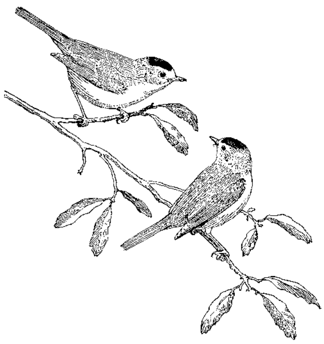

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BREEDING PRODUCTIVITY OF BACHMAN'S SPARROWS IN FIRE-MANAGED LONGLEAF PINE FORESTS

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ABSTRACT.—Bachman's Sparrows (*Aimophila aestivalis*) occupy fire-dependent, longleaf pine (*Pinus palustris*) ecosystems of the southeastern United States. Their populations have declined, due, in part, to fire suppression and degradation of longleaf pine forests. Populations decline when longleaf stands go more than 3 years without fire. The influence of fire on breeding productivity, however, is poorly understood because territories are large and it is difficult to find the well-hidden nests of this ground-nesting sparrow. In an earlier study, densities of Bachman's Sparrows were similar across pine stands burned 1 to 3 years previously, but declined significantly by the 4th year since burning. To assess whether the decline in density might be associated with a decline in breeding success, in 2001 we used a reproductive index to estimate breeding productivity of 70 territorial males, and from 1999 to 2001 we monitored 28 nests. We examined the influence of (1) season (growing versus dormant) when last burned and (2) years since burning on breeding productivity of Bachman's Sparrows in longleaf pine stands in the Conecuh National Forest, Alabama. Reproductive indices were greater ($Z = 1.99$, $P = 0.047$) during the first 3 years after burning (mean = 3.8, SE = 0.4, $n = 10$) than they were 4 years after burning (mean = 2.0, SE = 0.5, $n = 3$), similar to the pattern of change in Bachman's Sparrow density. We found no effect of burn season on the breeding productivity index ($Z = 0.075$, $P = 0.94$). The parallel patterns of declining density and lower breeding success suggest that Bachman's Sparrow density may be positively correlated with habitat quality. We conclude that burning longleaf pine forests on a 2–3 year rotation will best maintain populations of Bachman's Sparrows. *Received 8 February 2005, accepted 25 November 2005.*

Bachman's Sparrow (*Aimophila aestivalis*) is one of the bird species most characteristic of longleaf pine (*Pinus palustris*) forests and it ranks high among species of management concern in the southeastern United States (Hunter et al. 1994). It is classified as threatened or endangered in several states (Dunning 1993) and in 2002 it was red-listed (i.e., one of most at-risk species) by the National Audubon Society on its WatchList (see http://audubon2.org/webapp/watchlist/viewSpecies.jsp?id=18). Loss and degradation of habitat are the most probable causes for the species' population decline (Haggerty 1988). Prescribed fire has been identified as a key tool for managing Bachman's Sparrow habitat (Plentovich et al. 1998,

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Tucker et al. 1998). Until recently, however, prescribed fire has been used mainly during the winter (dormant season) to minimize its negative effects on sparrow reproductive success, despite evidence that historically, natural fires occurred most often during late spring and summer (growing season; Robbins and Myers 1992). Growing-season fires are most beneficial to native plant communities (e.g., Platt et al. 1988, Waldrop et al. 1992, Streng et al. 1993), but the way in which fire timing influences sparrow breeding success is unknown.

Similarly, evidence from botanical studies indicates that frequent fires are needed to maintain dense, herbaceous ground cover preferred by Bachman's Sparrows (e.g., Platt et al. 1988, Dunning and Watts 1990, Waldrop et al. 1992, Streng et al. 1993, Plentovich et al. 1998, Tucker et al. 1998). Engstrom et al. (1984) followed changes in bird species composition through 15 years of fire exclusion in a stand of "oldfield pines" (mostly loblolly, *P. taeda*; and shortleaf, *P. echinata*, pines) in northwestern Florida that had previously been burned annually during the dormant season; Bachman's Sparrows disappeared from the stand after 5 years of fire exclusion. In studies on Florida dry prairies, Bachman's Sparrow densities increased on sites burned in mid-June relative to those on control sites (≥2.5 years since burning; Shriver et al. 1999), but there were no differences in density or reproductive success during the first three breeding seasons following winter fires (Shriver and Vickery 2001). Yet, no data are available to evaluate directly the influence of time since burning and season of burning on breeding productivity of this elusive sparrow species.

