

FINAL REPORT

Movements and Survival of Bachman's Sparrows in response to prescribed summer burns in South Carolina

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Abstract

Bachman's sparrow (*Aimophila aestivalis*) is a species of special concern that has experienced gradual population declines over much of its previous range. Many local populations of this species now exist in isolated patches of landscape, and further reductions due to poor forest management are possible. Forest managers are increasingly using growing season prescribed burns to enhance southern pine woodlands for the threatened red-cockaded woodpecker (*Picoides borealis*). Although growing season prescribed burns are beneficial for creating and maintaining suitable habitat for Bachman's sparrows, little was known about the direct effects of prescribed burns on the survival, reproduction, and movements of individual birds. Growing season prescribed burns were conducted in South Carolina at Carolina Sandhills National Wildlife Refuge (CSNWR) and the Savannah River Site (SRS) during the spring and summer of 1997. We captured sparrows in four experimental (burned) and five control (unburned) stands and monitored them daily with radio telemetry. None of the sparrows in the experimental stands died as a direct result of prescribed burning. Period survival rate from April 20 to July 26 was 80 % (SE=11.1) for all sparrows combined. Period survival was 88% (SE=11.7) in control stands and 78% (SE=13.9) in experimental stands. Average daily movements by sparrows in control and experimental stands before burning were not significantly different at either CSNWR ($P=0.299$, $F_{1,18}=1.14$) or SRS ($P=0.919$, $F_{1,14}=0.01$). Daily movements after prescribed burning were significantly longer for sparrows in experimental stands than in control stands at CSNWR ($P=0.068$, $F_{1,17}=3.79$). All sparrows dispersed away from experimental stands within 3 days after burning. Some birds continued to exhibit large dispersal movements for a few days after the burn. The mean distance for the initial dispersal movement

was 737 m/day (SE=240, n=8 for eight sparrows), with subsequent movements averaging 1,147 m/day (SE=304, n=6 for four sparrows). The juxtaposition of seemingly suitable Bachman's sparrow habitat in relation to experimental stands also influenced average dispersal movements at CSNWR ($P=0.077$, $F_{1,6}=4.55$). We discuss the possible detrimental effects of these large dispersal movements after prescribed burning on the survival of Bachman's sparrows during the breeding season.

Introduction

Bachman's sparrow (*Aimophila aestivalis*) is an obligate ground-nesting, ground-foraging resident of mature pine forests and open habitats throughout the southeast. The conversion of deciduous forests to pasture and farmlands in the nineteenth and early twentieth centuries allowed the Bachman's sparrow to expand its traditional range as far northward as Pennsylvania, Ohio, Indiana, and Illinois (Brooks 1938, Dunning 1993). Since the 1930's, the species has undergone a gradual retraction of its range and an overall population decline. Bachman's sparrows have become rare and now exist in many isolated local populations (Dunning and Watts 1990).

Bachman's sparrow is considered a vulnerable species by the U. S. Fish and Wildlife Service (USFWS) and is on the National Audubon Society's Blue List of species of special concern (Tate 1986). Bachman's sparrow was at one point classified as a Category 2 species by the USFWS, indicating that classification as a threatened or endangered species may have been warranted, but the data to support official listing was lacking. Habitat loss, along with fire suppression, has been suggested as contributing to the population decline (Engstrom et al. 1984,

Dunning and Watts 1990). Therefore, forest managers must consider the species' habitat requirements when formulating management plans.

In the southeast, Bachman's sparrows traditionally are associated with the mature longleaf pine (*Pinus palustris*) and wiregrass (*Aristida* spp.) ecosystem (Noss 1989). This fire-dependent ecosystem is characterized by a moderate overstory, an open midstory and understory, and a dense ground layer of grasses and forbs (Dunning and Watts 1990, Dunning 1993). Lightning strikes, which are frequent throughout the spring and summer months, caused natural wildfires and were essential to the maintenance of the longleaf pine-wiregrass ecosystem before European colonization (Jackson 1989). Indigenous people also used fire regularly and on a large scale basis, which contributed to the stability of this ecosystem (Christensen 1988). Since European colonization, fire suppression and the replanting of cleared stands with faster growing loblolly (*Pinus taeda*) and slash (*Pinus elliottii*) pine have resulted in an 86% reduction of the longleaf pine-wiregrass ecosystem in the southeastern United States (Brown and Kirkman 1990). The reduction in the longleaf pine-wiregrass ecosystem over the past century has resulted in declines in populations of red-cockaded woodpeckers (*Picoides borealis*, RCW; Ligon et al. 1986). Red-cockaded woodpeckers were classified as endangered by the USFWS in 1970. Since then, management practices to sustain and expand RCW populations have been used frequently. Management practices for RCWs, which include longer stand rotations, thinning of overstory trees, midstory removal, and prescribed burning, also are beneficial for creating and maintaining suitable habitat for Bachman's sparrows (Dunning and Watts 1990, Wilson et al. 1995).

To date, the effects of prescribed burning on habitat use by Bachman's sparrows have been studied only in the context of winter burns (Haggerty 1986, Gobris 1992, Dunning 1993).

Frequent winter burning regimes are more beneficial to Bachman's sparrows than complete fire suppression (Engstrom et al. 1984, Haggerty 1986, Gobris 1992, Dunning 1993). Growing season burns are being used increasingly for management of RCWs, rather than the traditional winter season burns, because they select against hardwood regeneration and for grass and forb cover (Gaines et al. 1995, James 1995). Despite the positive long range effects of growing season burns, such burns, used for the management of RCWs, may have detrimental short-term effects for Bachman's sparrows through direct mortality as well as lowered recruitment (Liu et al. 1995).

The purpose of this study was to assess the movements and survival of Bachman's sparrows in response to growing season burns. The null hypotheses tested were: 1) growing season burns do not cause direct mortality of adult Bachman's sparrows; 2) Bachman's sparrows are not displaced by growing season burns; and 3) Bachman's sparrows that are displaced by growing season burns do not have a lower survival rate than Bachman's sparrows in unburned (control) stands.

Methods

Study Site

Research for this study was conducted in South Carolina at Carolina Sandhills National Wildlife Refuge (CSNWR) and the Savannah River Site (SRS) between April and July 1997 (Fig. 1).

