Wildlife Session

Movements and Survival of Bachman's Sparrows in Response to Prescribed Summer Burns in South Carolina

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Abstract: Prescribed winter burning is a common practice in longleaf pine *(Pinus palustris)* to manage for red-cockaded woodpeckers (*Picoides borealis*). The effect of these burns on non-target animals is not well studied. Bachman's sparrows (*Aimophila aestivalis*) were captured in predominantly longleaf pine stands to be burned and not to be burned at Carolina Sandhills National Wildlife Refuge (CSNWR) and the Savannah River Site (SRS), South Carolina. Sparrows were marked with radio-transmitters and monitored daily. Before burning, daily movements did not differ among sites within or among study areas. Additionally, daily movements did not differ by sex or time within the breeding season. After prescribed burning, daily movements were longer for sparrows in burned stands than in unburned stands. All marked sparrows dispersed 1–3 days after a stand was burned and never returned. We found no evidence that dispersing sparrows successfully breed elsewhere. Bachman's sparrow survival rates and reproductive output after burning were lowered. The juxtaposition of seemingly suitable Bachman's sparrow habitat in relation to burned stands influenced both the duration and length of dispersal movements. Managers need to consider the proximity of available habitats when developing burning plans when managing for Bachman's sparrows.

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In the southeastern United States, Bachman's sparrows *(Aimophila aestivalis)* are associated usually with the mature longleaf pine *(Pinus palustris)*-wiregrass (*Aristida* spp.) ecosystem, although their use of young clearcuts (1–5 years—Noss 1989, Dunning and Watts 1990, Stober 1996) and mid-age pine stands (Tucker et al. 1998) has been documented. This fire-dependent longleaf-wiregrass ecosystem is

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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). Frequent spring and summer lightning strikes caused natural wildfires and were essential to the maintenance of the longleaf pine-wiregrass ecosystem before European colonization (Jackson 1988). Fire suppression and the replanting of cleared stands with loblolly *(P. taeda)* and slash *(P. elliottii)* pine have resulted in an 86% reduction in area of the longleaf pine-wiregrass ecosystem in the Southeast (Brown and Kirkman 1990). The loss of longleaf pine-wiregrass over the past century has caused declines in populations of red-cockaded woodpeckers (RCW; Ligon et al. 1986). Red-cockaded woodpeckers were classified as endangered by the U.S. Fish and Wildlife Service (USFWS) in 1970. Since then, management practices to sustain and expand RCW populations have been used frequently. Management practices for RCWs, including 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 over the long-term (Dunning and Watts 1990, Gobris 1992, Wilson et al. 1995, but see Plentovich et al. 1998).

The Bachman's sparrow is considered a vulnerable species by the 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 were lacking. Habitat loss and habitat alteration, via fire suppression, are likely causes of the population decline (Engstrom et al. 1984, Dunning and Watts 1990, Dunning 1993).

Most studies of prescribed burning and Bachman's sparrows have focused on dormant season (winter) burns (Haggerty 1986, Gobris 1992, Dunning 1993). Frequent winter burns are more beneficial to Bachman's sparrows than is fire suppression (Engstrom et al. 1984, Haggerty 1986, Gobris 1992, Dunning 1993). Growing season (summer) burns are being used increasingly for management of RCWs because of the increase in grass and forb cover and decrease in hardwood regeneration that results from growing season burns (Gaines et al. 1995, James 1995). Despite the positive long-term effects of growing season burns for red-cockaded woodpeckers on Bachman's sparrows, such burns may have detrimental direct and indirect short-term effects on non-target species, such as the Bachman's sparrow, through direct mortality as well as lowered recruitment (Liu et al. 1995, Plentovich et al. 1998).

