7.4)	15 (55.6)	6 (22.2)	4 (14.8)
KP	2	5 (25.0)	6 (30.0)	5 (25.0)	4 (20.0)
TL	0.5	6 (15.4)	7 (17.9)	14 (37.8)	12 (30.8)
TL	1	1 (3.2)	4 (12.9)	15 (48.4)	11 (35.5)
TL	1.5	8 (14.5)	19 (34.5)	16 (29.1)	12 (21.8)
TL	2	0 (0.0)	3 (23.1)	8 (61.5)	2 (15.4)
TL	2.5	2 (10.5)	4 (21.1)	7 (36.8)	6 (31.6)

[1]Indicates the number of growing seasons post burn.

Shriver et al. (1996, 1999) found that summer fires increased the length of singing period by males in burned plots versus control plots. Birds sang into late August on summer-burned plots and maintained a greater number of territories through this period. After the burn dates, unburned plots had lower densities and singing generally stopped in mid-late July. Shriver et al. (1996) theorized that this extended breeding season may increase the number of nesting opportunities and increase the number of pairs that attempt additional clutches. In this study, Florida Grasshopper Sparrows were present on summer burns within one week after the fire. Dean (2001) followed two Florida Grasshopper Sparrows with radio telemetry during a March 1997 fire at Avon Park. One individual flew up over the flames and then landed in the burned area. The second individual remained in the burned area, possibly in a subterranean burrow, during the fire and appeared to be unharmed. These two birds were back in the burned area within two days of the fire.

Table 4. Comparisons of reproductive success between years for Florida Grasshopper Sparrows (FGS) at Avon Park Air Force Range (AP), and Bachman's Sparrows (BASP) at Three Lakes Wildlife Management Area (TL), Florida from 1995 to 1998. Underscores indicate years within a species where years were not different (*P* > 0.05) based on nonparametric Tukey test for unequal samples. Table shows no clear trend in reproductive success between years.

Species	Site	Year				
		High Success			Low Success	
FGS	AP	1995	1996	1994	1997	1998
BASP	TL	1995	1998	1997	1996	1994

We think that fires conducted prior to 28 June had a positive impact on Florida Grasshopper Sparrow breeding ecology. Prescribed burn plots are selected from the oldest burn class and generally have fewer territorial Florida Grasshopper Sparrows. Control plots in these same burn classes had very little breeding activity after the fire dates. Without summer fires, very little breeding activity would occur on these older post-burn areas. While summer fires likely burn up some nests, the areas selected for burns are usually in the oldest burn classes and therefore have the lowest densities and number of nests. The extended breeding season and increase in density likely makes up for any loss of nests. It seems evident that this taxon has evolved with, and has successfully adapted to, summer fires.

Bachman's Sparrow. Unlike Florida Grasshopper Sparrows, Bachman's Sparrow densities increased on burn plots for burns after 20 June, but did not increase on burns conducted prior to 20 June. Using a subset of this data set, Shriver et al. (1999) found that Bachman's Sparrows responded favorably to July fires. It may be that Bachman's Sparrows have more generalized habits and are adapted to a wider range of conditions than Florida Grasshopper Sparrows. Bachman's Sparrows on control plots did not decline as much as Florida Grasshopper Sparrows after the earlier burn date. Bachman's Sparrows have a longer breeding season than Florida Grasshopper Sparrows and may be able to adapt to late summer burns, while it appears that it is too late for Florida Grasshopper Sparrows to initiate breeding activity after late summer burns. We documented that Bachman's Sparrows are reproductively successful in these post-burned areas. Bachman's Sparrow reproductive success was lower on post burn plots despite higher densities, possibly indicative of an increase in younger breeders or increased nest predation.

SUMMER VERSUS WINTER FIRES

Seasonality of prescribed fires did not appear to affect the breeding ecology of either Florida Grasshopper or Bachman's Sparrow in years after the initial fire. For both species, neither territory density, nor reproductive indices differed according to season of burn. It appears that suitable habitat may be found in both summer-and winter-burned areas, despite notable differences in the overall vegetation structure. Shriver et al. (1996, 1999) and this study support positive effects of summer fires on Florida Grasshopper Sparrows in the year they occur. This study shows that in years after the initial fire, summer fires do not negatively affect territory density or reproductive success.

Summer prescribed fires may be beneficial to Florida Grasshopper Sparrows for reasons beyond breeding ecology. The seasonality of prescribed burns may affect survivorship during winter when mortality is likely highest due to an increase in the number of overwintering raptors (Dean 2001). Perkins and Vickery (2001) found that annual survivorship of adult males was higher on sites that were burned in summer than on sites burned in winter. Thus, the dense grass canopy that results from summer burns may provide better cover for this ground-foraging species. Shriver (1996) found that vegetation at the summer-burned Audubon was dominated by tall grass cover and had lower shrub cover than at winter-burned Avon Park and Three Lakes. At Audubon wire grass flowered profusely after summer burns which changed the structure of vegetation in comparison to Avon Park and Three Lakes. At Audubon wire grass flower stalks reached heights over 1.2 m, yet on winter-burned areas flower stalks rarely developed and grass cover was lower and more sparse (Shriver 1996). Frequent winter burning, when combined with cattle grazing, leads to declines in several dry prairie grasses, but increases in saw palmettos (Sievers 1985), and other brush cover (Fults 1991). Platt et al. (1988) found that burns conducted during the growing season (April-August) increased synchronization of flowering plants more than between growing season fires (November-February). Fires during the growing season also produced the greatest number of flowering stems, and enhanced flowering among dominant species in long-leaf pine forests in Florida (Platt et al. 1988). Ultimately, such changes in vegetation structure could affect sparrow survival and reproductive success.