CSNWR is a 18,600 ha refuge in northeastern South Carolina that is managed by the USFWS. It lies along the fall line separating the Piedmont Plateau from the Atlantic Coastal Plain. Most of the refuge is covered by longleaf pine forests interspersed with scrub oaks

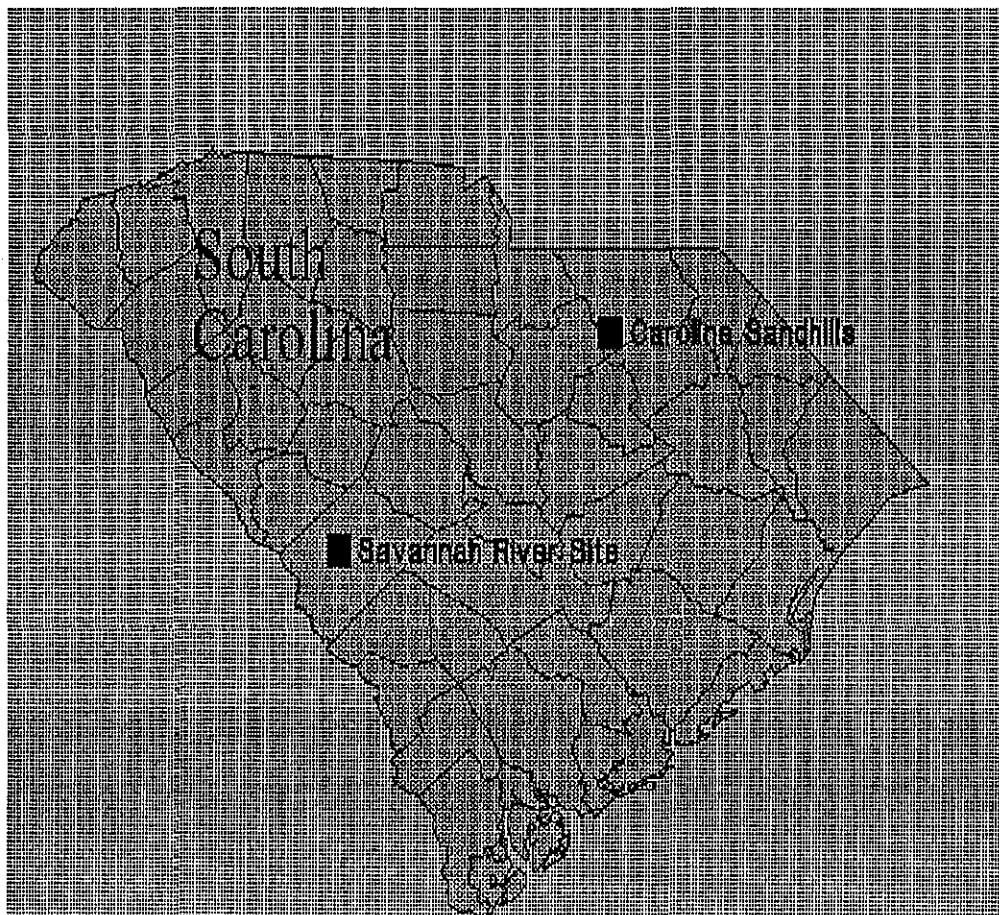


Figure 1. Map of South Carolina showing the locations of CSNWR and SRS.

(*Quercus* spp). Soils in this region are composed mainly of rolling beds of deep sand. There is relatively more mature longleaf pine stands (greater than 80 years of age), along with a greater abundance of grasses and herbaceous vegetation, at CSNWR than at SRS. Little mature longleaf pine that would be suitable for Bachman's sparrows occurs in the surrounding area off refuge. The USFWS is in the process of increasing the use of prescribed summer burning on a 3-4 year rotation for management of the RCW. Previously, only winter burns were used at CSNWR. Thus, many stands on the refuge are either winter burned or summer burned within the same year. This transition period has resulted in the understory of most stands being quite young (<3 yrs).

SRS is located in western South Carolina along the Savannah River. SRS is a 770 km² U. S. Department of Energy facility and is designated as a National Environmental Research Park, managed as an 'experimental forest' by the U. S. Forest Service (USFS). Presently, mature longleaf pine stands cover only 0.2% of the total forested area on site, whereas 47.7% of the total forested area is covered in intermediate (30-80 years old) stands of loblolly and longleaf pine. A portion of the mature pine stands have been set aside for the recovery of the RCW populations at SRS. Active colonies and RCW recruitment stands are burned on a 3-5 year rotation using both winter and summer burns.

Experimental Design

At each site, we selected two mature pine stands scheduled to be summer burned (treatment) and two stands not scheduled for summer burning (control). Pine stands that had been burned the previous winter were not used. We collected data for sparrows in experimental and control stands before and after prescribed burning.

Field Methods

In mid-April, we surveyed stands slated for summer burning for Bachman's sparrows using a modified spot mapping method (Dunning et al. 1995). Throughout each stand, we walked parallel transects spaced 100-m apart. Listening posts were flagged every 100-m along each transect where we stopped and played a tape-recorded song and alternately listened for a response over a 3 min period before moving to the next listening post. Playback of the Bachman's sparrow's song and call note is a common method of surveying this species (Dunning et al. 1995). All Bachman's sparrows encountered (i.e., either seen or heard) were recorded. At the end of each survey, observations of all singing sparrows recorded in the same general location but at different times during the survey were pooled and counted as only one sparrow. This insured that all territorial males were counted only once. From these surveys, we estimated the number of territorial males in each stand.

We also used the modified spot mapping method to survey mature pine stands at each site that were not scheduled for summer burning (controls). Because of the difficulty of capturing Bachman's sparrows, and the unpredictable timing of prescribed burning, netting in stands with the highest number of territorial males allowed the best chance of obtaining an adequate sample size. Therefore, we selected the two control and two experimental stands for each site that had the highest number of territorial males.

Bachman's sparrows were captured with mist nets (30-mm mesh) on both control and experimental stands before prescribed burning at SRS. The target sample size was five sparrows per stand, with a total of 40 sparrows captured between the two sites. Due to time constraints, it was only possible to capture sparrows on experimental stands before prescribed burning at

CSNWR. Sparrows in control stands at CSNWR were captured after prescribed burning. Captured Bachman's sparrows were weighed, aged, sexed (if possible), and banded with a National Biological Survey leg band. We used a thigh harness (Rappole and Tipton 1991) to fit a 0.95-g radio transmitter (Holohil Systems Ltd.) to each bird. Stober (1996) observed that Bachman's sparrows tagged with this method behaved normally.

Radio-tagged birds were tracked daily using a 3-element yagi antenna. The homing technique (White and Garrott 1990) was used to locate and approach each sparrow to within 5-10 m. The bird's status (alive or dead), location, and behavior were recorded. Location was determined by taking a compass bearing and pacing the distance to the nearest listening post. Each listening post was plotted on a stand map overlaid with a Universal Transverse Mercator (UTM) grid. The sparrow's location was then plotted on this map and UTM coordinates were determined for the location. If a radio-tagged bird could not be found, a 5-element yagi antenna mounted on the top of a truck was used to search the study area and the surrounding area. The search effort concentrated around the bird's last known location and gradually extended outward. Search time per km² decreased with distance from the central location. Aerial tracking was also used at CSNWR to try and locate lost sparrows. Radio-tagged sparrows were tracked, or at least searched for, for a period of 45 d after the radio transmitter was activated. Expected transmitter battery life was 30 d (Holohil Systems Ltd.).