The purpose of our study was to assess movements and survival of Bachman's sparrows in response to growing season burns. We wanted to determine if growing season burns cause mortality of adult Bachman's sparrows, whether Bachman's sparrows are displaced by growing season burns, whether Bachman's sparrows that are displaced by growing season burns breed elsewhere that season, and if the survival rates of Bachman's sparrows displaced by growing season burns are lower than survival rates of Bachman's sparrows in unburned (control) stands.

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Methods

Study Sites

This study was conducted in South Carolina at CSNWR (18,600 ha) and the SRS (770-km^2) between April and August 1997. The CSNWR, in northeastern South Carolina, is in longleaf and longleaf/loblolly pine forests interspersed with scrub oaks (*Quercus* spp.) and is managed mostly for RCWs. There are relatively more mature longleaf pine stands (>80 years) at CSNWR than at SRS. Little mature longleaf pine that would be suitable for Bachman's sparrows (Dunning 1993) occurs in the surrounding off-refuge areas. At CSNWR, there is increasing use of prescribed summer burning on a 3–4 year rotation for RCWs. Previously, only winter burns were used at CSNWR. Thus, a large percentage of stands on the refuge were either winter or summer burned, sometimes within the same year. This transition period resulted in the understory of most stands being quite young (<3 years).

The SRS, in western South Carolina, is a U.S. Department of Energy facility. It is designed as a National Environmental Research Park, and is managed as an experimental forest by the U.S. Forest Service (USDA 1995). Presently, mature longleaf pine stands (>80 years) 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. Some mature pine stands have been set aside for RCW recovery ('recruitment stands'). Stands with active RCW colonies and recruitment stands are burned on a 3–5 year rotation using both winter and summer burns.

Experimental Design

At each site, we selected 2 mature pine stands scheduled to be summer-burned (treatment) and 2 stands not scheduled for summer burning (control). Stands that had been burned the previous winter were not used. The 4 treatment and 4 control stands constituted the replication, and the experimental manipulation occurred over time. At each refuge, the burning schedule was fixed, so stands studied could not be chosen randomly. However, replication of stands and spatial controls protected against serious errors of interpretation that might otherwise occur in the absence of a completely randomized design (Eberhardt and Thomas 1991).

Field Methods

Starting in mid-April we surveyed stands for sparrows using a modified spot mapping method (Dunning et al. 1995). Throughout each stand, parallel transects were spaced 100 m apart. Listening posts were flagged every 100 m along each transect where a tape-recorded Bachman's sparrow song was played and we listened for a response over a 3-minute period. All Bachman's sparrows detected along the transect, along with their perpendicular distance from the line, were recorded. These surveys were repeated between 4–9 times throughout the study period on both control and experimental stands. From these surveys, density estimates of territorial males were estimated. We define density of sparrows as the average number of territorial (singing) males per hectare (Dunning and Watts 1990, Dunning et al. 1995, Stober 1996).

Bachman's sparrows were captured with 4-panel mist nets (30-mm mesh) on both control and experimental stands before prescribed burning at SRS. Sparrows were captured before prescribed burning in experimental stands at CSNWR, but were captured after prescribed burning in control stands at CSNWR. 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 affix 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 and were documented to successfully nest and raise young.

Radio-tagged birds were tracked daily using a 3-element yagi antenna on foot or a 5-element yagi antenna by truck. 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), and location (Universal Transverse Mercator coordinates [UTM]) were recorded. Aerial tracking was used once at CSNWR to try and locate lost sparrows. Radio-tagged sparrows were tracked over a period of 45 days. Expected transmitter battery life was 30 days.

Daily Movement Analysis

We computed daily distance moved by each marked sparrow from the UTM coordinates of the daily observations. Daily movements were movements made by a sparrow from one day to the next within that bird's previously established territory. Dispersal movements were analyzed separately from daily movements. A dispersal movement was any permanent movement away from a sparrow's territory.

