The Wilson Journal of Ornithology 118(2):138–144, 2006

VARIATION IN BACHMAN'S SPARROW HOME-RANGE SIZE AT THE SAVANNAH RIVER SITE, SOUTH CAROLINA

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ABSTRACT.—Using radiotelemetry, we studied variation in home-range size of the Bachman's Sparrow (*Aimophila aestivalis*) at the Savannah River Site (SRS), South Carolina, during the 1995 breeding season. At SRS, sparrows occurred primarily in two habitats: mature pine habitats managed for Red-cockaded Woodpecker (*Picoides borealis*) and pine plantations 1 to 6 years of age. The mean 95% minimum convex polygon home-range size for males and females combined ($n = 14$) was 2.95 ha ± 0.57 SE, across all habitats. Mean home-range size for males in mature pine stands (4.79 ha ± 0.27, $n = 4$) was significantly larger than that in 4-year-old (3.00 ha ± 0.31, $n = 3$) and 2-year-old stands (1.46 ha ± 0.31, $n = 3$). Home-range sizes of paired males and females ($n = 4$ pairs) were similar within habitat type; mean distances between consecutive locations differed by habitat type and sex. We hypothesize that a gradient in food resources drives home-range dynamics. *Received 16 December 2004, accepted 28 November 2005.*

The Bachman's Sparrow (*Aimophila aestivalis*) is a species of concern due to its population decline (Sauer et al. 2004) and large reductions in range (Dunning 1993). The impact of prescribed fire and timber management on Bachman's Sparrow abundance (Dunning and Watts 1990; Gobris 1992; Plentovich et al. 1998; Tucker et al. 1998, 2004) and habitat occupancy (Wan A. Kadir 1987; Haggerty 1998, 2000) have been well documented. The sparrow's secretive nature, however, makes it difficult to obtain basic information on its reproduction, survival, movement, and home-range dynamics (Dunning 1993).

Bachman's Sparrow home-range sizes have been estimated using spot mapping of unmarked (McKitrick 1979, Meanley 1990) and color banded (Haggerty 1998) males, but this approach is problematic in some habitats because detecting Bachman's Sparrows is difficult in dense, early successional stands (Bibby et al. 1992). Bachman's Sparrows are extremely cryptic in dense vegetation, particularly after 3–4 years of vegetative succession in rapidly growing pine plantations. Males are often only seen while perched on singing posts; such observations do not accurately reflect their entire home range. Because females do not sing, it is impossible to consistently follow or locate their movements. Using spot mapping, mean estimates of home-range size ranged from 5.1 ha ± 1.2 SD (range = 4–6.7, $n = 6$) in mature Florida pine flatwoods (McKitrick 1979) to 2.5 ha ± 0.2 SE (range = 0.7–4.5, $n = 25$) in several Arkansas clearcuts during the initial 3 years of succession (Haggerty 1998). How home-range sizes vary across the species' range or habitat types is unknown (Dunning 1993). Because of widespread conservation concern for Bachman's Sparrows, wildlife managers require a better understanding of the species' natural history. We estimated home-range size using radiotelemetry in early and late successional longleaf pine (*Pinus palustris*) stands, examined how home-range size varied with habitat type, and monitored movements within territories by habitat type and sex.

METHODS

During the 1995 breeding season, we studied Bachman's Sparrows at the Savannah River Site (SRS) (33° 14′ N, 81° 31′ W), an 800-km² National Environmental Research Park managed by the U.S. Department of Energy. The SRS is located in western South Carolina along the Savannah River in Aiken, Barnwell, and Allendale counties and lies in the Upper Coastal Plain physiographic province. At the SRS, Bachman's Sparrows inhabit understory grass and grasslands found in mature loblolly