Daily Movement Analysis

We computed the daily distance moved by each radio-tagged sparrow from the UTM coordinates of the daily observations. All dispersal movements were analyzed separately from the

daily movements. We defined a dispersal movement as any permanent movement away from a sparrow's territory. We defined daily movements as movements made by a sparrow from one day to the next within its established home range.

Because we monitored some birds more than once per day, we were unable to track other birds daily. To make full use of all three classes of movements [within-day (n=46), daily (n=581), among-day (n=71)], we tested whether the distances moved across movement categories differed among each other. We found no significant difference in the distances moved among movement categories (PROC GLM, $F_{5,683}=0.65$, $P=0.660$). Therefore, we combined the three categories together in conducting analyses for daily movements.

We tested for differences in individual daily movements between control and treatment birds before prescribed burning, for each site separately using a general linear modeling (PROC GLM, SAS Inst. 1990). We used the following model:

$$\text{Daily distance} = \text{Treatment}_i + \text{Sparrows (Treatment)}_{j(i)}$$

where **Daily distance** = distance in meters/day moved by a marked sparrow, **Treatment** = the effect on daily distance by the i th level of the treatment variable (i = control or treatment stand), **Sparrows (Treatment)** = the effect on the daily distance by the j th individual sparrow nested within the i th treatment (j = 20 - for original experimental design). The sparrows (treatment) term was used as the error term for the hypothesis test of treatment because our experience has been that individual birds have a strong tendency to behave as individuals (see Krementz and Pendleton 1994). We compared daily movements of CSNWR sparrows which had settled into a new territory after dispersing from their previous territory on treatment stands to the daily movements

of sparrows on control stands using GLM. This test was not performed for sparrows at SRS due to the low number of observations ($n=3$) of sparrows from treatment stands after burning. We used a low α -value (0.10) because sample sizes were small and we were also concerned about the Type II error rate.

To investigate any inherent difference in daily movements by stand, we first tested for a difference between daily movements of control and treatment sparrows before burning, for each site separately. We used the following model:

$$\text{Daily distance} = \text{Site}_k + \text{Sparrows (Site)}_{j(k)}$$

where **Daily distance** = distance in meters/day moved by a marked sparrow, **Site** = the effect on daily distance by the k th level of the site variable ($k = \text{CSNWR or SRS}$), **Sparrows (Site)** = the effect on the daily distance by the j th individual sparrow nested within the k th site ($j = 40$ - for original experimental design). The sparrow (site) term was used as the error term for the hypothesis test of site. We used a low α -value (0.10) because sample sizes were small and we were also concerned about the Type II error rate.

To investigate a possible seasonal effect on movements, we compared early and late-season daily movements for sparrows in control stands. We compared daily movements by sex for all sparrows before prescribed burning. We used ANOVA to test for both sex and seasonal effects at an alpha level of 0.10.

Unless otherwise indicated, we are presenting average daily movements as least-square estimates of marginal means. Least-squares means (LSM), also called population marginal means, are the expected value of class means for a balanced design involving the class variable with all

covariates at their mean value (LSMEANS, SAS Inst. 1990). Least-squares means are given due to the unbalanced nature of the model and help reduce any biases that may be caused by a few sparrows with a large number of daily observations compared to other sparrows.

Dispersal Movements Analyses

Dispersal movements were categorized as either initial or subsequent. An initial dispersal movement was the first movement by a sparrow permanently leaving its territory. We classified all daily movements after the initial dispersal as subsequent dispersals until the sparrow was observed to stay in the same general location for at least two consecutive days. When a sparrow was observed in the same general location for at least two days, these observations were then included in the analysis of the non-dispersal daily movements. Two dispersal movements with more than one day between observations were recorded. These two dispersal movements were weighted by dividing the number of days between observations by the total distance traveled. This yielded an average dispersal distance traveled per day. We used this average movement dispersed per day in the analysis to estimate the actual dispersal distance per day traveled by a sparrow.

We tested for differences between average dispersal distances of experimental sparrows and average daily distances after burning for experimental sparrows at CSNWR (PROC GLM). We used the following model:

$$\text{Distance} = \text{Type}_i + \text{Stand}_m + \text{Sparrows (Stand)}_{j(m)} + \text{Type}_i * \text{Stand}_m + \\ \text{Type}_i * \text{Sparrows (Stand)}_{j(m)}$$

where **Distance** = distance in meters/day moved by a marked sparrow, **Type** = the effect on distance by the l th level of the type variable (l = dispersal or daily movement), **Stand** = the effect on distance by the m th level of the stand variable ($m = 2$), **Sparrows (Stand)** = the effect on the daily distance by the j th individual sparrow nested within the m th stand ($j = 10$ - for original experimental design), **Type*Stand** = the effect on the daily distance by the interaction of type and stand, **Type*Sparrows (Stand)** = the effect on the daily distance by the interaction of type and individuals sparrows nested within stand. The sparrows nested within stand term was used as the error term for the hypothesis test of stand and the type*sparrows (stand) interaction term was used as the error term for the test of type. This test was not performed for sparrows at SRS due to the low number of observations ($n=3$) for the average daily movement of sparrows from experimental stands after burning. A p-value greater than 0.10 was considered to be significant.

The difference between initial dispersal movements per day for sparrows from the two experimental stands at CSNWR was tested with the following GLM:

$$\text{Dispersal distance} = \text{Stand}_m + \text{Sparrows(Stand)}_{j(m)}$$

where **Dispersal distance** = distance in meters/day for the initial dispersal movement by a marked sparrow, **Stand** = the effect on dispersal distance by the m th level of the stand variable ($m = 2$), **Sparrows (Stand)** = the effect on the dispersal distance by the j th individual Sparrow nested with the m th stand ($j = 10$ - for original experimental design). The sparrows nested within stand term was used as the error term for the hypothesis test of stand. A p-value greater than 0.10 was considered significant.

Survival Analyses

We estimated period survival rates from April 20 to July 26, 1997 using the Kaplan-Meier method (Kaplan and Meier 1958). A period survival rate was calculated for all birds combined and separately for control and experimental birds. Each individual was classified as either a mortality, survived, or censored. Mortality was assigned when the bird's remains were recovered, or when the recovered radio transmitter or harness showed evidence that the bird had been killed by a predator (e.g. bite marks, blood stains). Survival was assigned if the radio became weak and then expired a few days later, or if the radio-tagged bird survived 28 d (avg. battery life was 29.8 d). A radio-tagged bird was classified as censored if the bird could not be found, there were no signs of transmitter failure, and the transmitter had been active for less than 28 d.