In a previous study, we examined the influence of burn season and fire frequency on the density of Bachman's Sparrows in longleaf pine forests in southern Alabama and northwestern Florida (Tucker et al. 2004) and found that density was unaffected by burn season. Furthermore, density was similar within the first 3 years after burning, but declined precipitously in stands 4 or more years after a fire (Tucker et al. 2004). We hypothesized that reduced breeding success in stands unburned for 4 or more years might explain this decline in density. To test this hypothesis, we compared the breeding productivity of Bachman's Sparrows across burned units of longleaf pine habitat that differed in time since burning. We also evaluated the potential influence of fire timing within the growing season on nesting success by comparing daily survival rates between nests initiated early and late in the growing season.

METHODS

We estimated breeding success by monitoring nests and using a reproductive index based on behavioral observations (Vickery et al. 1992b). The reproductive ecology of Bachman's Sparrows is poorly known because nests are hidden on the ground, usually below tufts of overhanging grasses, and are therefore exceptionally challenging to locate (Weston 1968, Harrison 1975, Haggerty 1986). In response to the difficulties of finding ground-nesting sparrow nests, Vickery et al. (1992b) developed a reproductive index based on readily observable behaviors that reduces the necessity of locating nests to measure breeding success (Vickery et al. 1992a, Dale et al. 1997). During the breeding season of 2001, we monitored the territories of 70 male Bachman's Sparrows in longleaf pine stands of the Conecuh National Forest, Alabama. To complement this intensive study of focal individuals, we monitored nests found in the same habitat units from 1999 through 2001.

Between 22 April and 12 May 2001, we located territories within 13 habitat compartments (a group of adjacent stands managed as a prescribed burn unit), which varied from 387 to 700 ha in size and comprised four treatment combinations of burn season (dormant [1 October–31 March] or growing [1 April–30 September]) and time since burning (1–3 years or 4 years). We sampled two compartments for each treatment but one: there was only one compartment that had been burned during the growing season 4 years earlier (i.e., 1997). No stands were burned during the 2000 growing season, so territories within stands the 1st year after growing-season burning could not be included. Because the number of compartments was small and the study design was unbalanced, we grouped compartments burned ≤3 years earlier to test our hypotheses that reproductive success would parallel trends in density (Tucker et al. 2004) and be greater during the first 3 years (n = 10) than 4 years (n = 3) post-burning.

Female and juvenile Bachman's Sparrows are very secretive and difficult to observe, so we concentrated our efforts on searching individual territories, rather than mapping territories within habitat compartments, to increase our chances of observing evidence of reproduction. Furthermore, Bachman's Sparrow territories are relatively large (see Dunning 1993) and densities are relatively low, especially in stands not burned for ≥4 years (Tucker et al. 2004); thus, monitoring individual territories also allowed us to sample a sufficient number of territories to characterize breeding productivity within each burn treatment (i.e., each combination of burn season and years since burning). Within each compartment, we selected territories for monitoring by visiting an area known to contain several Bachman's Sparrows and selecting the first four or six singing males encountered within each compartment. Although unmated males of many species sing more frequently than mated males (Best 1981), the territories that we monitored within habitat compartments were adjacent to each other (although often separated by ≥100 m) and we did not observe evidence (e.g., appearance of additional territories) that would suggest that we overlooked mated birds during selection of the territories. We monitored 10 territories within each burn treatment, but we divided territories unequally between the two habitat compartments within treatments to allow a team of two observers traveling together to efficiently monitor two habitat compartments (i.e., 5 territories per observer) each day. We marked singing perches for each male with plastic flagging and noted the territorial boundaries and location of adjacent territories not selected for study. We also used mist nets to capture most of the males (53 of 70) and marked them with unique combinations of colored leg bands. All 70 territories were monitored once per week from 21 May to 12 July 2001, spanning the peak of breeding activity at our study site.