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(*Pinus taeda*) and longleaf pine stands (40–98 years old) managed for Red-cockaded Woodpeckers (*Picoides borealis*); they also occur in regenerating pine stands during the initial 6–10 years after planting (Dunning and Watts 1990, Gaines et al. 1995, Kilgo and Bryan 2005). Mature pine stands were managed with periodic prescribed fires on a 3- to 5-year rotation during both the growing and dormant seasons. All mature stands in which we monitored sparrows had been burned 1–2 years previously and were on a 3-year burn rotation. Both the mature and regenerating stands were characterized by understories dominated by *Andropogon* spp. and *Panicum* spp. grasses, rather than native wiregrass (*Aristida* spp.; Stober 1996). Regeneration stands consisted of areas recently clear-cut and machine planted with bare-root longleaf pines at densities of 1,400–1,700 trees/ha; site preparation generally included a prescribed burn before planting. Patches of shrubs within understories of grasses and forbs occurred in both regeneration and mature stands. We randomly selected five stands from groups with similar management histories: one 2-year-old stand (19.2 ha), one 4-year-old stand (15.0 ha), and three mature stands (17.6, 16.7, and 5.2 ha). Selected stands were >1 km apart.

To capture Bachman's Sparrows, in each stand we placed 25 12-m-long (30-mm mesh) mist nets in a 5×5 grid with nets 50 m apart (Krementz and Christie 1999). Captured birds were weighed, sexed, aged, and banded with a federal leg band. We categorized sparrows as either hatch-year or after-hatch-year and determined sex by the presence or absence of a brood patch (Pyle et al. 1987). Using the Rappole and Tipton (1991) thigh-harness method, we attached radio transmitters to 20 sparrows in five stands: 6 sparrows (4M:2F) in 2-year-old longleaf pine habitat, 6 sparrows (4M:2F) in 4-year-old longleaf habitat, and 8 sparrows (6M:2F) in three mature pine habitats. The radio with harness weighed 1.1–1.2 g (Advanced Telemetry Systems, Isanti, Minnesota), about 6% of body mass relative to all captured birds (females: 18.6 g $\pm$ 0.24 SE, $n = 36$; males: 18.2 g $\pm$ 0.31 SE, $n = 69$; Stober 1996, Krementz and Christie 1999). Within a few hours after release, all radio-tagged sparrows resumed normal activities, and we observed no unusual behaviors associated with the radio-attachment method.

We located radio-marked sparrows daily, and made observations on each sparrow throughout the day, from sunrise to twilight, throughout the breeding season. We recorded status (live, dead, or lost radio), location, and any reproductive, foraging, or other behavior. Occasionally, we monitored individuals twice a day, with a minimum of 2 hr between observations. Sparrows readily traversed their home ranges within this time period; therefore, consecutive observations likely did not result in autocorrelation problems (Swihart and Slade 1985) that would have yielded underestimates of home-range size (Cresswell and Smith 1992).

To provide an index of Bachman's Sparrow density, we also conducted spot mapping three times in each stand by using playback tapes of the Bachman's Sparrow's primary song and counting all males (Bibby et al. 1992, Dunning et al. 1995, Stober 1996). While recording daily locations of marked sparrows, we also mapped the locations of unmarked sparrows within each stand. Counter-singing exchanges between unmarked and marked individuals were recorded as well.

We marked sparrow locations with flagging, and we used a Trimble Pathfinder Pro GPS (3-D mode) unit to establish benchmark Universal Transverse Mercator (UTM) coordinates within each territory. All GPS locations were differentially corrected and were accurate to <5 m. Individual locations were then referenced to an established UTM location using a survey laser. The survey laser was used to calculate distance (± 0.10 m) and azimuth (± 0.01 degrees) between locations, which were then converted into UTM coordinates. Once an individual's locations were mapped, we used program HOME RANGE (Ackerman et al. 1990) to estimate the 95% minimum convex polygon (MCP) for home range (Mohr 1947). We attempted to collect 35 observations per bird (Ackerman et al. 1990). We recognize that the 95% MCP has certain limitations, but all other breeding season home-range sizes for Bachman's Sparrows described in the literature were estimated using this metric (Dunning 1993). Distances moved between locations were calculated for each individual, as were distances from each location to the arith-

TABLE 1. Home-range size estimates and densities of male Bachman's Sparrows in pine habitats, by stand age, during the 1995 breeding season at the Savannah River Site, South Carolina.