We tested for differences in individual daily movements of birds in control and experimental stands before prescribed burning (pre-burn), for each site separately, using the following general linear model (PROC GLM, SAS 1990): Daily distance = Treatment $_i$ + Sparrows (Treatment) $_{j(i)}$ where Daily distance = distance in meters/day moved by a marked sparrow, Treatment = the effect on daily distance by the ith level of the treatment variable (i = control or experimental stand), Sparrows (Treatment) = the effect on the daily distance by the jth individual sparrow nested within the ith treatment. The sparrows (treatment) term was used as the error term for the hypothesis test of treatment because past experience has shown that individual birds have strong individual tendencies that can swamp true average effects simply due to unequal sample sizes (Krementz and Pendleton 1994). We also compared daily movements of sparrows at CSNWR that had settled into a new territory after dispersing from their previous territory on experimental stands (post-burn daily movements) to the daily movements of sparrows on control stands using the above

GLM. This test and subsequent similar tests were not performed for sparrows at SRS due to the low number of post-burn observations (3 daily movements for 1 sparrow) from experimental stands.

We first tested for a difference between pre-burn daily movements of control and experimental sparrows for each site separately to investigate any inherent difference in daily movements by site. When no difference was detected at either site (see below), we then tested for a difference in overall pre-burn daily movements between sites. We used the following GLM: Daily distance = Site $_k$ + Sparrows (Site) $_{j(k)}$ where Daily distance = distance in meters/day moved by a marked sparrow, Site = the effect on daily distance by the kth level of the site variable (k = CSNWR or SRS), Sparrows (Site) = the effect on the daily distance by the jth individual sparrow nested within the kth site. The sparrow (site) term was used as the error term for this test of site effects.

To investigate a possible seasonal effect on movements, we divided the field season in half and compared early and late-season daily movements for sparrows in control stands. We also compared pre-burn daily movements by sex for all sparrows before prescribed burning. We used analysis of variance (PROC ANOVA, SAS 1990) to test for both sex and seasonal effects at an α-value of 0.10.

Unless otherwise indicated, we present average daily movements as least-square estimates of marginal means. Least-squares means are given due to the unbalanced nature of the model and because they reduce biases that may be caused by a few sparrows with a large number of daily observations compared to other sparrows.

Dispersal Movements Analyses

We tested for differences between average dispersal distances (due to burning) of experimental sparrows and average post-burn daily distances for experimental sparrows at CSNWR. We used the following GLM: Distance = Type$_l$ + Stand$_m$ + Sparrows (Stand)$_{j(m)}$ + Type$_l$*Stand$_m$ + Type$_l$*Sparrows (Stand)$_{jm}$ where Distance = distance in meters/day moved by a marked sparrow, Type = the effect on distance by the lth level of the type variable (l = dispersal or daily movement), Stand = the effect on distance by the mth level of the stand variable (m = 2), Sparrows (Stand) = the effect on the daily distance by the jth individual sparrow nested within the mth 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 (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.

The difference between dispersal movements per day for sparrows from the 2 experimental stands at CSNWR was tested with the following GLM: Dispersal distance = Stand$_m$ + Sparrows (Stand)$_{j(m)}$ where Dispersal distance = distance in meters/day for the dispersal movement by a marked sparrow, Stand = the effect on dispersal distance by the mth level of the stand variable (m = 2), Sparrows (Stand) = the effect on the dispersal distance by the jth individual sparrow nested with the mth stand ($j = 10$—for original experimental design). The sparrows (stand) term was used as the error term for the hypothesis test of stand.

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 ≥2 consecutive days. When a sparrow was observed in the same general location for ≥ 2 days, these observations were then included in the analysis of the (non-dispersal) daily movements. We tested for differences between initial and subsequent dispersal movements for sparrows from the second experimental stand at CSNWR using a Student's *t*-test.

Survival Analyses

We estimated period survival rates from 20 April—26 July 1997 using the Kaplan-Meier (1958) method for both sites combined. A period survival rate was calculated for all sparrows combined and then separately for control and experimental birds. We used program CONTRAST (Sauer and Williams 1989) to test for differences in survival rates between control and experimental sparrows. We did not estimate a site-specific period survival rate or a survival rate for each treatment group within each site because there were few mortalities and many censored birds. Pooling the data for both sites allowed smaller confidence intervals and a more precise estimate of period survival rate.