Sparrows that were classified as censored decreased our ability to detect a difference in period survival rate between experimental and control birds. This may result in an estimated period survival rate that is too conservative and an overestimate of the true unknown period survival rate, especially for experimental birds after dispersing. It has been shown with American Black Ducks that certain individuals forced to make longer and more frequent dispersals to feeding sites have a lower survival rate than other individuals (Conroy et al. 1987). In order for us to calculate period survival rates that may be closer to the true unknown rates than our conservative estimates, we reclassified all radio-tagged sparrows that were censored to mortalities based on the following assumptions: 1) the inability to locate some radio-tagged sparrows after prescribed burning is due in part to the large dispersal movements caused by the prescribed burning; 2) these large dispersal movements to other stands result in a lower survival rate than radio-tagged sparrows in control stands; and 3) these dispersal stands may be sub-optimal habitat

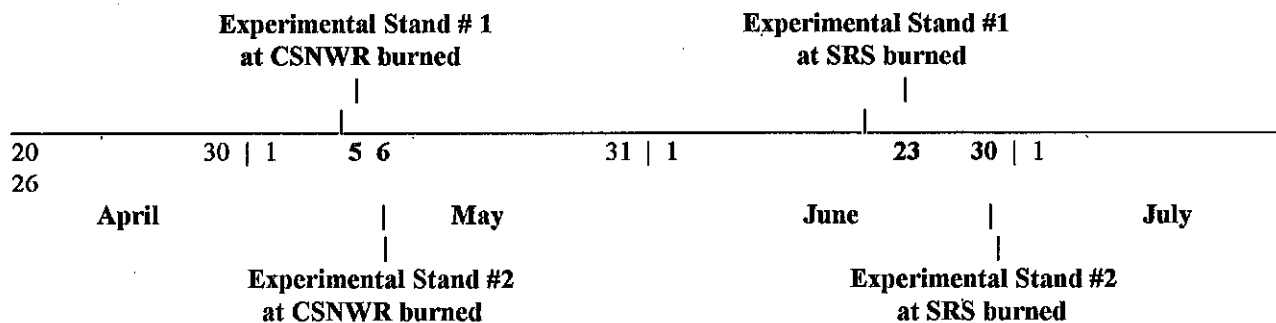
for Bachman's sparrows, which would cause greater daily movements, resulting in greater exposure to predators.

Results

Prescribed Burns

The two experimental stands at CSNWR were burned by USFWS personnel on May 5 and May 6, 1997. USFS fire crews burned the two experimental stands at SRS on June 23, 1997 and June 30, 1997 (Fig. 2).

Figure 2. Time line showing the prescribed burns of the four experimental stands at CSNWR and SRS during the field season of 1997.



Daily Movements

We used observations from 36 Bachman's sparrows in both experimental and control stands for our daily movements analyses (Table 1). All radio-tagged sparrows resumed normal activities shortly after release, and the thigh harness did not seem to impair bird mobility. One sparrow that was recaptured after 19 d was fitted with a new transmitter. No sparrows slipped out of their radios. We excluded two marked birds in experimental stands from the daily movement analyses because one died before the treatment and the other one was classified as

censored before the treatment.

Average daily movements by Bachman's sparrows in control and experimental stands before burning were not significantly different at either CSNWR ($P=0.299$, $F_{1,18}=1.14$) (Table 2) or SRS ($P=0.919$, $F_{1,14}=0.01$) (Table 3). We therefore lumped observations for both control and experimental birds before burning when testing for site differences. Daily movements after combining observations of both sparrows in control and experimental stands before burning were not significantly different between sites ($P=0.930$, $F_{1,34}=0.01$) (Table 4).

Table 1. Numbers and sexes of Bachman's sparrows captured in experimental and control stands during the 1997 breeding season in South Carolina at CSNWR and SRS and used for the daily movement analyses.

Site	Stand Type	Sex		Total
		Male	Female	
CSNWR	Experimental	7	1	8
CSNWR	Control	6	6	12
SRS	Experimental	6	2	8
SRS	Control	7	1	8
Total		26	10	36

At CSNWR, the daily movements of sparrows from experimental stands after prescribed burning were significantly longer ($P=0.068$, $F_{1,17}=3.79$) (Table 5) than for sparrows in control stands (Fig. 3). We found no effect of sex on daily movements at either CSNWR ($P=0.894$, $F_{1,18}=0.02$) or SRS ($P=0.907$, $F_{1,14}=0.01$) for observations before prescribed burning. As well, we found no difference between the first and second half of the field season on daily movements at either CSNWR ($P=0.467$, $F_{1,9}=0.58$) or SRS ($P=0.211$, $F_{1,7}=1.89$).

able 2. ANOVA table for the test of H_0 : there is no difference between the average daily movements of sparrows on control and experimental stands before prescribed burning at CSNWR. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)					
Source	DF	SS	MS	F-value	P-value
Model	19	291,749	15,355	2.89	0.0001
Error	307	1,631,453	5,314		
Corrected Total	326	1,923,202			
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	17,149	17,149	3.23	0.0734
Sparrows(Treatment)	18	270,846	15,047	2.83	0.0001
Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term					
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	17,149	17,149	1.14	0.2998
Treatment	LSMEAN	SE(LSMEAN)			
Control	93.7	8.2			
Experimental	113.1	16.2			

Table 3. ANOVA table for the test of H_0 : there is no difference between the average daily movements of sparrows on control and experimental stands before prescribed burning at SRS. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)					
Source	DF	SS	MS	F-value	P-value
Model	15	214,822	14,321	2.60	0.0010
Error	355	1,956,457	5,511		
Corrected Total	370	2,171,279			
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	162	162	0.03	0.8640
Sparrows(Treatment)	14	214,821	15,344	2.78	0.0006
Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term					
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	162	162	0.01	0.9196
Treatment	LSMEAN	SE(LSMEAN)			
Control	103.1	10.5			
Experimental	101.7	9.0			

Table 4. ANOVA table for the test of H_0 : there is no difference between the average daily movements of sparrows (control and experimental) before prescribed burning between sites. P-values > 0.10 are considered significant.

Independent variable: Daily distance					
Source	DF	SS	MS	F-value	P-value
Model	35	507,409	14,497	2.67	0.0001
Error	662	3,587,910	5,419		
Corrected Total	697	4,095,320			
Source	DF	Type III SS	MS	F-value	P-value
Site	1	115	115	0.02	0.8839
Sparrows(Site)	34	506,571	14,899	2.75	0.0001
Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term					
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	115	115	0.01	0.9303
Site	LSMEAN	SE(LSMEAN)			
CSNWR	101.5	8.1			
SRS	102.4	6.8			

Table 5. ANOVA table for the test of H_0 : there is no difference between the average daily movements of sparrows from experimental stands than from control stands after prescribed burning at CSNWR. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)					
Source	DF	SS	MS	F-value	P-value
Model	18	2,318,929	128,829	8.89	0.0001
Error	302	4,378,056	14,496		
Corrected Total	320	6,696,986			
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	278,134	278,134	19.19	0.0001
Sparrows(Treatment)	17	1,247,704	73,394	5.06	0.0001
Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term					
Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	278,134	278,134	3.79	0.0683
Treatment	LSMEAN	SE(LSMEAN)			
Control	93.7	18.1			
Experimental	201.1	52.1			