Stand age (years)	Stand size (ha)	No. marked sparrows	95% MCP[a] (SE)	Range	Male density/ 10 ha[b]
2	19.2	3	1.46 (0.31)	0.99–2.04	2.59
4	15.0	3	3.00 (0.31)	2.80–3.37	4.65
Mature	17.6	3	—	—	3.41
Mature	16.7	1	—	—	1.79
Mature (both stands)[c]		4	4.79 (0.27)	4.23–5.69	

[a] Mean 95% minimum convex polygon estimates.
[b] Includes both radio-marked and unmarked singing males; densities determined using spot mapping technique within each stand.
[c] Home-range estimate for mature stands is pooled across the two stands.

metic center of each home range, defined as the mean distance from the estimated central coordinate to each observation within the home range.

Only 14 of the 20 radio-marked sparrows were included in the analysis of home-range size. We obtained <35 locations for two females and one male, and three males were treated as outliers and excluded from analyses. The outliers included (1) a bird with two distinct home ranges (a combined total of 20.9 ha) in a mature stand, (2) one whose home range (1.63 ha) ended up outside the study stand in an adjacent 33-year-old stand of planted pine, and (3) one (in the 2-year-old habitat) that behaved like a floater and used part of an adjacent 43-year-old stand of pine (5.46 ha). Due to these exclusions, we used only two (the 17.6- and 16.7-ha stands) of the three mature pine stands in our analyses.

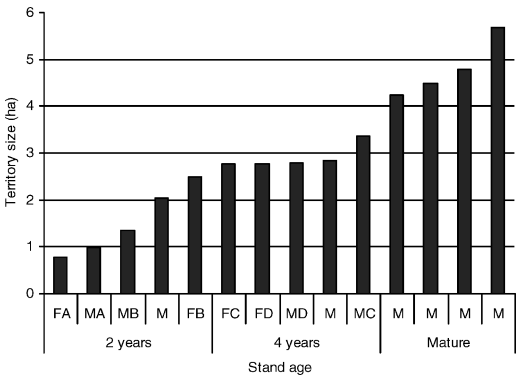

FIG. 1. Home-range size, by habitat age (2 years, 4 years, mature), using 95% minimum convex polygon estimates for Bachman's Sparrows (n = 4 females, 10 males) during the 1995 breeding season, Savannah River Site, South Carolina. Pairs designated by similar alpha characters (A–D); F = female, M = male.

We used a general linear model procedure (PROC GLM; SAS Institute, Inc. 1987) to conduct three pre-planned tests comparing home-range sizes of males by habitat type. We included only males because all marked females were paired to marked males. Once we determined differences in home-range sizes by habitat type (F-test), we used Tukey tests to compare the least-squares means. Due to insufficient sample sizes, we did not test for the effect of sex (female n = 4) or conspecific density (n = 4) on home-range size. We also used the GLM procedure and Tukey tests to compare the least-squares means for mean distance moved and distance from home-range arithmetic center by habitat type and sex. All statistical tests were one-tailed. The level of statistical significance was set at 0.05 and means are reported ± SE.

RESULTS

For the 14 radio-marked individuals in our analyses, we recorded an average of 63 locations (range = 45–81) per individual over an average of 50 days of observation (range = 38–62 days). Ten birds were monitored in the 2-year-old (3M:2F) and the 4-year-old (3M:2F) stands, and four males were monitored in the two mature stands (3M:0F and 1M:0F). The mean 95% minimum convex polygon home-range size for males and females combined (n = 14) across all habitats was 2.95 ha ± 0.57. Mean 95% MCP home-range size across all habitats was 3.26 ha ± 0.49 for males (n = 10; Table 1) and 2.20 ha ± 0.48 (n = 4) for females. For males, home-range size increased with habitat age ($F_{2,7}$ = 33.9, P < 0.001; Fig. 1). Home-range sizes differed between 2-year-old (mean = 1.46 ha ± 0.31, n = 3) and 4-year-old (mean = 3.00 ha ±

0.31, $n = 3$) regeneration habitat ($t = 3.54$, $P = 0.009$), and were significantly larger in mature pine habitats than in the 2- and 4-year-old habitats ($t = 8.18$, $P < 0.001$; $t = 4.40$, $P = 0.003$, respectively).