Each individual was classified as dead, 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 signal became weak and then expired a few days later, or if the radio-tagged bird survived 28 days (avg. battery life was 29.8 days). 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 days.

Density Estimates

We estimated stand densities of Bachman's sparrows from the line-transect surveys using the program DISTANCE (Buckland et al. 1993, Laake et al. 1993). The density estimates for each stand were pooled to give overall density estimates for control and experimental stands at each site. The 95% confidence intervals (CI) computed by DISTANCE were used to test for density differences between sites, control and experimental (pre-burn) densities at each site, and experimental pre-burn and experimental post-burn densities at CSNWR. Non-overlapping CIs indicated a significant difference in densities of Bachman's sparrows.

Results

The 2 experimental stands at CSNWR were burned on 5 and 6 May 1997 while the 2 experimental stands at SRS were burned on 23 and 30 June 1997. Twenty-one

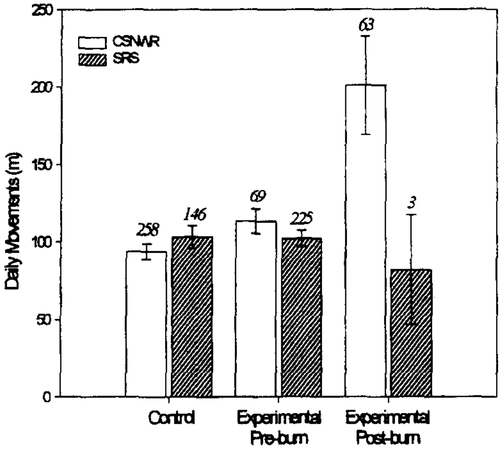

Figure 1. Average daily movements (± 1 SE, sample size shown above bar) by Bachman's sparrows from control stands, experimental stands before prescribed burns, and experimental stands after prescribed burns in South Carolina, at Carolina Sandhills National Wildlife Refuge (CSNWR) and Savannah River Site (SRS), from 20 April to 26 July 1997. Daily movements were blocked by sparrow (treatment) for the analysis of variance.

sparrows were marked at CSNWR (9 experimental, 12 control), and 17 sparrows were marked as SRS (9 experimental, 8 control).

Daily Movements

Average pre-burn daily movements by Bachman's sparrows ($N=36$) in control and experimental stands were not significantly different at either CSNWR ($F_{1,18}=1.14$, $P=0.30$) or SRS ($F_{1,14}=0.01$, $P=0.92$) (Fig. 1). Pre-burn daily movements, after pooling observations of sparrows in both control and experimental stands, were not significantly different between sites ($F_{1,34}=0.01$, $P=0.93$).

At CSNWR, the post-burn daily movements of sparrows from experimental stands were longer ($F_{1,17}=3.79$, $P=0.07$) than for sparrows in control stands (Fig. 1). We found no effect of sex on daily movements at either CSNWR ($F_{1,18}=0.02$, $P=0.89$) or SRS ($F_{1,14}=0.01$, $P=0.91$) 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 ($F_{1,9}=0.58$, $P=0.47$) or SRS ($F_{1,7}=1.89$, $P=0.21$).

Dispersal Movements

Eight of the 18 Bachman's sparrows that were marked in experimental stands either died or were censored before prescribed burning. We monitored 10 sparrows in experimental stands (8—CSNWR, 2—SRS) both during and after prescribed burning. One bird flew from the stand during the fire and was found 1,282 m east 3 hours later. Seven of the 10 sparrows dispersed from the experimental stands within 1–3 days after the burn. The other 2 sparrows (1—CSNWR, 1—SRS) were censored because they were observed alive in the experimental stand 3 hours after the burn, but were not found after that time. Four sparrows continued to make long dispersal movements for a few days after the burn. Three of these sparrows exhibited subsequent dispersal movements until their signals were lost, while the remaining sparrow established a new territory in a winter burned stand that was ~2.5 km distant.