BURN CLASS

Florida dry prairie has evolved with frequent fires. It appears that these two grassland birds have adapted to this burn regime. Time since the most recent burn affected both species more than seasonality of fire. Frequent burning is essential to Florida Grasshopper Sparrow habitat.

Managers should first ensure that the habitat burns frequently (every 2-3 years), and as a second priority should try to schedule some of those fires in the summer. If a summer fire is missed due to drought or other reasons, a fire conducted the following winter would still be valuable.

Florida Grasshopper Sparrow. Florida Grasshopper Sparrows had the highest territory densities on the youngest burn classes at all three sites. This taxon selected habitat in relation to time since burn more than the season of burn. Shriver and Vickery (2001) also found that Florida Grasshopper Sparrows had higher densities in recently burned areas. Delany et al. (1985) and Delany and Cox (1986) also provide anecdotal information that Florida Grasshopper Sparrows occur more on areas that have been recently burned. Delany et al. (2002) found no difference in territory density at Avon Park based on data from 1997 to 1999. We used data from 1993 to 1996 as well as Delany et al.'s (2002) data from 1997 and 1998 and found that territory density was higher at Avon Park in the earliest burn classes. The response of other subspecies of Grasshopper Sparrow differs in other parts of the country. Herkert (1994) found that the eastern subspecies (*A. s. pratensis*) was more common on recently burned areas in Illinois. Others have found that Grasshopper Sparrows in Maine (Vickery 1993) and California (Collier 1994) avoid the areas immediately after the burn, but had the highest densities in areas two to four years post-burn. Grasshopper Sparrows avoided recently burned areas in Arizona (Bock and Bock 1992) and Montana (Bock and Bock 1987). Thus, it appears that Grasshopper Sparrows respond to fires differently depending on ecosystem vegetation.

Reproductive success was higher in the earliest burn class at one (Avon Park) of the three sites. Nest predators may forage preferentially in different burn classes. It is likely that the youngest burn class provides less cover for nest predators, potentially decreasing predator densities in early burn classes. Many nest predators (snakes and small mammals) are also prey themselves, and are susceptible to raptor predation. Sparrows rely on micro-site selection for nest location, and suitable habitat may be found in these early burn classes despite reduced cover.

Bachman's Sparrow. Bachman's Sparrows did not appear to prefer any particular burn class; territory density did not change in response to burn classes. Bachman's Sparrows did have higher reproductive success on the youngest burn class at Avon Park, similar to Florida Grasshopper Sparrows. Tucker et al. (2004) found that Bachman's Sparrows had higher densities in the first three years post-fire than areas that were ≥ four years post-fire, and that season of burning had little effect on densities in Alabama and Florida longleaf pine forests. They suggested a two- to three-year burn rotation with a preference for growing-season burns over dormant-season burns. In Georgia and South Carolina, Bachman's Sparrows populations have decreased in areas that had not been burned for ≥ three years (Johnson and Landers 1982, Dunning and Watts 1990, Gobris 1992), and they disappeared from forest stands that had not been burned for four to five years in Florida, South Carolina, and Georgia (Engstrom et al. 1984, Gobris, 1992, Dunning 1993). Bachman's Sparrows were common in longleaf and loblolly (*Pinus taeda*) pine stands that were managed on a three- to five-year burn rotation in South Carolina (Dunning and Watts 1990). In our study, no plots were left unburned for more than three years. Thus, it appears that Bachman's Sparrows are not strongly affected by different age burn classes until these sites reach an advanced successional stage, perhaps four to five years post-burn.

Fire appears to be highly beneficial to both of these sparrows and the dry prairie in central Florida. It is likely that other species of plants and animals in this ecosystem have also evolved with this frequent fire regime. Florida Grasshopper and Bachman's Sparrows were affected by the time since prescribed burn more than seasonality of burn. Frequent burning in summer or winter is paramount to maintaining habitat for Florida Grasshopper Sparrows. However summer burns appear to increase breeding activity for Florida Grasshopper Sparrows when conducted prior to 28 June. We think that it is important that summer burns continue to be conducted at all sites in order to more closely simulate the natural fire regime and provide a variety of habitats. Summer fires should be conducted prior to 28 June in order to maximize breeding opportunities for Florida Grasshopper Sparrows. One reason given by management agencies to not conduct summer fires is concern for mortality to Florida Grasshopper Sparrows. This study shows that Florida Grasshopper Sparrows occur on burns within a week after the fire, have an increase in reproduction in the year of the fire, and have no decrease in territory density and reproduction when compared to winter fires in future years, and therefore removes this concern. They appear well adapted for a summer fire regime. Current fire management at these sites, prescribed burns every two to three years, is essential for maintaining high-quality breeding habitat for Florida Grasshopper Sparrows. This management regime also appears to be adequate for Bachman's Sparrows.

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Appendix

Burn dates, number, and size of burned and control plots from three sites, Avon Park Air Force Range (AP), Three Lakes Wildlife Management Area (TL), and Ordway-Whittell Kissimmee Prairie Sanctuary (KP) in central Florida, 1994-1998.

			Burn		Control	
Site	Year	Date	Plots	Hectares	Plots	Hectares
KP	1994	15 July	3	34.00	1	6.00
TL	1994	22 June	3	26.00	1	11.25
KP	1995	29 June	3	38.50	2	18.75
TL	1995	31 July	3	43.00	1	12.00
KP	1996	18 June	2	18.75	4	34.00
TL	1996	18 June	3	27.50	3	23.75
KP	1997	18 June	3	34.00	3	38.50
TL	1997	13 June	2	22.50	3	25.00
AP	1998	30 June	3	29.00	3	34.00