Home ranges were always adjacent to a stand edge. Conspecific density was highest (4.65 males/10 ha) in the 4-year-old stand (Table 1) and lower in the 2-year-old stand and one mature stand, both of which were isolated with no suitable adjacent sparrow habitat. Of the four sparrow pairs in which both the male and female were marked, two inhabited the 2-year-old stand and two inhabited the 4-year-old stand. In one pair, the female had a larger home-range size than the male (pair B; Fig. 1); otherwise, male and female home ranges were roughly similar.

Mean distance moved between consecutive observations was 83.9 m ± 12.78 ($n = 14$); distance moved differed among habitat types ($F_{2,11} = 14.66$, $P < 0.001$) and was marginally different between sexes ($F_{1,12} = 3.73$, $P = 0.077$). Mean distance moved in mature stands (106.6 m ± 6.4) was not different from that in the 4-year-old stand (88.8 m ± 5.7), but differed from the distance moved in the 2-year-old stand (61.0 m ± 5.7). The mean distance from the arithmetic center of an individual's home range to each location differed by habitat type ($F_{2,11} = 12.69$, $P = 0.001$), but not by sex ($F_{1,12} = 0.78$, $P = 0.40$). Mean distance from arithmetic center in mature stands (81.8 m ± 4.7) was not different from that in the 4-year old stand (73.6 m ± 4.2, $t = 1.32$, $P = 0.21$) but differed from that in the 2-year-old stand (51.9 m ± 4.2, $t = 4.77$, $P < 0.001$). The longest movement between daily observations was 824 m by a male, and most long-distance movements were about 200 m. In one case, a male crossed a riparian area 200 m wide to an adjacent regeneration stand, remained there for 2 days, and then returned to the original stand.

DISCUSSION

Because we located birds through radiotelemetry rather than by visual documentation at singing posts, our estimates of home-range size were slightly larger and more precise than those reported by Haggerty (1998). Home-range estimates of McKitrick (1979) and Haggerty (1998) were biased by their dependence on visual records of males (color banded or unmarked) perched in conspicuous locations. Nonetheless, home-range sizes of male sparrows in our study were similar to those reported by Haggerty (1998), with the smallest territories found in the 1- and 2-year-old pine regeneration habitat and home range increasing with succession of habitat. Radiotelemetry also allowed us to obtain the first estimates of female home-range size, which were similar to male home-range size ($n = 4$ pairs). Home-range size between paired birds is probably influenced by the mate-guarding behavior that males exhibit during the breeding season (Haggerty 1986). Some locations for the female whose home range was larger than the male's (2-year-old stand) were recorded after her brood had fledged, which may explain the larger size of her home range.

We recorded few instances of direct conflict between adjacent sparrows defending home ranges. The persistent use of primary song and counter-singing (Meanley 1990, Dunning 1993) apparently mediated the need for direct conflict in establishing and maintaining home ranges. Spot mapping revealed the highest density of sparrows in the 4-year-old stand. Similarly, spot mapping conducted by Stober (1996) in regeneration habitats 1–6 years of age revealed that Bachman's Sparrow densities were greatest in 3- to 4-year-old habitats. Overlap of sparrow home ranges was limited to three instances and occurred in grassy patches in mature pine stands or in regeneration habitats where trees and shrubs were suppressed and grasses dominated the vegetation.

Although Haggerty (1986) reported that sparrow density was inversely related to home-range size, we were unable to corroborate this. Stober (1996) found more sparrows in stands with suitable adjacent habitat than in isolated, disjunct stands. Dunning et al. (1995) also found that areas connected by corridors of suitable habitat had a greater probability of sparrow occupancy than isolated patches of suitable habitat. Greater conspecific density may constrict the size of home ranges in breeding season, but this hypothesis needs to be tested by removing territorial individuals and monitoring the behavior of adjacent individuals. Vegetation succession and arthropod food resources also may play important roles in determining home-range size.