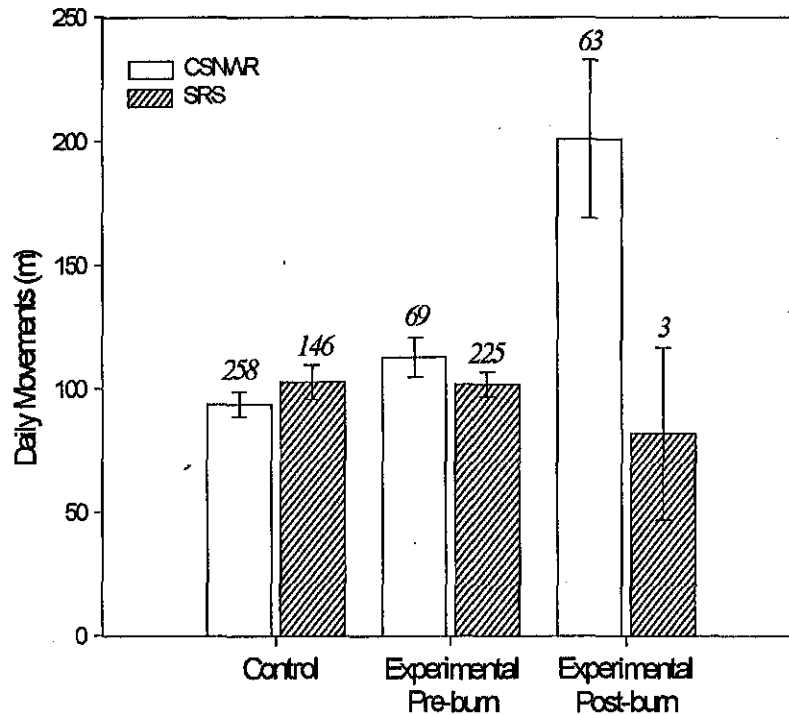


Figure 3. Average daily movements (± 1 SE, sample size shown above bar) by Bachman's sparrows from control stands, experimental stands before prescribed burns, and experimental stands after prescribed burns in South Carolina, at CSNWR and SRS, for the period of April 20 to July 26, 1997.

Dispersal Movements

Eight of the 18 Bachman's sparrows in experimental stands that we captured and radio-tagged either died or were censored before prescribed burning. We monitored 10 sparrows in experimental stands (eight at CSNWR and two at SRS) during and immediately after prescribed burning. One bird flew from the stand during the fire and was found 1,282 m east three hours later. Seven of the 10 sparrows dispersed from the experimental stands within 1-3 d after the

burn. The other two sparrows were classified as censored because they were observed alive in the experimental stand 3-4 h immediately after the burn, but were not found after that time. Four of the birds that made initial dispersals continued to exhibit large subsequent dispersal movements for a few days after the burn until either their signal was lost or the sparrow established a new territory on a different stand. The average distance of the initial dispersal movement was 737 m/day (SE=240, n=8 for eight sparrows), with subsequent movements averaging 1,147 m/day (SE=304, n=6 for four sparrows).

At CSNWR, average dispersal movements for experimental sparrows were significantly greater than average daily movements of experimental sparrows after prescribed burning ($P=0.006$, $F_{1,4}=27.17$) (Table 6). This indicates that a difference can be seen between dispersal movements and the regular daily movements a sparrow makes after settling into a new territory. However, stand, sparrow within stand, and stand*type interaction were also significant, indicating that individual birds within stands contribute to the difference between movements.

Initial dispersal distances were stand specific for experimental stands at CSNWR ($P=0.003$, $F_{1,5}=28.99$) (Table 7). Three of the four radio-tagged sparrows in one experimental stand simply crossed the fire break (a road) 1-2 d after the prescribed burn and set up territories in the adjacent stand. This resulted in short initial dispersal movements for these three birds, with no subsequent dispersals (Table 8). One marked bird had previously used this adjacent stand on two occasions before the burn. The fourth sparrow from the first experimental stand was found six days later, 2,982 m from his last known location. The largest initial dispersal movements were made by sparrows in the second experimental stand at CSNWR (Table 8). Sparrows in the

second experimental stand also had large subsequent dispersals, averaging 1,245 m/day (SE=352, n=5 for three sparrows).

Table 6. ANOVA table for the test of H_0 : there is no difference between average dispersal movements per day of experimental sparrows than for daily movements of experimental sparrows after prescribed burning at CSNWR. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)					
Source	DF	SS	MS	F-value	P-value
Model	13	11,722,636	901,741	13.80	0.0001
Error	61	3,985,266	65,332		
Corrected Total	74	15,707,903			

Source	DF	Type III SS	MS	F-value	P-value
Type	1	3,081,323	3,081,323	47.16	0.0001
Stand	1	1,760,687	1,760,687	26.95	0.0001
Sparrows(Stand)	6	2,323,915	387,319	5.93	0.0001
Type*Stand	1	2,450,057	2,450,057	37.50	0.0001
Type*Sparrows(Stand)	4	453,556	113,389	1.74	0.1537

Tests of Hypotheses using the Type III MS for Type*Sparrows(Stand) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Type	1	3,081,323	3,081,323	27.17	0.0065

Tests of Hypotheses using the Type III MS for Sparrows(Stand) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Stand	1	1,760,687	1,760,687	4.55	0.0770

Type	MEAN*	SE(MEAN)*
Dispersal	987.3	213.6
Daily Movement	239.7	32.2

*LSMEANS could not be estimated so the regular mean and SE is given

Table 7. ANOVA table for the test of H_0 : there is no difference between the initial dispersal movements per day for sparrows from the two experimental stands at CSNWR. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)

Source	DF	SS	MS	F-value	P-value
Model	6	2,976,961	496,160		
Error	0				
Corrected Total	6	6,696,986			

Source	DF	Type III SS	MS	F-value	P-value
Stand	1	2,539,009	2,539,009		
Sparrows(Stand)	5	437,952	87,590		

Tests of Hypotheses using the Type III MS for Sparrows(Stand) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Stand	1	2,539,009	2,539,009	28.99	0.0030

Treatment	LSMEAN	SE(LSMEAN)
Experimental Stand #1	282.0	148.0
Experimental Stand #2	1,499.0	170.9

Table 8. Distance per day of initial dispersal, average distance per day of subsequent dispersals (with ± 1 SE and # of subsequent dispersals), and the fate of Bachman's sparrows from two experimental stands at CSNWR and from one experimental stand at SRS. (N = No subsequent dispersal movements observed)

Site	Stand #	Bird #	Initial dispersal (m/day)	Subsequent dispersal			Fate
				(Avg. m/day)	(SE)	(n)	
CSNWR	1	031	497	N	N	N	Lived
CSNWR	1	049	428	N	N	N	Censored
CSNWR	1	228	103	N	N	N	Censored
CSNWR	1	089	100	N	N	N	Lived
CSNWR	2	273	1,282	615	57	2	Censored
CSNWR	2	251	1,265	1,057	0	1	Censored
CSNWR	2	309	1,950	1,968	777	2	Censored
SRS	2	692	277	656	0	1	Lived

Survival

None of the radio-tagged Bachman's sparrows died as a direct result of prescribed burning. One radio-tagged bird in an experimental stand at CSNWR was not used for the survival

analysis due to the small number of observations ($n=2$) taken before the bird was censored. We felt that the short exposure period for this bird would not contribute to predicting an accurate period survival rate. Another Bachman's sparrow was captured in a control stand and later flew to another stand that was subsequently burned. This sparrow was counted as two different birds, once as a control bird that lived (up to the date it moved to the experimental stand) and once as a treatment bird that was censored (starting from the date it moved to the experimental stand).