Behavioral evidence of reproductive activity was monitored during 45-min visits to each territory once per week. A visit began when we arrived on a territory, and entailed recording all evidence of reproductive activity—the primary objective being the discovery of an active nest. In addition, we marked new song perches to delineate more accurately territory boundaries. Each territory was assigned a cumulative score indicating increasing evidence of breeding success, slightly modified from the method of Vickery et al. (1992b). The scores for evidence of reproductive success were assigned as follows: 1 = presence of the territorial male, 2 = presence of a mated pair, 3 = evidence of an active nest, 4 = adults carrying food to presumed nestlings, 5 = direct observation or evidence of fledglings, 6 = evidence of an active nest after successful fledging of a first brood, 7 = evidence of successful fledging for two broods, 8 = evidence of an active nest after successful fledging of two broods, and 9 = evidence of successful fledgling for three broods. Bachman's Sparrows are not known to attempt more than three broods within one breeding season (Stober and Krementz 2000).

A cumulative reproductive score corresponding to the maximum evidence of breeding success was assigned to each of the 70 territories. Because individual territories within habitat compartments were not independent sampling units, we calculated median reproductive scores for each compartment and treated individual compartments as our sampling units. The reproductive scores were ranked (i.e., ordinal) data, so we used a nonparametric normal approximation to the Mann-Whitney *U*-test (Zar 1984) to compare median reproductive scores in compartments burned ≤3 versus 4 years previously and compartments burned in the growing versus dormant season.

All Bachman's Sparrow nests found from 1999 through 2001 were monitored according to standard methods (Martin and Geupel 1993) on a 2–3 day schedule until the nests failed or the offspring fledged. We calculated daily survival rates (DSR) of nests (Mayfield 1961, 1975) to evaluate the influence of burn season, years since burning (≤3 versus 4), and timing of fire within the growing season on nesting success. For Mayfield calculations, we used our observations for length of the incubation period (13 days) and nestling period (9 days), which were similar to those reported by Haggerty (1986, 1988). Overall nest success (i.e., the probability of a completed clutch producing ≥1 fledgling) was calculated by raising daily nest survival to the 22nd power. We calculated variances in DSR and evaluated effects by examining 95%

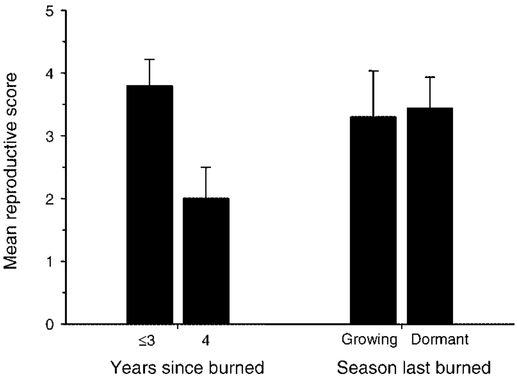

FIG. 1. Mean (± SE) reproductive scores of Bachman's Sparrows calculated using median scores from individual habitat compartments at the Conecuh National Forest, Alabama, during 2001 were greater in the first 3 years after burning (n = 10) than 4 years after burning (n = 3) but did not differ between seasons when last burned (n = 5 and n = 8 for growing and dormant seasons, respectively). Reproductive scores were collected using methods modified from Vickery et al. (1992b).

confidence intervals (±2 SE) around the DSR (Johnson 1979).

RESULTS

Breeding productivity.—Of the 70 Bachman's Sparrow territories monitored, we found evidence of successful reproduction (i.e., fledglings observed) within 30 and evidence of two successful broods within 4 territories. Overall, 28% (14/50) of territorial males in compartments burned ≤3 years earlier remained unpaired, and 50% (10/20) of territorial males in compartments burned 4 years earlier remained unpaired (χ^2 = 3.07, P = 0.080). Furthermore, 52% (26/50) of territories in compartments burned ≤3 years earlier successfully produced young, but only 20% (4/20) of territories burned 4 years earlier successfully produced young (χ^2 = 5.97, P = 0.015). Reproductive scores of Bachman's Sparrows were greater (Z = 1.99, P = 0.047) in the first 3 years after burning (mean = 3.8, SE = 0.4, n = 10) than 4 years after burning (mean = 2.0, SE = 0.5, n = 3) but did not differ (Z = 0.075, P = 0.94) between stands burned in the growing season (mean = 3.3, SE = 0.7, n = 5) versus those burned in the dormant season (mean = 3.4, SE = 0.5, n = 8; Fig. 1).