We found that home-range size increased with habitat succession: home ranges in mature habitats often were twice the size of those in regeneration habitats. We hypothesize that the distribution of resources within home ranges may explain this pattern. Bachman's Sparrows are omnivorous, foraging exclusively from the ground for insects (orthopterans, arachnids, lepidopteran larvae, coleopterans, hemipterans) and grass seeds, especially those of *Panicum* spp. (Allaire and Fisher 1975, Haggerty 1992, Dunning 1993). Early successional habitats have greater arthropod productivity than mature pine stands in the Southeast (Menhinick 1963, Landers and Mueller 1986, Hurst 1992). Cross (1956) surveyed a range of upland habitats at the SRS for Orthoptera and found >40 species in early successional habitats compared with only 7 species in mature loblolly pine stands. In contrast, ground-level arthropod communities in mature pine stands managed for Red-cockaded Woodpeckers at the SRS include an abundance of spiders and ants, but few grasshoppers (New and Hanula 1998). Stober (1996) found that, as a percentage of total vegetation cover, *Panicum* spp. were more abundant in regeneration stands (0.8–1.3%) than in mature pine stands (0.1–0.4%); thus, differences in home-range size between habitats may be a reflection of greater seed resources and arthropod productivity in early regeneration habitats than in mature pine habitats managed for Red-cockaded Woodpeckers. In examining previous studies on Bachman's sparrows across their range (Wan A. Kadir 1987; Dunning and Watts 1990; Gobris 1992; Haggerty 1998, 2000; Plentovich et al. 1998; Tucker et al. 1998, 2004), we observed that, in general, sparrow densities and arthropod communities were reduced with succession of understory vegetation.

Despite the differences we observed in home-range sizes by habitat type and the differences in male densities among stand ages, Stober and Krementz (2000) detected no significant differences in survival rates between sexes or habitat types. Apparently, the larger home-range sizes of Bachman's Sparrows in mature pine stands do not predispose those birds to lower survival rates, as might be expected from longer movements throughout their territories. Breeding season survival rates were high (0.905, 95% CI = 0.794–0.992), with only 2 mortalities (raptor and mammal depredations) out of 20 individuals radio-tagged.

We found that Bachman's Sparrows did not move far (~100 m/day) between consecutive observations, as was also found for radio-marked Eastern Towhees (*Pipilo erythrophthalmus*) at the Savannah River Site (Krementz and Powell 2000). Like towhees, Bachman's Sparrows moved among adjacent stands, but unlike towhees, Bachman's Sparrows used middle-aged (~20- to 35-year-old) stands infrequently (Stober 1996). Not surprisingly, we found that daily movements reflected home-range sizes: smaller home ranges among habitat types were associated with shorter daily distances moved.

Management for Bachman's Sparrow populations in forested habitats often involves prescribed fire and reduced pine densities. If small home-range size is a surrogate for habitat suitability, managers should maintain a continuous matrix of herbaceous understory vegetation. Clear-cuts should be managed for perches (Dunning and Watts 1990), abundant herbaceous vegetation (Mills et al. 1991, Dunning 1993), and connectivity with nearby suitable habitat (Dunning et al. 1995). Although it is known that mature stands of pine become more suitable for sparrows with frequent prescribed fire and moderate basal areas of pine, further research should ascertain whether home-range size in mature pine stands is dependent on the distribution of herbaceous understory, as arthropod communities in mature pine stands are a function of primary productivity occurring on the forest floor (Cross 1956). Additional information on Bachman's Sparrow reproduction and survival across the range of occupied habitats is needed to determine the viability of populations inhabiting intensively managed industrial forests versus forests managed on longer logging rotations with fire management.