At CSNWR, average dispersal movements for experimental sparrows (987 ±213.6 m/day SE) were significantly longer than average post-burn daily movements of experimental sparrows (239 ±32.2 m/day SE; $F_{1,4}=27.17$, $P=0.01$). However, stand, sparrow within stand, and stand*type interaction were also significant ($P<0.05$), indicating that individual birds within stands contributed to the difference between movement types.

Dispersal distances per day were stand specific for experimental stands at CSNWR ($F_{1,5}=6.72$, $P=0.05$). Three of the 4 marked sparrows in experimental stand 1 at CSNWR simply crossed the fire break (a road) 1–2 days after the prescribed burn and set up territories in the adjacent stand. None of these 3 birds dispersed subsequently (Table 1). We monitored 1 marked bird in this adjacent stand on 2 occasions before the burn. The fourth sparrow from experimental stand 1 was found 6 days later ~3 km from its last known location. Three sparrows in the experimental stand 2 at CSNWR made the longest initial dispersal movements (Table 1). There was no difference ($t=0.37$, $df=5$, $P=0.73$) between average initial dispersal movements (1,499 ±225 m/day SE; $N=3$ for 3 sparrows) and subsequent average dispersal movements (1,174 ±450 m/day; $N=8$ for 3 sparrows) for these 3 sparrows from stand 2 at CSNWR.

Table 1. Site, experimental stand number, bird number, distance per day of initial dispersal, average distance per day of subsequent dispersals (with ± 1 SE and number of subsequent dispersals), total distance dispersed, and fate of Bachman's sparrows from 2 experimental stands at Carolina Sandhills National Wildlife Refuge (CSNWR) and from one experimental stand at Savannah River Site (SRS). (N = No subsequent dispersal movements observed).

Site	Exp. stand no.	Bird no.	Initial dispersal m/day	Subsequent dispersal(s) Avg. m/day	SE	N	Total distance dispersed m	Fate
CSNWR	1	031	497[a]	497	0	5	2,982	Survived
CSNWR	1	049	428	N	N	N	428	Censored
CSNWR	1	228	103	N	N	N	103	Censored
CSNWR	1	089	100	N	N	N	100	Survived
CSNWR	2	273	1,282	615	57	2	2,512	Censored
CSNWR	2	251	1,265	1,057[b]	0	4	5,493	Censored
CSNWR	2	309	1,950	1,968	777	2	5,886	Censored
SRS	2	692	277	656	0	1	1,348	Survived

a. Bird found 6 days after burn, 2,982 m from experimental stand, so the initial dispersal movement the day after the burn is an average of the total distance dispersed.

b. Bird was located again 4 days after its initial dispersal movement, 4,228 m from last known location, so an average dispersal distant over the 4 days is given.

Table 2. Fate of radio-tagged Bachman's sparrows in control and experimental stands in South Carolina at Carolina Sandhills National Wildlife Refuge (CSNWR) and Savannah River Site (SRS) as used for the Kaplan-Meier survival rate analysis for the period of 20 April to 26 July 1997.

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

a. Source of mortality: * = avian predation, # = unknown, + = snake predation.

b. Includes a sparrow that was captured in a control stand and later flew to an experimental stand. This sparrow was counted once as a control bird that survived (up to the date it moved to the experimental stand) and once as a experimental bird that was censored (starting from the date it moved to the experimental stand).

Survival

None of the radio-tagged Bachman's sparrows died as a direct result of prescribed burning (Table 2). However, 2 Bachman's sparrow nests were destroyed by the prescribed fires. We estimated the period survival rate from 20 April–26 July 1997 for both sites combined was 0.80 (0.111 SE) based on 38 marked sparrows. When sparrows were grouped by treatment, period survival in experimental stands (0.78, 0.139 SE) was not different (χ^2=0.303, df = 1, P =0.58) from survival in control stands (0.88, 0.117 SE).