We estimated the period survival rate from April 20 to July 26, 1997 for both sites combined to be 80% ($SE=11.1$) using the data from 38 radio-tagged sparrows (Table 9). When sparrows were grouped by treatment, period survival was 78% ($SE=13.9$) for experimental stands and 88% ($SE=11.7$) for control stands.

Ten experimental birds were censored. When censored birds were reclassified as mortalities and the period survival rate was re-estimated, the period survival rate was reduced to 57% ($SE=14.4$) for control and 17% ($SE=8.9$) for experimental stands.

Table 9. Fate of radio-tagged Bachman's sparrows in control and experimental stands in South Carolina at CSNWR and SRS as used for the Kaplan-Meier survival rate analysis for the period of April 20 to July 26, 1997.

Site	Stand Type	Mortality	Censored	Survived	Total
CSNWR	Experimental	1*	6	2	9
CSNWR	Control	1 [#]	3	8	12
SRS	Experimental	1 ⁺	4	4	9
SRS	Control	0	1	7	8
Total		3	14	21	38

Source of mortality: *avian predation #unknown +snake predation

Discussion

Daily Movements

In a previous study, the mean distance moved between daily observations for Bachman's sparrows at SRS was 87 m (SE=7) (Stober 1996). The average daily movement for control birds for this study was similar at 94 m (SE=8) and 103 m (SE=11) for CSNWR and SRS, respectively. The significant increase in daily movements at CSNWR for experimental birds after prescribed burning as compared to birds in control stands shows that there is a treatment effect caused by the prescribed burns. This increase in daily movements for experimental birds after burning may be due to conspecific competition on their new territory, or the selection of sub-optimal habitat after dispersing. Competition from Bachman's sparrows with already established territories could force the dispersing bird to become a floater. If the dispersing bird chooses to defend a territory in sub-optimal habitat, the bird may have to defend a larger territory for the same resources than a bird in optimal habitat. Since none of the dispersing birds were observed with mates in their new territory, they may also defend a larger territory in the hopes of attracting one.

Dispersal Movements

The difference between the initial dispersal movements of sparrows from the two experimental stands at CSNWR seems to indicate that the presence or absence of suitable Bachman's sparrow habitat around the stand to be burned can drastically effect the distance and the duration of dispersal movements. Maps of the refuge indicate that seemingly suitable sparrow habitat around the second experimental stand was lacking. Dunning et al. (1995) found that isolated habitat patches supported fewer sparrows than did patches of habitat that were close to

other suitable patches. This may effect the recolonization of experimental stands in the future. Dunning et al. (1995) hypothesized that the particular juxtaposition of suitable and unsuitable habitat throughout a landscape matrix strongly affects the ability of Bachman's sparrows to maintain a local populations. This lack of apparently suitable habitat around the second experimental stand may have contributed to these sparrows having long initial and subsequent dispersals to locate suitable habitat. If suitable habitat could not be located, sparrows may be forced to settle for sub-optimal habitat. Both the prospect of several long dispersals in search of suitable habitat, or a sparrow having to settle for sub-optimal habitat, may have an adverse effect on their survival (Conroy et al. 1987).

Survival

Few survival rates for Bachman's sparrows have been estimated. Annual survival rates for similar ground-foraging species, calculated through mark-recapture data, range from 40% to 60% (Karr et al. 1990, Brawn et al. 1995).

Stober (1996) estimated the survival rate for Bachman's sparrows at SRS for the period of May 2 to August 29, 1994-1995 was 90.5% (SE=6.4), and survival rates between sex or habitat (mature pine stands vs. pine regeneration stands) were not significantly different. This is similar to the period survival rate for sparrows in control stands for this study.

Though survival rates by sex were not tested for this study, all three sparrows classified as mortalities were female. Females probably are more susceptible to predation because they exclusively incubate the eggs, and 80% of Bachman's sparrow's nests in Haggerty's (1988) study were destroyed by predation. A male-biased sex ratio was observed in this and other studies

(Wolf 1977, Haggerty 1986, Stober 1996). This trend is consistent with higher female mortality, though it could be due to different capture probabilities between the sexes. Males are easier to detect when they are singing and defending their territories, whereas females are much more secretive and rarely seen.

Censored birds decreased our ability to detect a difference in period survival rate between experimental and control birds (only four control birds were censored). In American black ducks, individuals forced to make longer and more frequent dispersals to feeding sites have a lower survival rate than other individuals (Conroy et al. 1987). Based on our null hypothesis that birds that are forced to disperse do not have a lower survival rate than control birds, all radio-tagged sparrows classified as censored were assumed to have died. Whereas these liberally estimated survival rates are probably an underestimate of the true survival rate, they do demonstrate the potential negative effects of long dispersals caused by prescribed burning.

Conclusions

Though prescribed burning during the growing season is advantageous for creating and maintaining suitable Bachman's sparrow habitat, the juxtaposition of suitable Bachman's sparrow habitat to stands that are to be burned should carefully be considered by forest managers when creating management plans (Dunning et al. 1995). Prescribed burns should be arranged spatially to allow sparrows a shorter dispersal movement (< 1000 m) and a greater probability of encountering suitable habitat. Corridors connecting patches of suitable habitat are also useful in helping sparrows recolonize patches (Dunning et al. 1995). A shorter dispersal movement may result in a higher survival rate, which is important for isolated populations with a low probability

of immigration. Careful forest management planning can prevent isolating populations.

Acknowledgments

We were supported in this research by the U. S. Department of the Interior. R. Ingram and other USFWS personnel implemented the prescribed burns at CSNWR and provided logistical support. P. Range at CSNWR captured two Bachman's sparrows at a MAPS station that were subsequently radio-tagged and served as a third control stand for this study. J. Blake, B. Jarvis and other USFS personnel gave logistical support and implemented the prescribed burns at SRS. P. Lewis, C. Stringer, and P. Curlin assisted with the collection of field data. We thank G. Brister for statistical advice and C. Jennings for extensive comments of the manuscript.