Nesting success.—We found 34 nests during the study: 2, 12, and 20 in 1999, 2000, and 2001, respectively. Two nests were found the day of fledging, two were destroyed during construction, and two were burned during egg laying, leaving 28 nests for calculating DSR. Overall, 13 of the 28 (46%) nests fledged young. All nest failures resulted from depredation; no parasitism by Brown-headed Cowbirds (*Molothrus ater*) was observed.

DSR of early-season nests (found in April and May) were slightly greater than those of late-season nests (found June and July), although the 95% confidence intervals overlapped (Table 1). In addition, DSR of nests dur-

TABLE 1. Exposure days (number of nests), number of nest failures, daily survival rates (DSR), and 95% confidence intervals (95% CI) by nesting stage and time within the breeding season (nest cycle) for 28 Bachman's Sparrow nests in the Conecuh National Forest, Alabama, from 1999 through 2001.

Stage	Nest cycle[b]	Exposure days	Failures	DSR	95% CI[a] Lower	Upper
Incubation[c]	Early	66.0 (8)	2	0.970	0.928	1.012
	Late	52.5 (8)	1	0.981	0.943	1.019
	Total	118.5 (16)	3	0.975	0.946	1.004
Nestling[d]	Early	64.5 (13)	5	0.923	0.856	0.989
	Late	46.5 (12)	7	0.850	0.745	0.954
	Total	111.0 (25)	12	0.892	0.833	0.951
Combined[e]	Early	130.5 (15)	7	0.946	0.907	0.986
	Late	99.0 (13)	8	0.919	0.864	0.974
	Total	229.5 (28)	15	0.935	0.902	0.967

[a] Calculated as mean ± 2 SE (Johnson 1979).
[b] Early nest cycle included nests found in April and May; late nest cycle included nests found in June and July.
[c] Incubation stage included a 13-day period from laying of the penultimate egg until the first egg hatched.
[d] Nestling stage included a 9-day period from 1st day of hatching until fledging.
[e] Includes the sum of incubation and nestling periods.

ing the incubation period tended to be greater than during the nestling period, but again the 95% confidence intervals overlapped (Table 1). DSR of all nests from the beginning of incubation through fledging was 0.935 (Table 1), and the probability of a completed clutch producing at least one fledgling was 0.226. DSR was similar between the first 3 years (DSR = 0.94, 95% CI = 0.90–0.97, n = 22 nests) and the 4th year (DSR = 0.93, 95% CI = 0.86–1.00, n = 6 nests) after burning and between sites burned in the growing (DSR = 0.89, 95% CI = 0.81–0.97, n = 7 nests) and dormant (DSR = 0.95, 95% CI = 0.92–0.99, n = 21 nests) seasons.

DISCUSSION

Nesting success averaged across all our habitat compartments was 23%, which falls within the range previously reported for Bachman's Sparrows in Arkansas pine forests (25%; Haggerty 1988), South Carolina clear-cuts (8–34%; Stober and Krementz 2000), and Florida dry prairies (7–38%; Perkins 1999). Neither burn season nor time since burning had a large effect on nest survival rates at our study sites. Although our sample size of nests was one of the largest yet obtained in a Bachman's Sparrow study, the sample was nevertheless relatively small, indicating that only large effects could be detected (Johnson 1979). In contrast, our results from the reproductive scores (i.e., 70 territories; Fig. 1) suggested that breeding productivity was greater the first 3 years after burning than in older burns. The latter result is consistent with our hypothesis that reduced breeding success in older burns may help explain the lower densities of Bachman's Sparrows in those burns (Tucker et al. 2004).