Bachman's Sparrow Densities

We used data from 53 line-transect surveys (25 at CSNWR and 28 at SRS) to estimate Bachman's sparrow densities/ha for each stand. There was no difference in the densitites of Bachman's sparrows between control and experimental stands before burning at either CSNWR (P >0.05) or SRS (P >0.05) (Fig. 2). We also found no difference between sites for density estimates when control and experimental stand (pre-burn) densities were pooled (P >0.05).

In experimental stands at both CSNWR and SRS, Bachman's sparrow densities dropped to zero within 1–3 days after prescribed burning (Fig. 2). Subsequent surveys showed densities to remain at zero for approximately 50 days after burning. During this 50-day period, as the grass and forb components of the ground vegetation regenerated profusely, other ground-dwelling birds such as ovenbirds *(Seiurus aurocapillus)* and eastern towhees *(Pipilo erythrophthalmus)* were observed in experimental stands at CSNWR. Few Bachman's returned to the experimental stands at CSNWR within 100 days (Fig. 2). Post-burn densities were significantly lower (P<0.05) than pre-burn sparrow densities for either experimental stand at CSNWR. Bachman's sparrows were not observed to return to either experimental stand at SRS within 50 days after burning.

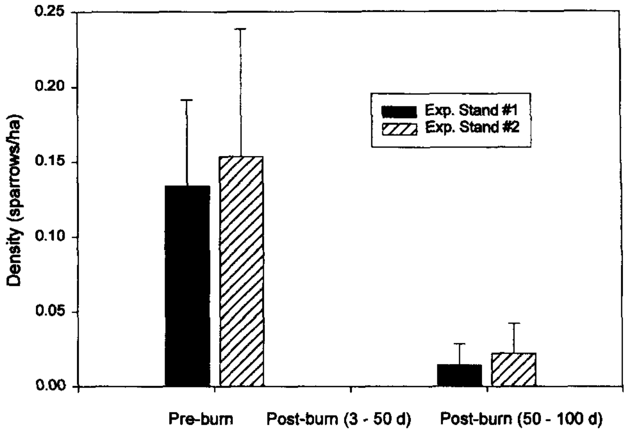

Figure 2. Densities (sparrows/ha) (± 1 SE) of Bachman's sparrows for 2 experimental stands at Carolina Sandhills National Wildlife Refuge (CSNWR) during the 1997 breeding season. Density estimates are for 3 periods: before prescribed burning, 3–50 days after prescribed burning, and 50–100 days after prescribed burning.

Discussion

Daily Movements

Stober (1996) found that the mean distance moved between daily locations for Bachman's sparrows at SRS was 87 m (SE=7). The average daily movement for control birds for our study was similar to the daily movements documented by Stober (1996) at both CSNWR (94 m, SE=8) (t=0.677, df=26, P >0.10) and SRS (103 m, SE=11) (t=1.357, df=22, P=0.10). The significant increase in post-burn daily movements at CSNWR for experimental birds compared to birds in control stands demonstrates that there was a treatment effect caused by the prescribed burns. We believe this increase in post-burn daily movements for experimental birds was due to either nonspecific competition on their new territory, and/or the selection of suboptimal habitat after dispersing. Competition from Bachman's sparrows with established territories apparently forced the dispersing birds 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) (Smith 1978). We observed no dispersing birds with mates in their newly defended territory, though we did observe territorial singing by these displaced birds. Newly defended territories were occupied anywhere from 2–17 days before the marked individuals dispersed again (N=2), were censored (N=4), or remained on their new territory until their radio expired (N=2).