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Independent variable: Daily distance (m)

Source	DF	SS	MS	F-value	P-value
Model	18	2,318,929	128,829	8.89	0.0001
Error	302	4,378,056	14,496		
Corrected Total	320	6,696,986			

Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	278,134	278,134	19.19	0.0001
Sparrows(Treatment)	17	1,247,704	73,394	5.06	0.0001

Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	278,134	278,134	3.79	0.0683

Treatment	LSMEAN	SE(LSMEAN)
Control	93.7	18.1
Experimental	201.1	52.1

Figure 3. Average daily movements (± 1 SE, sample size shown above bar) by Bachman's sparrows from control stands, experimental stands before prescribed burns, and experimental stands after prescribed burns in South Carolina, at CSNWR and SRS, for the period of April 20 to July 26, 1997.

Dispersal Movements

Eight of the 18 Bachman's sparrows in experimental stands that we marked either died, or

were censored before prescribed burning. We monitored 10 sparrows in experimental stands (eight at CSNWR and two at SRS) during and after prescribed burning. One bird flew from the stand during the fire and was found 1,282 m east three hours later. Seven of the 10 sparrows dispersed from the experimental stands within 1-3 d after the burn. The other two sparrows were censored because they were observed alive in the experimental stand 3 hrs after the burn, but were not found after that time. Four of the birds that made initial dispersals continued to make long movements for a few days after the burn until either their signal was lost ($n=3$) and the remaining sparrow established a new territory in a winter burned stand that was ~2.5 km distant. There was no significant difference ($t=$, $df=12$, $P=0.85$) between average initial dispersal movements 737 ± 240 m/day ($n=8$ for eight sparrows) and subsequent average movements $1,147 \pm 304$ m/day ($n=6$ for four sparrows).

At CSNWR, average dispersal movements for experimental sparrows were significantly longer than average daily movements of experimental sparrows after prescribed burning ($P=0.006$, $F_{1,4}=27.17$) (Table 6). However, stand, sparrow within stand, and stand*type interaction were also significant, indicating that individual birds within stands contribute to the difference between movement types.

Initial dispersal distances were stand specific for experimental stands at CSNWR ($P=0.003$, $F_{1,5}=28.99$) (Table 7). Three of the four marked sparrows in one experimental stand simply crossed the fire break (a road) 1-2 d after the prescribed burn and set up territories in the adjacent stand. This resulted in short initial dispersal movements for these three birds, with no subsequent dispersals (Table 8). One marked bird had previously used this adjacent stand on two occasions before the burn. The fourth sparrow from the first experimental stand was found six days later ~3 km from its last known location. The largest initial dispersal movements were made by three sparrows in the second experimental stand at CSNWR. Sparrows in the second experimental stand also had large subsequent dispersals, averaging 1,245 m/day ($SE=352$, $n=5$ for three sparrows).

Table 6. ANOVA table for the test of Ho: there is no difference between average dispersal movements per day of experimental sparrows than for daily movements of experimental sparrows after prescribed burning at CSNWR. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)					
Source	DF	SS	MS	F-value	P-value
Model	13	11,722,636	901,741	13.80	0.0001
Error	61	3,985,266	65,332		
Corrected Total	74	15,707,903			
Source	DF	Type III SS	MS	F-value	P-value
Type	1	3,081,323	3,081,323	47.16	0.0001
Stand	1	1,760,687	1,760,687	26.95	0.0001
Sparrows(Stand)	6	2,323,915	387,319	5.93	0.0001
Type*Stand	1	2,450,057	2,450,057	37.50	0.0001
Type*Sparrows(Stand)	4	453,556	113,389	1.74	0.1537
Tests of Hypotheses using the Type III MS for Type*Sparrows(Stand) as an error term					
Source	DF	Type III SS	MS	F-value	P-value
Type	1	3,081,323	3,081,323	27.17	0.0065
Tests of Hypotheses using the Type III MS for Sparrows(Stand) as an error term					
Source	DF	Type III SS	MS	F-value	P-value
Stand	1	1,760,687	1,760,687	4.55	0.0770
Type	MEAN*	SE(MEAN)*			
Dispersal	987.3	213.6			
Daily Movement	239.7	32.2			

*LSMEANS could not be estimated so the regular mean and SE is given

Table 7. ANOVA table for the test of Ho: there is no difference between the initial dispersal movements per day for sparrows from the two experimental stands at CSNWR. P-values > 0.10 are considered significant.

Independent variable: Daily distance (m)					
Source	DF	SS	MS	F-value	P-value

Model	6	2,976,961	496,160		
Error	0				
Corrected Total	6	6,696,986			

Source	DF	Type III SS	MS	F-value	P-value
Stand	1	2,539,009	2,539,009		
Sparrows(Stand)	5	437,952	87,590		

Tests of Hypotheses using the Type III MS for Sparrows(Stand) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Stand	1	2,539,009	2,539,009	28.99	0.0030

Treatment	LSMEAN	SE(LSMEAN)
Experimental Stand #1	282.0	148.0
Experimental Stand #2	1,499.0	170.9

Table 8. Distance per day of initial dispersal, average distance per day of subsequent dispersals (with ± 1 SE and # of subsequent dispersals), and the fate of Bachman's sparrows from two experimental stands at CSNWR and from one experimental stand at SRS. (N = No subsequent dispersal movements observed)

Site	Stand #	Bird #	Initial dispersal (m/day)	Subsequent dispersal			Fate
				(Avg. m/day)	(SE)	(n)	
CSNWR	1	031	497	N	N	N	Lived
CSNWR	1	049	428	N	N	N	
Censored							
CSNWR	1	228	103	N	N	N	Lived
Censored							
CSNWR	1	089	100	N	N	N	
CSNWR	2	273	1,282	615	57	2	Lived
Censored							
CSNWR	2	251	1,265	1,057	0	1	
Censored							Lived
CSNWR	2	309	1,950	1,968	777	2	
Censored							
SRS	2	692	277	656	0	1	Lived

Survival

None of the radio-tagged Bachman's sparrows died as a direct result of prescribed burning. We estimated the period survival rate from April 20 to July 26, 1997 for both sites combined was 80% (SE=11.1) based on 38 marked sparrows (Table 9). When sparrows were grouped by treatment, period survival was 78% (SE=13.9) for experimental stands and 88% (SE=11.7) for control stands.

Table 9. Fate of radio-tagged Bachman's sparrows in control and experimental stands in South Carolina at CSNWR and SRS as used for the Kaplan-Meier survival rate analysis for the period of April 20 to July 26, 1997.

Site	Stand Type	Mortality	Censored	Survived	Total
CSNWR	Experimental	1*	6	2	9 _i
CSNWR	Control	1 [#]	3	8	12
SRS	Experimental	1 ⁺	4	4	9
SRS	Control	0	1	7	8
Total		3	14	21	38

Source of mortality: *avian predation [#]unknown ⁺snake predation

Ten experimental birds were censored. When censored birds were reclassified as mortalities and the period survival rate was re-estimated, the period survival rate was 17% (SE=8.9) for experimental stands, and 57% (SE=14.4) for control stands.