Although logistic constraints prevented us from simultaneously measuring density and breeding productivity of Bachman's Sparrows, our results suggest a positive correlation between the two measures in our study area. We acknowledge that these results only are suggestive of a positive association between density and breeding productivity, but our consistent results among the 3 years of our studies—1999 and 2000 for density of Bachman's Sparrows (Tucker et al. 2004) and 2001 for this study of breeding productivity—strongly support the conclusion that a regime of burning every 2–3 years will best maintain healthy populations of Bachman's Sparrows in longleaf pine forests. Bock and Jones (2004) reviewed studies that examined the association between avian density and reproductive success and found that a preponderance of studies in relatively undisturbed areas reported a positive association between the two measures; most studies that reported a decoupling between the two measures were conducted in disturbed habitats. Our study area was within the largest remaining extent of longleaf pine forest (Outcalt and Sheffield 1996), and habitats were relatively natural and managed under a paradigm of ecosystem management. Thus, a positive correlation between density and breeding productivity of Bachman's Sparrows in the area would be expected.

Why do density and breeding success decline in older burns? Previous studies suggest that percent coverage by herbaceous ground cover, particularly grass (Dunning and Watts 1990, Plentovich et al. 1998, Haggerty 2000, Tucker et al. 2004), is a primary factor influencing habitat occupancy by Bachman's Sparrows. Herbaceous ground cover and, thus, habitat suitability decreases with time since burning (Engstrom et al. 1984, Tucker 2002). Haggerty (1998) found that territory sizes were inversely correlated with percent coverage of herbaceous ground cover. Thus, higher sparrow densities are facilitated by smaller territories in high-quality habitat.

It should be noted that small territory sizes could have an effect on detectability of reproductive status, as well. The stealthy behavior of female and juvenile Bachman's Sparrows makes them difficult to detect, but they may be easier to detect in smaller territories (i.e., higher quality habitat) because their activities are confined to a smaller area. Despite a potential bias in detectability resulting from territory size, the scores for reproductive success nevertheless would be positively correlated with habitat quality.

Future studies should address the effects of timing of fires within the breeding season. We were unable to examine breeding productivity immediately before and after growing-season fires. Although we did not find differences in sparrow reproductive success between burn seasons, timing of fire *within* the growing season may be an important factor and needs additional study. For example, both our study

(Table 1) and one in South Carolina (Stober and Krementz 2000) revealed that early-season nests tended to be more successful than late-season nests. Fires during late April and early May could destroy a large percentage of the nestlings or young fledglings from the first nesting cycle and result in low annual recruitment from those nesting attempts. Furthermore, we do not yet know whether territory holders move to unburned sites and breed elsewhere or quit all reproduction efforts for a given year when their territories are burned early in the growing season (Seaman and Krementz 2000). Alternatively, productivity of food resources (i.e., seed production and invertebrates) may be enhanced sufficiently by early-season fires to compensate for the loss of nests early in the season; if vegetation re-grows quickly enough, it could provide cover for nests that season. Although Seaman and Krementz (2000) found that Bachman's Sparrows abandoned stands burned in the growing season and failed to return within 50 days after the fires, anecdotal observations (JWT unpubl. data, J. B. Dunning pers. comm.) suggest that Bachman's Sparrows often return and/or establish territories in burned stands within a few days after fire and remain there through the remaining breeding season. Shriver et al. (1996, 1999) found that burning Florida dry prairies during mid-June resulted in an extended breeding season for Florida Grasshopper Sparrows (*Ammodramus savannarum floridanus*) but fires in July did not.

In conclusion, results of this study on breeding productivity and our earlier study on density of Bachman's Sparrows (Tucker et al. 2004) suggest that land managers interested in providing habitat for Bachman's Sparrows in longleaf pine forests should burn at least every 3 years, regardless of burn season. Sites left unburned for ≥4 years host few to no breeding Bachman's Sparrows (Tucker et al. 2004) and it appears that breeding productivity is low among birds that do settle in those habitats. Thus, low breeding productivity may be a plausible explanation for the low densities of sparrows in pine stands unburned for more than 3 years. Because most natural fires historically occurred during the growing season (Robbins and Myers 1992), prescribed burning during the growing season probably will be most beneficial for longleaf pine communities overall. Our study, based on one of the largest sample sizes of reproductive success yet obtained for this elusive sparrow, suggest that burn season may be of little consequence to the reproductive output of Bachman's Sparrows; however, the effects of fire timing within the growing season still need to be evaluated.

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LITERATURE CITED

BEST, L. B. 1981. Seasonal changes in detection of individual bird species. Studies in Avian Biology 6: 252–261.

BOCK, C. E. AND Z. F. JONES. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment 2:403–410.