ACKNOWLEDGMENTS

This project was funded by the USGS Biological Resources Division and by the U.S. Department of Energy—Savannah River Operations Office through the U.S. Forest Service—Savannah River under Interagency Agreement DE-AI09-00SR22188 (Cooperative Agreement contract no. 12-11-008-876). J. C. Kilgo, G. O. Ware, J. B. Dunning, Jr., J. Blake, and two anon-

ymous reviewers commented on the manuscript. Thanks to J. S. Christie, A. Allen, H. McPherson, C. E. Moorman, and J. B. Dunning, Jr., for assistance in the field.

LITERATURE CITED

ACKERMAN, B. B., F. A. LEBAN, M. D. SAMUEL, AND E. O. GARTON. 1990. User's manual for program HOME RANGE, 2nd ed. Technical Report, no. 15. Forestry, Wildlife and Range Experiment Station, University of Idaho, Moscow.

ALLAIRE, P. N. AND C. D. FISHER. 1975. Feeding ecology of three resident sympatric sparrows in eastern Texas. Auk 92:260–269.

BIBBY, C. J., N. D. BURGESS, AND D. A. HILL. 1992. Bird census techniques. Academic Press, London, United Kingdom.

CRESSWELL, W. J. AND G. C. SMITH. 1992. The effects of temporally autocorrelated data on methods of home-range analysis. Pages 272–284 *in* Wildlife telemetry: remote monitoring and tracking of animals (I. G. Priede and S. M. Swift, Eds.). Ellis Horwood, London, United Kingdom.

CROSS, W. H. 1956. The arthropod component of old-field ecosystems: herb stratum population with special emphasis on the Orthoptera. Ph.D. dissertation, University of Georgia, Athens.

DUNNING, J. B. 1993. Bachman's Sparrow (*Aimophila aestivalis*). The Birds of North America, no. 38.

DUNNING, J. B., JR., R. BORGELLA, JR., K. CLEMENTS, AND G. K. MEFFE. 1995. Patch isolation, corridor effects, and colonization by a resident sparrow in a managed pine woodland. Conservation Biology 9:542–550.

DUNNING, J. B., JR., AND B. D. WATTS. 1990. Regional differences in habitat occupancy by Bachman's Sparrow. Auk 107:463–472.

GAINES, G. D., K. E. FRANZREB, D. H. ALLEN, K. S. LAVES, AND W. L. JARVIS. 1995. Red-cockaded Woodpecker management on the Savannah River Site: a management/research success story. Pages 81–88 *in* Red-cockaded Woodpecker: recovery, ecology and management (D. L. Kulavy, R. G. Hooper, and R. Costa, Eds.). Center for Applied Studies in Forestry, Stephen F. Austin State University, Nacogdoches, Texas.

GOBRIS, N. 1992. Habitat occupancy during the breeding season by Bachman's Sparrow at the Piedmont National Wildlife Refuge in central Georgia. M.Sc. thesis, University of Georgia, Athens.

HAGGERTY, T. M. 1986. Reproductive ecology of Bachman's Sparrow (*Aimophila aestivalis*) in central Arkansas. Ph.D. dissertation, University of Arkansas, Fayetteville.

HAGGERTY, T. M. 1992. Effects of nestling age and brood size on nestling care in the Bachman's Sparrow (*Aimophila aestivalis*). American Midland Naturalist 128:115–125.

HAGGERTY, T. M. 1998. Vegetation structure of Bachman's Sparrow breeding habitat and its relationship to home range. Journal of Field Ornithology 69:45–50.

HAGGERTY, T. M. 2000. A geographic study of the vegetation structure of Bachman's Sparrow (*Aimophila aestivalis*) breeding habitat. Journal of the Alabama Academy of Science 71:120–129.

HURST, G. A. 1992. Foods and feeding. Pages 75–95 *in* The Wild Turkey: biology and management (J. G. Dickson, Ed.). Stackpole Books, Harrisburg, Pennsylvania.