Discussion

Daily Movements

Stober (1996) found that the mean distance moved between daily observations for Bachman's sparrows at SRS was 87 m (SE=7). The average daily movement for control birds for this study was similar at 94 m (SE=8) and 103 m (SE=11) for CSNWR and SRS, respectively. The significant increase in daily movements at CSNWR for experimental birds after prescribed

burning as compared to birds in control stands demonstrates that there was a treatment effect caused by the prescribed burns. This increase in daily movements for experimental birds after burning may be due to conspecific competition on their new territory, or the selection of sub-optimal habitat after dispersing. Competition from Bachman's sparrows with already established territories could force the dispersing bird to 'float'. Floaters are surplus individuals that are sexually mature birds prevented from breeding by some factor (e.g. territorial behavior of others, high quality habitat unavailable) (see Smith 1978). Usually, the latter territory is located in sub-optimal habitat. We observed no dispersing birds with mates in their newly defended territory. Newly defended territories were usually occupied for around 2-5 days before the marked individual moved on. We suspect that these birds dispersed again because no females were responding to their courtship advertisements.

Dispersal Movements

The difference between the initial dispersal movements of sparrows from the two experimental stands at CSNWR indicates that the presence or absence of suitable Bachman's sparrow habitat around the stand to be burned can effect the distance and the duration of dispersal movements. Maps of the refuge indicate that apparently suitable sparrow habitat around the second experimental stand was lacking. Dunning et al. (1995) found that isolated habitat patches supported fewer sparrows than did patches of habitat that were close to other suitable patches. This may effect the recolonization of experimental stands in the future. Dunning et al. (1995) hypothesized that the particular juxtaposition of suitable and unsuitable habitat throughout a landscape matrix strongly affects the ability of Bachman's sparrows to maintain local populations. If suitable habitat could not be located within a reasonable period of time (days?), the sparrows appeared to settle in sub-optimal habitat. We believe that sub-optimal habitat were longleaf stands younger than 30 yrs, heavy or medium midstory, and heavy or light ground cover. Either the prospect of several long dispersals in search of suitable habitat, or a sparrow having to settle in sub-optimal habitat may have an adverse effect on their

survival (Conroy et al. 1987).

Survival

Stober (1996) estimated the breeding season survival rate (May 2 to August 29, 1994-1995) for Bachman's sparrows at SRS was 90.5% (SE=6.4), and he found that survival rates between sexes or habitats (mature pine stands vs. pine regeneration stands) were not significantly different. Our control period survival rate was not significantly different ($X=0.035$, $df=1$, $P=0.85$) from Stober's (1996) period survival rate, however, Stober's (1996) period survival rate was estimated for 4 summer months while our estimate was for 3 months.

We found all three sparrow mortalities were female. Females probably are more susceptible to predation because they exclusively incubate the eggs, and 80% of Bachman's sparrow's nests in Haggerty's (1988) study were destroyed by predation. A male-biased sex ratio was observed in this and other studies (Wolf 1977, Haggerty 1986, Stober 1996). This trend is consistent with higher female mortality, though it could be due to different capture probabilities between the sexes.

Censored birds decreased our ability to detect a difference in period survival rate between experimental and control birds (only four control birds were censored). When we re-estimated the survival rates assuming that all censored birds were dead, survival rates were significantly lower for both experimental and control groups ($P<0.05$). Granted that assuming that all censored birds died is a liberal assumption, Conroy et al. (19) found that in American black ducks (*Anas rubripes*), individuals that moved more often had significantly lower survival rates because they had a higher probability of encountering a predator. Further, Conroy et al. (19) speculated that individuals that moved more often spent more time foraging and less time scanning for predators, again increasing the chances of predation. Thus, we hypothesize that without sufficient suitable habitat available, sparrows displaced by summer burns will suffer higher mortality rates than sedentary individuals, and more importantly, dispersing individuals will probably not successfully reproduce.

If Bachman's sparrows have annual survival rates similar to other passerines, about 50%

(Karr et al. 1990, Brawn et al. 1995), the expected mean life span (Anderson 1975) will be 1.4 yrs. Thus, losing the opportunity to breed during a single breeding season could have dire effects on the fitness of that individual, and more importantly, depending on the extent of habitat disturbance, the local deme could be affected. For this reason, we believe that during transition periods from predominantly winter burning to predominantly summer burning, and if no refugia are available nearby, there exists a chance that the local population of Bachman's sparrows could experience serious population declines.

Conclusions

Though prescribed burning during the growing season is advantageous for creating and maintaining suitable Bachman's sparrow habitat, the juxtaposition of suitable Bachman's sparrow habitat to stands that are to be burned should carefully be considered by forest managers when creating management plans (Dunning et al. 1995). Prescribed burns should be arranged spatially to allow sparrows a shorter dispersal movement (< 1000 m) and a greater probability of encountering suitable habitat. Corridors connecting patches of suitable habitat are also useful in helping sparrows decolonize patches (Dunning et al. 1995). A shorter dispersal movement may result in a higher survival rate, which is important for isolated populations with a low probability of immigration. Careful forest management planning can prevent isolating populations.

Acknowledgments

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Model	15	214,822	14,321	2.60	0.0010
Error	355	1,956,457	5,511		
Corrected Total	370	2,171,279			

Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	162	162	0.03	0.8640
Sparrows(Treatment)	14	214,821	15,344	2.78	0.0006

Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	162	162	0.01	0.9196

Treatment	LSMEAN	SE(LSMEAN)
Control	103.1	10.5
Experimental	101.7	9.0

Table 4. ANOVA table for the test of H_0 : there is no difference between the average daily movements of sparrows (control and experimental) before prescribed burning between sites. P-values > 0.10 are considered significant.

Independent variable: Daily distance

Source	DF	SS	MS	F-value	P-value
Model	35	507,409	14,497	2.67	0.0001
Error	662	3,587,910	5,419		
Corrected Total	697	4,095,320			

Source	DF	Type III SS	MS	F-value	P-value
Site	1	115	115	0.02	0.8839
Sparrows(Site)	34	506,571	14,899	2.75	0.0001

Tests of Hypotheses using the Type III MS for Sparrows(Treatment) as an error term

Source	DF	Type III SS	MS	F-value	P-value
Treatment	1	115	115	0.01	0.9303

Site	LSMEAN	SE(LSMEAN)
CSNWR	101.5	8.1
SRS	102.4	6.8

Table 5. ANOVA table for the test of H_0 : there is no difference between the average daily movements of sparrows from experimental stands than from control stands after prescribed burning at CSNWR. P-values > 0.10 are considered significant.

Model	15	214,822	14,321	2.60	0.0010
Error	355	1,956,457	5,511		
Corrected Total	370	2,171,279			

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