DALE, B. C., P. A. MARTIN, AND P. S. TAYLOR. 1997. Effects of hay management on grassland songbirds in Saskatchewan. Wildlife Society Bulletin 25:616–626.

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

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

ENGSTROM, R. T., R. L. CRAWFORD, AND W. W. BAKER. 1984. Breeding bird populations in relation to changing forest structure following fire exclusion: a 15-year study. Wilson Bulletin 96:437–450.

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. 1988. Aspects of the breeding biology and productivity of Bachman's Sparrow in central Arkansas. Wilson Bulletin 100:247–255.

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.

HARRISON, H. H. 1975. A field guide to the birds' nests: United States east of the Mississippi River. Houghton Mifflin, Boston, Massachusetts.

HUNTER, W. C., A. J. MUELLER, AND C. L. HARDY. 1994. Managing for Red-cockaded Woodpeckers and Neotropical migrants—is there a conflict? Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 48:383–394.

JOHNSON, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651–661.

MARTIN, T. E. AND G. R. GEUPEL. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:507–519.

MAYFIELD, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

MAYFIELD, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

OUTCALT, K. W. AND R. M. SHEFFIELD. 1996. The longleaf pine forest: trends and current conditions. Research Bulletin SRS-9, USDA Forest Service, Southern Research Station, Asheville, North Carolina.

PERKINS, D. W. 1999. Breeding ecology of Florida Grasshopper and Bachman's sparrows of central Florida. M.Sc. thesis, University of Massachusetts, Amherst.

PLATT, W. J., G. W. EVANS, AND M. M. DAVIS. 1988. Effects of fire season on flowering of forbs and shrubs in longleaf pine forests. Oecologia 76:353–363.

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.

ROBBINS, L. E. AND R. L. MYERS. 1992. Seasonal effects of prescribed burning in Florida: a review. Miscellaneous Publication, no. 8. Tall Timbers Research Station, Tallahassee, Florida.

SEAMAN, B. D. AND D. G. KREMENTZ. 2000. Movements and survival of Bachman's Sparrows in response to prescribed summer burns in South Carolina. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 54:227–240.

SHRIVER, W. G. AND P. D. VICKERY. 2001. Response of breeding Florida Grasshopper and Bachman's sparrows to winter prescribed burning. Journal of Wildlife Management 65:470–475.

SHRIVER, W. G., P. D. VICKERY, AND S. A. HEDGES. 1996. Effects of summer burns on Florida Grasshopper Sparrows. Florida Field Naturalist 24:68–73.

SHRIVER, W. G., P. D. VICKERY, AND D. W. PERKINS. 1999. The effects of summer burns on breeding Florida Grasshopper and Bachman's sparrows. Studies in Avian Biology 19:144–148.

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

STRENG, D. R., J. S. GLITZENSTEIN, AND W. J. PLATT. 1993. Evaluating effects of season of burn in longleaf pine forests: a critical literature review and some results from an ongoing long-term study. Proceedings of the Tall Timbers Fire Ecology Conference 18:227–263.

TUCKER, J. W., JR. 2002. Influence of season and frequency of fire on Bachman's and Henslow's sparrows in longleaf pine forests of the Gulf Coastal Plain. Ph.D. dissertation, Auburn University, Auburn, Alabama.

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.

VICKERY, P. D., M. L. HUNTER, JR., AND J. V. WELLS. 1992a. Is density an indicator of breeding success? Auk 109:706–710.

VICKERY, P. D., M. L. HUNTER, JR., AND J. V. WELLS. 1992b. Use of a new reproductive index to evaluate relationship between habitat quality and breeding success. Auk 109:697–705.

WALDROP, T. A., D. L. WHITE, AND S. M. JONES. 1992. Fire regimes for pine-grassland communities in the southeastern United States. Forest Ecology and Management 47:195–210.

WESTON, F. M. 1968. *Aimophila aestivalis bachmani* (Audubon) Bachman's Sparrow. Pages 956–970 *in* Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies (O. L. Austin, Jr., Ed.). U.S. National Museum Bulletin, no. 237. [Reprinted 1968, Dover Publications, New York]

ZAR, J. H. 1984. Biostatistical analysis, 2nd ed. Prentice Hall, Englewood Cliffs, New Jersey.