KILGO, J. C. AND A. L. BRYAN, JR. 2005. Nongame birds. Pages 223–253 *in* Ecology and management of a forested landscape: fifty years on the Savannah River Site (J. C. Kilgo and J. I. Blake, Eds.). Island Press, Washington, D.C.

KREMENTZ, D. G. AND J. S. CHRISTIE. 1999. Scrub-successional bird community dynamics in young and mature longleaf pine–wiregrass savannahs. Journal of Wildlife Management 63:803–814.

KREMENTZ, D. G. AND L. A. POWELL. 2000. Breeding season demography and movements of Eastern Towhees at the Savannah River Site, South Carolina. Wilson Bulletin 112:243–248.

LANDERS, J. L. AND B. S. MUELLER. 1986. Bobwhite quail management: a habitat approach. Miscellaneous Publication, no. 6. Tall Timbers Research Station, Tallahassee, Florida.

MCKITRICK, M. C. 1979. Territory size and density of Bachman's Sparrow in south central Florida. Florida Field Naturalist 7:33–34.

MEANLEY, B. 1990. Some observations of the singing behavior of Bachman's Sparrow. Chat 54:63.

MENHINICK, E. F. 1963. Density, diversity, and energy flow of arthropods in the herb stratum of a *Sericea lespedeza* stand. Ph.D. dissertation, University of Georgia, Athens.

MILLS, G. S., J. B. DUNNING, JR., AND J. M. BATES. 1991. The relationship between breeding bird density and vegetation volume. Wilson Bulletin 103: 468–479.

MOHR, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223–249.

NEW, K. C. AND J. L. HANULA. 1998. Effect of time elapsed after prescribed burning in longleaf pine stands on potential prey of the Red-cockaded Woodpecker. Southern Journal of Applied Forestry 22:175–183.

PLENTOVICH, S., J. W. TUCKER, JR., N. R. HOLLER, AND G. E. HILL. 1998. Enhancing Bachman's Sparrow habitat via management of Red-cockaded Woodpeckers. Journal of Wildlife Management 62:347–354.

PYLE, P., S. N. G. HOWELL, R. P. YUNICK, AND D. F. DESANTE. 1987. Identification guide to North American passerines. Slate Creek Press, Bolinas, California.

RAPPOLE, J. H. AND A. R. TIPTON. 1991. New harness design for attachment of radio transmitters to small passerines. Journal of Field Ornithology 62: 335–337.

SAS INSTITUTE, INC. 1987. SAS/STAT guide for PC, 6th ed. SAS Institute, Inc., Cary, North Carolina.

SAUER, J. R., J. E. HINES, AND J. FALLON. 2004. The North American Breeding Bird Survey: results and analysis 1966–2003, ver. 2004.1. USGS Patuxent Wildlife Research Center, Laurel, Maryland. www.mbr-pwrc.usgs.gov/bbs/bbs.html (accessed 30 September 2004).

STOBER, J. M. 1996. Territory dynamics and basic biology of the Bachman's Sparrow (*Aimophila aestivalis*) at the Savannah River Site, South Carolina. M.Sc. thesis, University of Georgia, Athens.

STOBER, J. M. AND D. G. KREMENTZ. 2000. Survival and reproductive biology of the Bachman's Sparrow. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 54:383–390.

SWIHART, R. K. AND N. A. SLADE. 1985. Testing for independence of observations in animal movements. Ecology 66:1176–1184.

TUCKER, J. W., JR., G. E. HILL, AND N. R. HOLLER. 1998. Managing mid-rotation pine plantations to enhance Bachman's Sparrow habitat. Wildlife Society Bulletin 26:342–348.

TUCKER, J. W., JR., W. D. ROBINSON, AND J. B. GRAND. 2004. Influence of fire on Bachman's Sparrow, an endemic North American songbird. Journal of Wildlife Management 68:1114–1123.

WAN A. KADIR, W. R. 1987. Vegetational characteristics of early successional sites utilized for breeding by the Bachman's Sparrow (*Aimophila aestivalis*) in eastern Texas. M.Sc. thesis, Stephen F. Austin State University, Nacogdoches, Texas.