Dispersal Movements

The difference between the average dispersal movements of sparrows from the 2 experimental stands at CSNWR indicated that the availability of suitable Bachman's sparrow habitat around the burned stand can affect the distance and the duration of dispersal movements. Experimental stand 1 had suitable habitat adjacent to it on 1 side. Three of 4 marked birds in this stand settled into this suitable habitat.

Maps of the refuge indicated that very little apparently suitable sparrow habitat was located within a 1-km radius around experimental stand 2. Dunning et al. (1995) found that isolated habitat patches supported fewer sparrows than did patches of habitat that were close to other suitable patches, thus the juxtaposition of suitable and unsuitable habitat throughout a landscape matrix affects the ability of Bachman's sparrows to maintain local populations. If suitable habitat could not be located within a reasonable period of time (3–4 days), the sparrows appeared to settle into sub-optimal habitat. We believe that sub-optimal habitats were longleaf or loblolly stands younger than 30 years with heavy or medium understory tree density and/or shrub density and a sparse layer of ground vegetation (Haggerty 1998, Tucker et al. 1998). A fire-displaced sparrow may encounter reduced survival because they either face several long dispersals in search of good habitat or avoid much searching but settle in sub-optimal habitat (see Conroy et al. 1987).

Survival

Stober (1996) estimated the breeding season survival rate (2 May to 29 August 1994–1995) for Bachman's sparrows at SRS was 90.5% (SE=6.4). He found that survival rates were not significantly different between sexes or habitats (mature pine stands vs. pine regeneration stands). All 3 sparrow mortalities we confirmed were females. Females appear more susceptible to predation because they alone incubate the eggs, and 80% of Bachman's sparrow's nests in Haggerty's (1988) study were destroyed by predators. A male-biased capture rate (2.6:1, m:f) was observed in this and other studies (Wolf 1977, Haggerty 1986, Stober 1996). This trend is consistent with higher female mortality, although it could also be due to different capture probabilities between the sexes.

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 years. Thus, losing the opportunity to breed during a single breeding season could have severe effects on the fitness of that individual, and more importantly, depending on the extent of habitat disturbance, the local population could be affected. For this reason we believe that if a large percentage of suitable sparrow habitat on a management area is burned each year, and if no refugia are available nearby (few marked birds moved >5 km), there exists a chance that the local population of Bachman's sparrows could experience serious population declines.

Densities

The displacement of all Bachman's sparrows from experimental stands for the period of 3 to 50 days after prescribed burning demonstrates a decreased potential for Bachman's sparrow reproduction on stands that are burned. It is possible that the presence of the radio transmitter interfered with successful reproduction by Bachman's sparrows. We think that this was not the case as Stober (1996), and Stober and Krementz (2000) have documented repeated nesting attempts by radio-marked Bachman's sparrows at SRS. Although a few unmarked Bachman's sparrows moved back into the experimental stands at CSNWR during 50 to 100 days post-burn, the densities were significantly lower ($P < 0.05$) compared to pre-burn densities. No evidence of reproduction by sparrows that recolonized the experimental stands 50 to 100 days post-burn was found. Gobris (1992) found higher densities of Bachman's sparrows in mature stands 1 to 3 years after prescribed winter burns compared to 4 to 5 years post-burn at Piedmont National Wildlife Refuge, Georgia. Her findings indicate that the experimental stands at SRS and CSNWR may become good breeding habitat a year or two after burning. However, for sparrows that exist in isolated populations, managers should be careful not to burn too much suitable breeding habitat within the same year (Robbins and Meyers 1992).

Conclusion

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 burned stands should be carefully considered by forest managers when creating management plans (Dunning et al. 1995). Prescribed burns should be arranged spatially to allow shorter dispersal distances (<5 km) and therefore a greater probability of encountering suitable habitat. Corridors connecting patches of suitable habitat may also enable sparrows to recolonize patches (Dunning et al. 1995). Shorter dispersal distances may result in higher survival rates, which are important for isolated populations with a low probability of immigration. Careful forest management planning can prevent isolating populations.

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